● 한국물리학회 초록집

2020년
봄 학술논문발표회 및 제96회 정기총회

2020 KPS Spring Meeting

2020년 7월 13일(월) – 15일(수)

Virtual Conference

구두발표논문

Oral session abstracts

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A7.01

Low-threshold amplified spontaneous emission from a bulk $CsPbBr_3$ single crystal at Room temperature

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Abstract:

Lead halide perovskites have received intense interest over the years for their promising photovoltaic and optoelectronic properties. One of those properties is high optical gain required for a laser gain medium. Amplified spontaneous emission (ASE) has been reported for both all-inorganic and hybrid perovskites in various forms including quantum dots, nanorods, nanocrystals, etc. Despite these recent progress, exact mechanism that provokes ASE is still in debate. In this presentation, we report on ASE from a bulk CsPbBr3 single crystal at room temperature where the corresponding ASE threshold intensity is only 40MW/cm2. Strangely, however, this room-temperature ASE was found to occur only at specific positions at the crystal. In order to investigate this position-dependent ASE mechanism, we employed both micro-photoluminescence and micro- Raman spectroscopy, together with microscopic imaging. We found that the ASE-active sites of a typical size (20~100um2) are embedded randomly over our single crystal, which can be readily identified by clear optical contrast. Although this specific region does not exhibit any difference in Raman response, we confirmed that it yields clear distinct photoluminescence spectra whose peak maximum coincide with that for ASE. This implies that ASE in this perovskite efficiently occurs via optical gain at the resonance around 540nm. A series of optical measurements as a function of wavelength and temperature can also be explained by this resonance effect. Although the nature of this ASE-active phase is not clear at the time, we believe that CsPbBr3 can be an excellent laser gain medium if the crystals can be engineered to be in this ASE-active phase.

Keywords:

Halide perovskite, ASE

A7.02

DNA 오리가미를 이용한 다이아몬드 광결정 디자인

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Abstract:

구형 콜로이드 입자로 이루어진 면심입방체 또는 블록공중합체로 이루어진 이중 자이로드는 구조색으로 구현되는 컬러픽셀의 한 가지 방법으로 제시되었다. 이러한 자기조립 방법은 저렴한 가격의 대면적 합성에 용이하여 컬러픽셀 구현에 대한 잠재력이 있다. 하지만 각 구조가 가진 구조적 한계로 인해 해당 구조색이 각도에 의존한다는 단점이 있고, 이 문제를 해결하기 위해 각도 의존성이 없는 파이로클로르 (Pyrochlore) 구조로 우회를 했다. 그러나 이러한 접근에도 불구하고, 파이로클로르의 광학적 특성은 각도 비의존적인 광결정 중 광학적 특성이 가장 뛰어난 막대로 연결된 다이아몬드 격자(Rod-connected diamond lattice)의 기록에 도달하기는 어렵다. 본 연구에서는 막대로 연결된 다이아몬드 격자의 구현 가능성을 DNA 오리가미와 후처리 공정 과정을 제시, 그리고 각 과정에서의 광자와 포논 분석을 통해 논하고자 한다.

Keywords:

DNA 오리가미, 광결정, 광 밴드갭, 다이아몬드 격자

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A7.03

Self-assembled Silica Opals for Colorful Radiative Coolers

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Abstract:

Recently, radiative cooling has emerged as an eco-friendly cooler because it is derived by the intrinsic phonon-vibration of the material which can produce cooling effects without additional energy consumption. When radiative coolers combine with the nanophotonic broadband solar reflector, they can maintain the temperature of targets below the ambient temperature even in the daytime. Although the use of the broadband solar reflector makes the cooler more efficient, the color of the cooler is very limited to white or silver. Because the radiative coolers are very likely to be expanded to the cooling of buildings, vehicles, and electronic devices, it must be more diverse in color to be more actively use in applications. To overcome the technical challenge, we demonstrate a reflection-based colorful radiative cooler by assembling silica nanospheres into face-centered-cubic (FCC) structures. We use silica nanospheres with diameters of 200 nm to 300 nm, which can selectively express the color of the visible light range by Bragg diffraction. Different from the colorization of the silica opal, electromagnetic emission in the mid-infrared (mid-IR) region induced by vibration of siloxane bonding on silica nanospheres can lower the temperature of the target in an environmentally friendly manner. To measure the cooling effect of the opal, we set the silicon substrate that is commonly used in optoelectronics as a target and measuring the temperature of it in the daytime. Under the solar irradiance of 912 W/m^2 on average, silica opals reduce the temperature of the target to a 13.5 °C and prove the cooling effect. Taken together, we believe that the discovery of new usage of silica opals will expand the radiative cooling field to more diverse applications.

Keywords:

Photonic bandgap, Radiative cooling, Colloids, Self-Assembly

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A7.04

Tunable rectification direction in molecular heterojunction with two-dimensional semiconductors

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Abstract:

Diverse types of molecules such as a donor-s-acceptor molecules and ferrocenyl alkanethiol have been suggested as potential candidates for the electronic component of a molecular rectifier.[1,2] Recently, we demonstrated a novel strategy and design rule for realizing molecular-scale diode features based on the energy band engineering between simple alkanethiol or conjugated molecules and two-dimensional (2D) semiconductors.[3] Here, we studied the rectifying characteristics in heterostructured molecular junction consisting of $CF_3(CF_2)_5(CH_2)_2SH$ (denoted as F6C2) and 2D semiconductor (MoS_2 or WSe_2). Depending on the types of 2D semiconductors, the rectification direction was changed with maintaining more than the rectification ratio of about 10 at least. Namely, the MoS_2(or WSe_2)-molecular junction shows a higher transport current at a positive (or negative) voltage regime. However, in the case of the non-functionalized $CH_3(CH_2)_7SH$ (denoted as C8) molecules, the rectification direction does not change regardless of the type of 2D. Change in the rectification direction is due to the opposite dipole moment direction of F6H2 and H8 affecting 2D semiconductor band alignments differently. In this presentation, we will discuss the influence of the direction of the molecular dipole moment on the rectification direction/ratio in the molecular heterojunction.

[1] Díez-Pérez, I. *et al.* Rectification and stability of a single molecular diode with controlled orientation. *Nat. Chem.* **1**, 635 (2009).

[2] Chen, X. *et al.* Molecular diodes with rectification ratios exceeding 10^5 driven by electrostatic interactions. *Nat. Nanotechnol.* **12**, 797 (2017).

[3] Shin, J. *et al. Nat. Commun.* (2020) *Accepted*. DOI: 10.1038s41467-020-15144-9

Keywords:

Molecular Electronics, 2D Semiconductor, Molecular Heterojunction, Rectification Direction

A7.05

Lead-free $CH_3NH_3BaCl_3$ Perovskite Crystals with Well-defined Crystal Structure and Photoexcited Conduction for Photodetection Devices

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Abstract:

Organic-inorganic perovskites have gained tremendous attention for its attractive optical and electronical properties. However, the toxicity of Pb is one of the downsides to their further commercialization. Ba is one of the substitutes for Pb in halide perovskite for use in optoelectronic devices. In that point, we grew $CH_3NH_3BaCl_3$ single crystals, which are free from interfacial defects and grain boundaries and investigated optoelectronic properties. The structurally well-defined crystals were characterized by Raman scattering spectroscopy for comparison to $CH_3NH_3PbCl_3$. We also conducted scanning probe microscopy to examine the work functions and conduction of a Ba-perovskite crystal under dark and light-illumination conditions. A shift and increase of the surface photovoltage and conductivity indicated the possibility of the sensitive excitation. We suggest the structural and electronic properties of $CH_3NH_3BaCl_3$ for the potential application in various photodetection devices.

Keywords:

Halide perovskite, Lead-free, Single crystal, Crystal structure

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A7.06

혼합 양이온 페로브스카이트 태양전지 제작 및 특성 연구
Fabrication and characterization of mixed-cation perovskite solar cells

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Abstract:

페로브스카이트는 ABX3의 구조를 가지는 유-무기 하이브리드 반도체 물질로, 큰 흡수 계수 (absoprtion coefficient), 긴 범위의 (long-range) 밸런스 전자(balanced electron)와 홀 수송 길이(hole transport length)로 인해, 최근 20 % 이상의 에너지 변환 효율을 보여 태양전지 활성 층(흡수 층) 물질로 주목 받고 있다. 페로브스카이트의 A 자리에 해당하는 양이온 물질로 초기에는 메틸암모늄(methylammonium)을 주로 사용하였는데, 이후 포름아미디늄(formamidinium)을 첨가하여 태양전지 소자의 안정성과 효율을 높였다. 하지만 유기물인 메틸암모늄과 포름아미디늄은 습도에 취약하여 시간이 지남에 따라 효율이 급격히 감소하는 단점을 보여, 이를 개선하여 태양전지의 안정성을 높이기 위한 다양한 연구들이 진행되고 있다. 본 연구에서 메틸암모늄과 포름아미디늄의 이중 양이온(double cation) 페로브스카이트 구조에 무기 양이온인 세슘(Cs)을 첨가를 통해 안정성을 높여 시간이 지나도 효율이 유지되도록 하고, 표면 passivation을 통해 소자 구동 특성을 개선하여 에너지 변환 효율을 향상 시키고자 한다.

Keywords:

triple cation, solar cells, perovskites

Study on the structural phase transition of methylammonium lead halide perovskite single crystals by Raman scattering spectroscopy

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Abstract:

For several decades, tremendous amount of research effort has been exerted to improve the efficiency of solar cell devices. This study focuses on understanding the structural characteristics, particularly the phase transition behavior of methylammonium (MA) lead halide perovskite materials with respect to temperature changes. Temperature- and polarization-dependences of Raman responses from single crystalline $MAPbCl_3$ samples were measured and abrupt changes were observed near the phase transition temperatures. Our results show that the contributions to phase transition of each atomic/molecular vibration are determined by the type of vibrations. From our results, we claim that Raman scattering spectroscopy is a very effective research tool that sensitively monitors structural phase transition by observing small changes in phonon spectra that reflect the microscopic environment.

Keywords:

perovskite, phase transition, Raman, temperature dependent, methylammonium lead halide

2020 KPS Spring Meeting
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A7.08

표면 개질된 적색발광 탄소 양자점/고분자 박막 제작 및 발광 특성 연구
Fabrication and optical characterization of polymeric films with surface-modified and red-fluorescent carbon quantum dots

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Abstract:

카드뮴(Cd), 납(Pb), 인듐(In) 기반의 양자 점들(quantum dots)은 우수한 광 특성에 비해 독성이 높아, 유해성 없는 대체 소재 개발에 대한 요구가 지속되고 있다. 최근 생체 적합성(bio-compatibility)을 가진 탄소 양자 점들(carbon quantum dots)이 물에 잘 분산되고 화학적으로 안정하며, 높은 양자 수득률(quntum yield)과 낮은 광 퇴색성(optical bleaching)과 같은 우수한 발광 특성으로 인해 주목 받고 있다. 현재까지 주로 청색, 녹색의 파장 영역에서 발광하는 탄소 양자 점들과 관련된 연구에 집중되어 왔고, 적색 발광 영역의 탄소 양자 점들은 합성이 어렵고 특유의 낮은 양자 수득률로 인해 도전적인 과제로 남아있다. 본 연구에서는 적색 발광 탄소 양자 점을 합성하고, 수산화 리튬을 첨가한 표면 개질을 통해 양자 수득률을 증가시켰으며, Polyvinyl alcohol 고분자를 이용하여 발광 특성이 우수하고 안정적인 박막을 제작하였다.

Keywords:

Carbon quantum dots, red-fluorescence , photonics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A7.09

Detailed Balance Analysis for Structured Solar Cells

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Abstract:

Detailed balance analysis, which first suggested by W. Shockely and H. J. Queisser, have been used for calculating efficiency limit of solar cells.[1] According to recent development of theory, detailed balance analysis become more accurate by reflecting various loss mechanism (e.g. Auger recombination, absorption of back mirror, Shockley-Read-Hall recombination).[2] By using this theory, we study the two cases of structured solar cells.
First, we suggest a high-index optical metamaterial which can enhance the absorption of solar cells proven by optical simulation. Furthermore, we show the increase of absorption leads to the increase of short-circuit current and power conversion efficiency of solar cells by using detailed balance analysis.[3]
Second, we design the neutral-colored transparent solar cell with periodic holes. To achieve the neutral-colored transparency, the size of these periodic holes are large enough to avoid diffraction and smaller than resolution of human eyes.[4] We analyze the characteristic of solar cell in this study (e.g. absorption, external quantum efficiency) by using detailed balance analysis. Especially, we confirm that calculation results with carrier lifetime fitting are well-matched to experimental result.

1) W. Shockley, H. J. Queisser, *J. Appl. Phys.* **1961**, *32*, 510.
2) L. M. Pazos-Outón, T. P. Xiao, E. Yablonovitch, *J. Phys. Chem. Lett.* **2018**, *9*, 1703.
3) K. Kim, S. Lee, *Opt. Express* **2019**, *27*, A1241.
4) K. Lee, N. Kim, K. Kim, H. Um, W. Jin, D. Choi, J. Park, K. J. Park, S. Lee, K. Seo, *Joule* **2020**, *4*, 235.

Keywords:

metamaterial, solar cell, detailed balance analysis

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A8.01

Synergistic effect of cooperating solvent vapor annealing for high efficient planar inverted perovskite solar cells

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Abstract:

Whereas SVA has been successfully adopted for the fabrication of perovskite films via the conventional two-step method, its adaptation to the simple single-step perovskite film deposition method has been limited because of the rapid transition of the precursor to the perovskite structure. In the present study, we demonstrate highly efficient and stable single-step-based inverted perovskite solar cells fabricated with perovskite films prepared using dimethyl sulfoxide (DMSO) and water as a combined solvent in an SVA treatment. The treatment with DMSO alone resulted in the growth of large grains (~900 nm) in the lateral direction at the surface region; however, voids and defects were observed in the vertical direction at the bottom interfacial region of the $CH_3NH_3PbI_3$ layer, which resulted in poor device properties. Interestingly, the combined DMSO–water induced vertical growth of almost single grains and the healing effect of water improved the grain quality. As a result, we fabricated co-SVA $CH_3NH_3PbI_3$ devices with a photon conversion efficiency (PCE) of 19.52%. This PCE, which is much higher than that of pristine devices, was attributed to reduced nonradiative recombination. In addition, co-SVA solar cells displayed remarkable stability and their universality in various types of perovskite materials was demonstrated.

Keywords:

perovskite solar cell, co-solvent, solvent vapor annealing, grain orientation, grain healing

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A8.02

Selective layer-controlled graphene exfoliation for millimetre sizes

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Abstract:

Since the first isolation of graphene from graphite, atomically thin graphene membranes of various materials have been studied for a larger scale. In this study, we have demonstrated metal-mediated exfoliation for the graphene and other 2D materials (TMDCs) in a large-scale by controlling initial cracking depth. The Au thin film, whose binding energy with graphene is similar to the interlayer binding energy of graphite, was used to selectively exfoliate topmost monolayer graphene. An average area and coverage of monolayer in 1 mm2 area graphene prepared by our technique was 62,300 μm2 and 32%, respectively, was obtained, which is an increase of 1,700 times and 3,300 times, more than those of monolayer graphene obtained by standard mechanical exfoliation. Also, we have demonstrated that a different metal-mediated exfoliation can initiate altered peeled-off condition, leading to a thickness selection for graphene films. This large-scaled exfoliation technique is also available for other 2D materials like TMDCs. We believe our results demonstrate that our new introduced exfoliation can be used to conveniently explore the technologically important TMDCs regime and to pave the way for future optoelectronic applications of 2D-materials based systems.

Keywords:

Graphene, Layer control, Large scale, Exfoliation, TMDCs

Evolution of mechanically-assisted electromigration breakdown junction as observed in a free-standing nanostructure

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Abstract:

In order to realize molecular electronics or single molecule based device, nanogap electrodes connected with molecules are needed as probes to measure mechanical, optical, thermoelectric properties. Feedback controlled electromigration (FCE) breakjunctions have been successfully used to create nanogap electrodes in metallic nanostructures, which enabled to reach critical stress loads controllably and minimize Joule heating effects. Here, we study the effects of mechanical stress and strain due to flexural modes of a free-standing Au nanobeam structure under FCE process in order to avoid excessive heating. Using pulsed current measurement as well as gradual bias ramping current measurement, heating effects of metallic nanostructures are discussed to study the controllability of nanogap size and positioning. We realized free-standing Au nanobeam structures by standard electron beam lithography techniques and released from the underlying substrate by a selective wet etch process. Breakdown junctions are made by utilizing FCE technique which prevents drastic wide gap formation, while electrostatically driving the free-standing beam at its resonance condition. As geometrical changes such as thinning, void, hillock formation during electromigration affect mechanical resonance frequency, we investigate the evolution of metal nanogap formation process not only by monitoring the resistance but also resonance frequency *in situ* by voltmeter and optical interferometry system respectively. Morphological evolution of the metallic nanobeam structures is ascertained by a scanning electron microscope as well at each step when its resistance reaches the threshold resistance.

Keywords:

Electromigration breakdown junction, Metallic nanogap, Feedback controlled electromigration (FCE)

Electrical characterization of metastability in $Cu(In,Ga)Se_2$ thin-films devices

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Abstract:

There have been increasing interests of $Cu(In,Ga)Se_2$ (CIGS) thin films devices due to their high light absorption. CIGS solar cells consist of several layers and resulting interfaces, whose optical and electrical properties can affect the performance of the devices. The optoelectronic properties of bulk or interface in CIGS thin film devices have known to show metastable behaviors, which is related to the energy conversion efficiency. In the study, with the different wavelength of light which differentiates between space-charge region and interface distribution, current-voltage (*I-V*) characterization of CIGS thin film solar cells showed the rollover behavior in the blue light. The charge density of CIGS thin film solar cells by deep level capacitance profiling (DLCP) measurement indicated the different variation as the wavelength of light. Admittance spectroscopy indicated that deep defect energy level causing electron charge loss disappeared at the illumination. Persistent photoconductivity measurement resulted in metastability of CIGS thin films solar cells and persistence of blue light was strongly appeared more than that of red light. As a result, we exhibited the comprehensively optoelectrical results of CIGS thin films solar cells and implied the correlation between rollover and persistent conductivity in the interface. The understanding of metastability in CIGS devices will contribute to apply thin films for optoelectronic devices.

Keywords:

Cu(In,Ga)Se2 thin film solar cells, persistent conductivity, metastability, rollover

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A8.06

Passivated defects and grain boundaries of $Cu_2ZnSn(S,Se)_4$ thin film solar cell by incorporation of sodium

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Abstract:

$Cu_2ZnSn(S,Se)_4$ (CZTSSe) on solid substrates is known to have passivation effects by Na. In this study, the effect of diffused Na on flexible Mo-foil is reported. Various thickness of NaF layer (5, 10, 15, 20, 25, and 30 nm) were applied on CZTSSe thin film deposited on flexible Mo-foil, resulting in different power conversion efficiencies (PCE). Remarkably, 25 nm NaF sample shows the highest PCE of 8.7% which is considerably high PCE as compared with recorded PCE 9.80% for flexible CZTSSe solar cells [1]. X-ray photoelectron spectroscopy confirmed that the larger amount of Na remains at the surface as thickness of NaF layer increases. Determining optical properties, Raman imaging was obtained and the higher PCE sample shows the less distribution of secondary phase and intensity of secondary phase peaks. Also, photoluminescence spectra was measured at room temperature to obtain optical energy band gap and determine the defects. As a result of PL measurement, 25 nm sample shows the highest intensity at 1.03 eV. To characterize the surface electrical properties, conductive-atomic force microscopy (c-AFM), Kelvin probe force microscopy (KPFM) were used. A change of surface voltage by illumination of light was obtained in the scheme of KPFM as well. The c-AFM results confirmed that surface current was formed along grain boundaries (GBs) and the highest average surface current was observed in 25 nm NaF sample. By utilizing KPFM, upward potential bending at the GBs was detected, and thicker NaF layer sample shows the larger potential bending. These results explain that better transport path was selected by separated minority carriers which are collected at the GBs, leading higher open-circuit voltage and efficiency. In addition, smaller magnitude of light-induced voltage was observed in high-efficient samples, implying that surface band bending can be decreased by generating the light-induced voltage.

[1] K. J. Yang *et al,* Nat. Comm., **10**, 2959 (2019).

Keywords:

flexible CZTSSe thin film solar cell, Na passivation, PL, KPFM

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

A8.07

Compare of Machine Learning Algorithm to Improve Measurement Accuracy of Frequency Variation

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Abstract:

By combining electro-mechanical resonator and artificial intelligence technology, we have developed an algorithm that can effectively remove noise generated when measuring frequency changes through machine learning.[1] In previous studies, spectral subtraction using FFT and IFFT was mainly used for noise reduction.[2] However, when the spectral subtraction method is used, it is possible to remove only noise of a set section, and thus it is difficult to remove various types of unexpected noise. As an alternative, we compared the performance with the spectral subtraction method by using the artificial neural network technology which is recently applied in many fields for noise removal. Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Convolutional-Recurrent Neural Networks (CRNNs) used to remove noise.[3][4] Before the machine learning algorithm was performed, tests were conducted to confirm the presence or absence of noise reduction in the spectral subtraction method. We performed Python coding for the synthesis and rejection of white noise at the initial frequency and used the result as a dataset for the machine learning algorithm. The measurement results of electromechanical resonators using spectral subtraction and three machine learning algorithms were compared. The data will be compared to predict and analyze various kinds of noise and to implement more accurate nano mass sensors.

Keywords:

machine learning, accuracy, frequency, measurement

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A8.08

Gate-switchable rectification in isotype van der Waals heterostructure of multilayer $MoTe_2/SnS_2$ with large band offsets

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Abstract:

We construct an n-n isotype heterojunction field-effect device combined with a multilayer moly ditelluride ($MoTe_2$) and tin disulfide (SnS_2) by exfoliating each material and stacking them by PDMS dry transfer method. The carrier transport through the heterostructure clearly shows a gate-switchable rectifying behavior exceeding the rectification ratio of 10^3, at a moderate source-drain voltage of 1 V in an ambient environment. SnS_2 has a very large electron affinity (~ 5.1 eV) and bandgap (~ 2.3 eV) for a bulk, which can form very unique band alignments by combining with other TMD groups.[1] Whereas, $MoTe_2$ has a relatively small electron affinity (~3.8 eV) and bandgap (~0.9 eV) among other TMD groups.[2] The band alignment between two materials is expected by comparing a numerical solution of Poisson's equation and experimental data. From the systematic analysis, we ascribe the rectifying behavior to the large band offsets between two materials and the carrier transport is dominated by the majority carrier via the thermionic emission and tunneling-mediated process through the potential barrier. In addition, we certify the switchable rectification characteristic by varying the gate voltage that the rectification ratio goes to 1 at negative gate voltages.

Keywords:

Field-effect diode, isotype heterojunction, SnS2, MoTe2

A9.01

Higher-order interacting networks: Introduction and current researches

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Abstract:

During the past two decades, network science has been successful in understanding structural and dynamical properties of complex systems using the notions of simple graph and multi-layer networks. However, these approaches may be inappropriate to complex systems with high-order interactions ranging from social relationship to biological complex interactions. Recently, using a mathematical tool called algebraic topology, researchers investigate diverse features of higher-order interacting systems. In this talk, I will introduce this new approach and recent reseaches.

Keywords:

A9.02

Evolution of coauthorship networks in view of simplicial complex

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Abstract:

Graph, composed of nodes and links, is a simple representation for constituents and pairwise interactions, respectively. This simple method was successful for explaining diverse properties of complex systems to some extent. Hypergraph which contains simplicial complex as a subspace is a generalization of graph, which takes into account not just pairwise interactions between multiple nodes but higher order interactions as well. Here, using this simplicial complex representation based on algebraic topology, we consider the evolution of coauthorship networks, a prototypical example of large-scale social relationships, based on empirical datasets on specific subfields in science. We found that the facet degree distribution exhibits power-law decaying behavior more elaborately than the graph degree distribution, and the first Betti number is useful for representing the emergence of a large-scale cooperative phenomenon. Moreover, we construct a model to reproduce such results, which would be useful for understanding further structural properties of such simplicial complexes.

Keywords:

Simplicial Complex, Coauthorship

2020 KPS Spring Meeting
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A9.03

Percolation process on signed complex networks

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Abstract:

Many complex systems in physics, biology and social science can be modeled as high-order interactive networks of dynamic systems evolving under the influence of interactive nodes. Signed complex networks in which nodes interact thorough two functionally-opposite interaction channels (links), termed positive and negative channels, respectively. Thus, our model introduces geometric frustration and dynamic heterogeneity into coexisting sign interactions, which has a significant impact on system dynamics and is a basis for studying high-order interactions.
We also propose a new type of connected components which are not interrupted by negative links. In this work, we study the percolation problem by employing random sequential search to sample percolation cluster configurations and to estimate the largest component size.
We consider the interacting layers by comparing mutually interacting signed networks with maximum correlated (MC), maximum anti-correlated (MA) and uncorrelated (UC) structures.
First in UC structure, our results shows maximal effect (meaning largest and quickest decrement with respect to positive unsigned network) when both layers are scale-free type. On the other hand, the MC and MA structure is similar to that of UC, but MP, which has high density negative links, has an excellent suppression effect compared to MN structure.

Keywords:

Signed networks, Percolation

2020 KPS Spring Meeting
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A9.04

Betweenness centrality distribution of hypergraphs

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Abstract:

Recently, simplicial complexes and hypergraphs have intensive attractions in the network science field. While simplicial complexes are used for studying their topological features, hypergraphs are widely employed to express characteristics of higher-order interactions. Here, we focus on diverse hypergraphs constructed from the real data, such as coauthorship data and protein-protein interactions. With their bipartite graph representations, we obtain the betweenness centrality distribution of these hypergraphs. By implementing the real-world features of our datasets, we found a difference in betweenness centrality distributions between unweighted and weighted hypergraph representations.

Keywords:

Hypergraph, Betweenness centrality

2020 KPS Spring Meeting
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A9.05

Spectra of block structured community matrix of mutualistic networks

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Abstract:

The largest eigenvalue of a matrix is important to determine the local stability of the system. We construct a block-structured community matrix which consists of 2 types of interactions between groups of a plant and pollinating animal species in the mutualistic network. Intraspecific competition matrices are built by an undirected adjacency matrix giving negative random weights asymmetrically respect to its diagonal. Interspecific interaction matrices are made from the empirical mutualistic network by giving positive random variables to its adjacency matrices. We perform a spectra analysis on this block-structured community matrix. We find that almost every largest eigenvalue is separated from the bulk of eigenvalues. Despite the importance of the largest eigenvalue, the method to detection of outlying the largest eigenvalues is little understood. Here, we propose an approximation of the largest eigenvalue of the community matrix by its degree of hub species. Numerical analyses of the model on 148 empirical networks are conducted to examine our prediction. Our results empower a claim that the heterogeneity that is inherent in natural mutualistic networks determines the stability of the ecosystem. We hope this study enhances our understanding of the structure–stability relationships of the ecosystem.

Keywords:

Eigenvalue, spectra, stability

2020 KPS Spring Meeting
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A9.06

Neural network approach to open quantum nonequilibrium phase transition

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Abstract:

Phase transitions in dissipative quantum systems are intriguing because they are induced by the competition between coherent quantum and incoherent classical fluctuations. Here, we investigate the interplay of quantum and classical effects arising in quantum contact process (QCP) in one dimension. The Lindblad equation contains two control parameters ω and κ that adjust the degrees of quantum and classical effects, respectively. We find a characteristic value of κ_* that separates the novel class of QCP from the directed percolation (DP) class. In the region $[0, \kappa_*]$, the exponent α associated with the density of active sites is continuously varying, whereas for $\kappa > \kappa_*$, α has the DP value. We used the neural network machine learning technique to identify the transition point $\omega_c(\kappa)$ and determine the correlation length exponent. Moreover, by performing extensive quantum jump Monte Carlo simulations at $\omega_c(\kappa)$, we successfully determine all the critical exponents of the 1D-QCP. Finally, we argue that the continuously varying exponent originates from long-range coherence similarly to the one in the tricritical contact process with long-range interactions.

Keywords:

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A9.07

Hysteresis and criticality in hybrid percolation transitions

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Abstract:

Phase transitions are normally classified into second-order and first-order transitions, which exhibit different intrinsic properties. For instance, a first-order transition has latent heat and hysteresis when a control parameter is increased and then decreased across a transition point; however, a second-order transition does not have such features. Recently, hybrid percolation transitions (HPTs) occur in diverse complex systems, in which features of first-order and second-order PTs appear at the same transition point. Thus a naturally arising question is if hysteresis appears in a HPT. Here, we investigate this fundamental question with a so-called restricted Erd₩H{o}s-R₩'enyi (r-ER) random network model, in which cluster fragmentation process is additionally proposed. We find that a hysteresis curve of the order parameter appears and the critical behavior of HPT may be conserved throughout the forward and reverse processes.

Keywords:

hybrid percolation transitions, hysteresis

2020 KPS Spring Meeting
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A9.08

K-selective percolation on various networks

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Abstract:

The robustness of complex networks, which is the longstanding problem on network science, can be approached in the perspective of percolation theory. We propose *K*-selective percolation model, dealing with the successive attacks on nodes with intermediate degree in the complex networks. We applied this model on scale-free network, Erdös-Rényinetwork, and simple cubic lattice, and observed their robustness. We derived numerical solution and verified them by Monte Carlo simulations. An interesting feature of *K*-selective percolation is that fragile valleys and the resurgent hills are observed in the order parameter behavior. This implies that complex networks with fewer links can be more robust. Also, several phase transition types were observed in *K*-selective percolation on various substrate networks. Especially, we observed hybrid phase transitions in three dimensions that have not been reported in the *k*-core percolation models so far. We obtained critical exponents of those phase transitions using finite-size scaling analysis.

Keywords:

K-selective percolation, multiple phase transition, hybrid phase transition

Measurement of the differential Drell-Yan cross sections at 13 TeV with the CMS detector

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Abstract:

A study is presented for the measurement of the differential Drell-Yan cross sections in the dimuon channel using proton-proton collision data at 13 TeV recorded with the CMS detector at the LHC. The study uses the data collected with dimuon triggers with low transverse momentum thresholds and high rate by storing reduced amount of information, which corresponds to an integrated luminosity of 97 fb^{-1}. The background estimation and various corrections for the measurement are discussed.

Keywords:

LHC, CMS, Drell-Yan, cross section

B1.02

A study of initial state radiation on the Drell-Yan events at sqrt(s) = 13 TeV

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Abstract:

We present the updated results of initial state radiation (ISR) study using the Drell-Yan (DY) events from pp collision at LHC with sqrt(s) = 13 TeV, 137.2 fb^{-1} CMS data. ISR from hadron collisions plays an important role in the jet physics, which has an impact on the precision measurements and searches for new physics. We develop a systematic way to study the ISR effect using the dielectron and dimuon channel of the DY events. The truncated mean of the dilepton transverse momentum distribution is found to have a logarithmic slope as a function of dilepton invariant mass square. This logarithmic slope can be used to control ISR effect in the SM processes and new physics processes.

Keywords:

CMS, Standard Model

2020 KPS Spring Meeting
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B1.03

Search for new physics in dilepton events using asymmetry

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Abstract:

We report a noble way to search for new physics in dilepton events using asymmetry at the LHC. Since the discovery of the Higgs particle, we have not observed any new physics signal yet in bump hunting. A tantalizing new physics signature can be hidden in the corners of kinematic phase space of the dilepton events. We measure differential asymmetry as functions of various kinematic variables to search for hints of new physics.

Keywords:

LHC, CMS, 13TeV, asymmetry, AFB

2020 KPS Spring Meeting
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B1.04

Measurement of the cross section for ttbar production with additional jets and b jets in pp collisions at 13 TeV

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Abstract:

Measurements of the cross section for the production of top quark pairs in association with a pair of jets from bottom quarks (ttbb) and in association with a pair of jets from quarks of any flavor or gluons (ttjj) and their ratio are presented. The data were collected in proton-proton collisions at a center-of-mass energy of 13 TeV by the CMS experiment at the LHC in 2016 and correspond to an integrated luminosity of 35.9 fb-1. The measurements are performed in a fiducial phase space, separately in the dilepton and lepton+jets channels, where lepton corresponds to either an electron or a muon. These measurements are the most precise to date and are consistent, within the uncertainties, with the standard model expectations obtained at next-to-leading order in quantum chromodynamics.

Keywords:

top quark, bottom quark, LHC, cross section, CMS

B1.05

Measurement $|V_{cb}|$ in Hadron Collisions with Top Pair Semi-Leptonic Decay Channel.

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Abstract:

The CKM matrix element $|V_{cb}|$ has been determined from the measured branching ratios of B-hadron to final states with c quarks from the B-factories. However, there is an inconsistency which depends on the final states of W boson. The purpose of this study is to develop another way of measuring $|V_{cb}|$. Since there is enough data from the LHC, as energy and luminosity are increased, we expect that the $|V_{cb}|$ can be measured. We estimate the sensitivity of $|V_{cb}|$ measurement in top quark pair-produced events, produced by MadGraph5, Pythia8, and Delphes. We generate the events that have semi-leptonic final states. The final states of $q\bar{q}'$ decay modes of W boson decays considered are $u\bar{d}$, $c\bar{s}$, and $c\bar{b}$. We estimate the relative fraction of these final states using b-tagging algorithm.

Keywords:

|Vcb|, CKM matrix

2020 KPS Spring Meeting
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B1.06

Measurement of the charge asymmetry in top pair production

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Abstract:

The charge asymmetry in top pair production is measured in the proton-proton collision at a center-of-mass energy of 13 TeV corresponding to an integrated luminosity of 35.9/fb collected by the CMS experiment. The measurement is performed at lepton+jets final state combining the resolved and boosted topologies.

Keywords:

Top, CMS, 13TeV, LHC, Charge Asymmetry

2020 KPS Spring Meeting
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Differential cross section measurement of ttbb in lepton+jets channel for CMS Run 2 data at sqrt{s} = 13 TeV

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Abstract:

In 2016 to 2018, Large Hadron Collider (LHC) has accumulated proton-proton collision data corresponding to
an integrated luminosity of 35.9, 41.5 and 59.7 fb^{-1} at a center-of-mass energy of 13 TeV with the CMS detector. Several million top quark candidates are produced in this data set. This large data set allows us to measure the differential cross section of two additional b jets in association with the top quark pair production. We present the differential cross section result using the events of one lepton, 6 jets
and 3 b jets final state.

Keywords:

ttbb

B1.08

Search for flavor-changing neutral current interaction of the top quark and the higgs boson decaying into bb bar at sqrt[s] = 13 TeV with CMS Run2 data

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Abstract:

In this presentation, the results of searching for flavor-changing neutral current in the interaction of top quark and Higgs boson are presented. Large Hadron Collider (LHC) has accumulated proton-proton collision data corresponding to an integrated luminosity of 140 fb-1 at a center-of-mass energy of 13 TeV with the CMS detector during Run2. Using these datasets, the search is performed with the events of the final state of one isolated lepton, at least three jets including more than two b jets. Multivariate analysis techniques are utilized in various stages of analysis to improve the sensitivity of signal events.

Keywords:

top quark, Higgs boson, flavor-changing neutral current

2020 KPS Spring Meeting
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B12.03

Measuring optical activity using heralded single photons

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Abstract:

Chirality is an important concept in various fields, including chemistry, life science, physics, and material science [1]. Optical activity, for example, has often been used in pharmacology to determine the toxicity or efficacy of drug molecules caused by the chirality between enantiomers [2]. Polarimetry is a representative method to measure the optical activity. However, the estimated direction of linear polarization would fluctuate due to the discrete nature of light even when the chirality is fixed. This fluctuation determines the precision that reflects sensing capability.
It is known that the Fock state ($|N>$) has the minimum uncertainty in intensity-sensitive measurements [3, 4]. Therefore, in this study, we conduct quantum polarimetry with heralded single-photon to measure the optical activity of sucrose solutions. With three kinds of estimators, the concentration of the sucrose solutions is estimated by measuring the polarization of output photons. Through repetition of independent and identical measurements, we compare the estimation uncertainty among the three schemes. The results from quantum polarimetry scheme are also compared to classical benchmarks for which the coherent state of light is taken into account. With our work, we lay out a route for future applications relying on quantum polarimetry.

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Keywords:

Quantum polarimetry, Single photon, Optical activity

2020 KPS Spring Meeting
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B12.04

Optical diffraction tomography of freestanding objects with isotropic resolution via tomographic mold for optical trapping

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Abstract:

Optical diffraction tomography (ODT) reconstructs volumetric refractive-index (RI) distributions of microscopic samples. The label-free imaging capability of ODT has been widely exploited in various microscopic studies. The applications of ODT range from tracking Brownian motions of colloidal particles to morphological analyses of long-term cell dynamics.
The accuracy and precision of ODT-based analyses, however, are inherently limited by the finite spatial resolution. In particular, the finite numerical aperture of the ODT imaging system leads to the loss of sample information along the objective axis, causing a reconstructed tomogram to appear axially elongated. Although previous studies overcame the anisotropic spatial resolution of ODT based upon sample rotation schemes using a mechanically rotating fiber needle, a rotating sample chamber, and a microfluidic device, it has been extremely challenging to image soft freestanding objects such as colloids and live cells at isotropic resolution.
Here, we experimentally demonstrate ODT of freestanding non-spherical objects at isotropic resolution by exploiting tomographic mold for optical trapping (TOMOTRAP) to stably trap samples, rotate their orientations, and reconstruct their 3D RI maps without missing cones in Fourier space. Using the proposed all-optical method, we showcase 3D RI images of colloidal multimers and red blood cells.

Keywords:

Optical diffraction tomography, optical trapping

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B12.05

Low-coherent optical diffraction tomography using ferroelectric liquid crystal spatial light modulator

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Abstract:

Optical diffraction tomography (ODT) has recently emerged as an effective label-free imaging technique based on the principle of interferometric microscopy, which reconstructs the distribution of the three-dimensional (3D) refractive index (RI) of samples from interferometric images acquired at multiple incident angles. Due to its ability to provide quantitative and structural sample information, ODT has been actively employed in various fields, including biophysics, immunology, pharmacology and nanotechnology.
Because conventional ODT systems inherently require interferometric configurations, they rely on coherent, single-longitudinal-mode continuous-wave laser as an illumination source. However, the use of coherent sources causes coherent noises, reducing the signal-to-noise ratios. To overcome this problem, several ODT techniques using low coherence light sources have been introduced. For example, common path ODT has been introduced as a temporally stable imaging technique by eliminating the instability of the complex structure of low-coherence interferometry. The condition of weak scattering, however, limits the application ranges of the method. An alternative method was an off-axis ODT method using two digital micromirror devices (DMD) and a supercontinuum source. Due to the low diffraction efficiency, however, this method is inappropriate for using a low-power illumination source.
Here we introduce a low coherence ODT configuration using a superluminescent light emitting diode (SLD) and a ferroelectric liquid crystal spatial light modulator (FLC SLM). The SLD has a bandwidth of 6 nm, which gives a coherent length of 10 mm which is sufficient to prevent coherent noises from the coverslip. Without complicated dispersion-compensating units, we integrated the proposed method with a fast camera to achieve tomographic imaging of colloidal microspheres and live HeLa cells at a maximum frame rate of 3 kHz.

Keywords:

Low coherent, Ferroelectric spatial light modulator, Qunatitative phase imaging, Interferometrometric microscopy, Optical diffraction tomography

2020 KPS Spring Meeting
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B12.06

A simple method for reference-free holographic imaging of speckle field

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Abstract:

Speckle fields are ubiquitous in nature: the familiar examples are the light transmitted through scattering biological tissues and the acoustic wave scattered from complex obstacles. Although highly randomized, speckle fields contain the essential information regarding the complex structures that interacts with a coherent wave. Here, we propose a simple method to retrieve the phase and amplitude of speckle fields without complicated instruments. Exploiting the self-interference of speckles, complex field information can be computationally reconstructed with a simple perturbation on the intensity-measurement system. We expect that the proposed method will be widely adapted in various fields, from biophotonics to industrial holographic measurement, thanks to the simplicity.

Keywords:

Holography, Reference-free, Speckle

A toolbox for improving the performance of a solid-state single-photon source

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Abstract:

Resonant excitation of individual quantum dots coupled to a micropillar cavity offers an interesting platform to implement a scalable source of single photons [1-2]. In this approach, multiphoton suppression in the quantum dot emission–as well as single-photon indistinguishability and brightness– are directly influenced by the spatiotemporal characteristics of the optical excitation pulses. For instance, a large mismatch between the laser pulse bandwidth or transverse field distribution and the micropillar/quantum dot system can significantly enhance multiphoton noise in the emission output, which degrades the source single-photon indistinguishability. Obtaining the optimal excitation laser pulses for a particular cavity/dot system introduce already yet another technical hurdle, given the large parameter space involved.
In this work, we explore machine-learning techniques to tailor the excitation laser pulse properties in real-time. The algorithm significantly reduces the task of searching for parameters favouring simultaneous high multiphoton suppression single-photon indistinguishability and source brightness. We dynamically modulate the laser spectral profile using a spatial light modulator [3]. In parallel, we study resonant pumping of the quantum dot using phonon-assisted [4]and two-colour excitation [5]. In this case, the machine learning algorithm obtains the optimal pump spectral shape, enabling the implementation of different excitation in both excitation schemes. In particular, phonon-assisted excitation eliminates the necessity of polarisation filtering the pump laser, resulting in a two-fold increase in single-photon brightness. Finally, we employ machine-learning to control a deformable mirror, and for correcting aberration on the single-photon wavefront field maximising the coupling between the source output and a single-mode fibre [6]. The combination of all these procedures provides a toolbox for enhancing the performance of any solid-state single-photon source.

This research was supported by the Australian Research Council Centre of Excellence for Engineered Quantum Systems (project ID CE170100009).

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Keywords:

OCIS codes: (230.6080) Sources, OCIS codes: (230.5590) Quantum-well, -wire and -dot devices

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2020-07-13 - 2020-07-15

B16.01

Single-molecule Force Spectroscopy Unfolds Membrane Protein Folding Mystery

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Abstract:

Membrane proteins carry out many vital tasks across the cell membrane and they are the largest class of drug targets. One of great challenges in membrane protein biophysics is to learn how they fold into their structures (the membrane protein folding problem). Protein misfolding is the cause of many genetic diseases, so fundamental folding studies will have broad medical impact. By developing and using single-molecule force spectroscopy, I have been seeking to understand how membrane proteins (un)fold and their potential biophysical implications. Here I present a unique single-molecule method that I have developed to study membrane protein folding problem, one application of the technique to an extremely complex ClC chloride transporter, and a touch of delicate lipid effects on the folding. Single-molecule methods are particularly useful in membrane protein folding studies because they can obviate the membrane protein aggregation issue. Understanding (mis)folding is a key to designing therapeutic strategies to combat membrane protein misfolding diseases, so we can ultimately contribute to medicine as well as fundamental folding biophysics.

Keywords:

ClC chloride transporter, membrane protein folding, single-molecule force spectroscopy

Single-molecule tracking of PAF15 and PCNA on DNA skybridge

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Abstract:

Proliferating cell nuclear antigen (PCNA) behaves as a sliding clamp that increases the processivity of eukaryotic and archea DNA polymerases through a physical interaction. Upon DNA damage during DNA replication, PCNA-associated factor 15 (PAF15) in complex with PCNA plays an important role in switching from a replicative polymerase to a translesion synthesis polymerase that is capable of bypassing nucleotide-lesions. Using the DNA skybridge that is a surface-condition independent and high-throughput single-molecule optical imaging platform, we monitored the diffusive motion of the PCNA-PAF15 complex on DNA molecules. We found that only one PAF15 molecule is associated with PCNA at physiological salt conditions, which results in slowing the diffusion of PCNA by up to 20 times and significantly stabilizing PCNA on DNA. The PCNA drag is likely to facilitate the switching of DNA polymerases. Taken together with the previous co-crystal structure of PCNA with a PAF15 fragment, our results propose a PAF15-PCNA conformation where the central domain of PAF15 interacts with the front face of PCNA and its N-terminal domain passes inside the PCNA ring.

Keywords:

PCNA, PAF15, p15, 1-D diffusion, DNA skybridge

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B16.03

High degree of coordination of subunits in NSF for efficiently utilizing ATP molecules

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Abstract:

N-ethylmaleimide sensitive factor (NSF) which belongs to AAA+ protein family is a key protein in the membrane trafficking. NSF converts chemical energy into mechanical energy to disassemble the soluble NSF attachment protein receptor (SNARE) complex with alpha-soluble NSF attachment protein (aSNAP). we examined ATP consuming in NSF subunits. We found differently operating two types of ATP hydrolysis modes. One is basal hydrolysis mode that operated perfectly independently between subunits in NSF hexamer. The other is stimulated hydrolysis mode that did perfectly cooperativeIy. In addition, ATP binding of NSF is dramatically changed when NSF formed the complex with SNARE and aSNAP. The details of this mechanism present that NSF changed the gear to concentrate the energy when disassembling the SNARE complex

Keywords:

AAA+ ATPase, N-ethylmaleimide sensitive factor (NSF), ATPase activity

B16.04

Bile acid transporter mediated endocytosis of novel nano-complex for targeted oral delivery of drugs using MD simulation

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Abstract:

Insulin is a peptide hormone, which helps to maintain the glucose levels in the cell. The patients with advanced type 2 diabetes mellitus (T2DM) and type 1 diabetes mellitus (T1DM) require insulin. Insulin has been administered through a subcutaneous injection. However, it causes a burden to the patients. As an alternative to the subcutaneous route, we investigated another route of insulin delivery to human body: buccal delivery. One of the challenging issue in the buccal delivery is the permeation of insulin into the cell membrane. In this study, we suggest an effective way of insulin delivery by making it complex with SDGC (sodium deoxyglycocholate) using molecular dynamics simulation.

Keywords:

B16.05

Folding pathway of human glucose transporter GLUT3 and its evolutionary model

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Abstract:

The major facilitator superfamily glucose transporters have a fundamental role on cellular uptake of glucose for metabolism, homeostasis and growth. Especially, GLUT3 is responsible for glucose uptake in neurons, preimplantation embryos and white blood cells. Although GLUT family have been central to the studies of function and mechanism of solute transport, its folding pathway and hidden biological implications are still unknown and challenging so far. Here, using membrane protein folding assay, we were able to watch the folding pathway of GLUT3 in bilayer environment. We find that GLUT3 with two domains (N- and C-domain) folds N-domain first with higher stability than that of C-domain. In terms of evolution, our observation of the N- to C-terminal folding pathway suggests that the transporters have been evolved to connect two domains with the N-terminal domain being more responsible for structural stability and the C-terminal domain more coping with the complexity of functional requirements, whereas the ancient transporter proteins found in archaea and bacteria have two separate domains and usually fuse them into homodimer.

Keywords:

Membrane protein folding, Single-molecule force-spectroscopy, Glucose transporter, Magnetic tweezers

2020 KPS Spring Meeting
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B16.06

Single-molecule studies on cotranscriptional G-quadruplex formation induced by R-loop formation

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Abstract:

G-quadruplex (GQ), a non-canonical nucleic acid structure, could be formed at various regions including telomeres and regulatory regions. Considering its forming regions, their biological functions have been expected and some of them like transcription regulation were revealed with experiments. GQ not resolved properly, however, may also cause genome instability becasue it can hamper the transcription or replication process. Therefore, it could be said that it is important to understood their formation and elimination process.
Here, we report single-molecule fluorescence experiments to monitor the cotranscriptional GQ formation coupled with
R-loop formation and this structure's reaction to RNase H.

Keywords:

G-quadruplex, R-loop, Co-transcriptional fording, G-loop

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B16.07

Binding modes of full-length PD-1 to PD-L1 revealed at the single-molecule level

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Abstract:

Immune checkpoint molecules expressed on the immune cell membrane or on the opponent antigen-presenting cell membrane tightly regulates the strength of the immune response. Programmed cell death-1 (PD1) and its ligand (PDL1) are membrane proteins and are prominent co-inhibitory checkpoint molecules, interacting with each other using extracellular binding domains. Here, using single-molecule fluorescence technique, we demonstrate the precise measurement of binding kinetics between PD1:PDL1. To understand the detailed binding mode between PD1 and PDL1, we used full-length PD1 proteins, and show that full-length PD1 molecule heightens the binding affinity toward PDL1 by increasing the association kinetics an order of magnitude compared to ECD $PD1_{1\text{-}150}$ having binding domain only. By combining the intensity data and time traces, we suggest that even tighter binding of full-length PD1 to PDL1 is enabled where PD1s are gathered more than three. Considering their important role as cancer immunotherapy targets, our work and a deeper understanding of biophysical mechanism between PD1:PDL1 would contribute to predicting non-responders, understanding resistance mechanisms, or development of further drug discovery.

Keywords:

Membrane protein, Single-molecule imaging, Protein-protein interaction, Immuno-oncology

2020 KPS Spring Meeting
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B16.09

Autonomous in situ generation of multi-stranded RNA complexes for synthetic molecular circuits

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Abstract:

Synthetic molecular circuits using DNA or RNA oligonucleotides can in principle perform complex functions including logic-gate operation, molecular computing and feedback control at low cost. Despite recent advances in methodology and theoretical concepts, application of nucleic acid-based circuits *in vivo* remains challenging due to a lack of efficient methods to prepare the essential components in living cells, e.g. multi-stranded oligonucleotides complexes with designed sequences and domains. Here, we utilize naturally occurring self-cleaving ribozymes to cut one long single-stranded RNA into many short strands that form multi-stranded complexes directly from transcription. The self-excising ribozyme module was designed by connecting two hammerhead ribozymes (HHRs) in a way that the double ribozyme module dissociates from the rest of multi-stranded RNA transcripts after successful cleavage reactions. These multi-stranded complexes generated via *in vitro* transcription reactions perform *in situ* toehold-mediated nucleic acid strand displacement reactions. As the activity of our module does not depend on the rest of the RNA context, which is "hidden" in double-stranded form, our design can be scaled and adapted to generate more complex multi-stranded RNA oligonucleotides.

Keywords:

RNA nanotechnology, Strand-displacement reaction, Synthetic biology, in-vitro transcription, Ribozyme

2020 KPS Spring Meeting
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B16.10

Study on the Intrinsic mechanical property of Bacteriophage P2 by using AFM

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Abstract:

We have investigated the intrinsic property of bacteriophage P2 bu using Atomic force microscopy. The bacteriophage phage P2 is known to physical shape model for the Moon Land Apollo project due to its unique property of internal pressure up to ~60 atm so that it has the capability of packing DNA inside the phage. We have fabricated the 2 different bacteriophages with DNAs fully packed, 2/3 packed. Then investigated the internal property such as Young's moduli by using atomic force microscope. We will report the details of the investigation processes and its results.

Keywords:

bacteriorphage, Youngs modulus, AFM,

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B2.01

Twisted Indices with Loop Operators in 3d-3d Correspondence

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Abstract:

We probe 3d-3d correspondence using supersymmetric loop operators along S^1 on a topologically twisted background $\Sigma_g \times S^1$. The loop operators come from co-dimension 4 defects in 6d A_{N-1} $(2,0)$ theory wrapping geodesic cycles on internal hyperbolic 3-manifold. Using the loop operator, we i) probe a discrete 6D polarization choice in 3d-3d correspondence at $N=2$ and ii) compute its expectation value at large N and find exact match with corresponding holographic computation. We also conjecture an non-trivial integral property of a topological quantity constructed from adjoint Reidemeister torsions for irreducible flat connections and complex lengths of geodesics.

Keywords:

3d-3d correspondence, supersymmetric loop operator, AdS/CFT, Topologically Twisted Index

B2.02

Enlarging the scope of the cosmological collider physics: Beyond the Positivity Bounds

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Abstract:

It is known that the consistency conditions such as unitarity and analyticity of the scattering amplitudes are useful to discuss UV completion of low-energy effective field theory. Well-known example is the positivity bounds which constrain the Wilson-coefficients using the consistency conditions. In this talk we show that the signs of coefficients, which are not constrained by the positivity bound, depend on the spin of particles which exsist in UV scale. We also discuss the appliciations to cosmology, especially so-called cosmological collider physics.

Keywords:

Scattering amplitude, Positivity bound, Cosmological Collider Physics

B2.03

Perturbative solution and Entanglement Entropy of 4D Janus

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Abstract:

We construct holographic Janus solutions, which describe a conformal interface in the theory of M2-branes, in four-dimensional gauged supergravities using a perturbative method. In particular, we study three Einstein-scalar systems and their BPS equations, which are derived by Bobev, Pilch, and Warner (2014) [1]. The actions of our interest are all consistent truncations of D = 11 supergravity chosen to be invariant under SO(4) × SO(4), SU(3) × U(1) × U(1), and G2 symmetry subgroups of SO(8) respectively. The utility of our semi-analytic result is illustrated by the calculation of minimal area surface and the associated holographic entanglement entropy.

Keywords:

Janus, Perturbation, Entanglement Entropy

B2.04

Transport and Thermodynamics of Non-Dirac materials from Holography

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Abstract:

We study thermodynamics of strongly interacting non-Dirac materials from gauge/gravity duality. To describe non-Dirac structure in dispersion relation, we introduce hyperscaling violation geometry in the bulk. We investigate proper boundary terms which make renormalized on-shell action to be finite. Together with boundary stress energy momentum tensor, we study thermodynamics of the boundary theory which contains a hyperscaling violation exponent and a critical dynamical exponent. We compare our result to the critical phenomena in the experiment.

Keywords:

gague/gravity duality, strongly correlated system, hyperscaling violation, non-Dirac materials, holographic renormalization

B2.05

Spinning binary Hamiltonian at first post-Minkowskian order from scattering amplitudes

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Abstract:

Classial Hamiltonian for a binary system of general compact spinning bodies at all orders in spin and at first post-Minkowskian order is obtained from scattering amplitudes of massive higher spin particles. The part of the scattering amplitude relevant for obtaining the classical Hamiltonian is bootstrapped from analytic properties of the S-matrix without resorting to a full Lagrangian description of massive higher spin particles. The result is compared with known post-Newtonian results and equivalent order black hole results.

Keywords:

Gravitational waves, post-Newtonian, post-Minkowskian

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B2.06

Hysteric Magnetoconductance Phase

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Abstract:

We find holgraphic DC conductivities in the presence of a magnetic field. An axionic field in AdS_4 plays a role of a magnetic impurity in the dual system. This impurity causes a phase transition showing hysteric behavior in magnetoconductance. We compare our result of electric conductivities $₩sigma_{ij}$ with experimental data. We also show the thermoelectric coefficient $₩bar{₩alpha}_{ij}$ for future experiments.

Keywords:

gauge/gravity correspondence, Topological Insulator

Large AdS_6 black holes from CFT_5

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Abstract:

We study supersymmetric AdS_6 black holes at large angular momenta, from the index of 5d SCFTs on $S^4 \times \mathbb{R}$ in the large N and Cardy limit. Our examples are the strong coupling limits of 5d gauge theories on the D4-D8-O8 system. The large N free energy scales like $N^{5/2}$, statistically accounting for the entropy of large black holes in AdS_6. Instanton solitons play subtle roles to realize these deconfined degrees of freedom.

Keywords:

Supersymmetric AdS6 Black Holes, 5d SCFTs, Large N Cardy Limit, Deconfined N5/2 Degrees of Freedom, Instanton Solitons

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B2.08

Dynamics of the Sachdev-Ye-Kitaev model coupled to external degrees of freedom

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Abstract:

The Sachdev-Ye-Kitaev (SYK) model has been thought to holographically correspond to black holes. Recently, a proposal [1] that the time evolution of
the SYK model coupled to external degrees of freedom describes the evaporation process of a black hole has attracted attention. In this talk, we
present our results [2] on quantities such as the entanglement entropy based on exact diagonalization and compare these results with analytical predictions
in the large-N limit.

[1] Ahmed Almheiri, Raghu Mahajan, Juan Maldacena, Ying Zhao, arXiv:1908.10996.
[2] Masamichi Miyaji, Masaki Tezuka, Zhenbin Yang, and Junggi Yoon, in preparation.

Keywords:

black hole, strongly correlated system, holography, black hole information, entanglement entropy

Calculation of differential elastic cross section for p + ^{12}C scattering in Cluster Effective Field Theory

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Abstract:

The radiative proton capture reaction, $^{12}C + p \rightarrow ^{13} N^* + \gamma$ plays an important role in the CNO cycle, which is one of the main series of reactions for hydrogen buring in stars. We calculated the differential cross section of the elastic p + ^{12}C scattering at low energies by using the cluster effective field theory[1]. The ground state (Jpi=1/2-) and the three low-lying resonance states (1/2+, 3/2- and 5/2+) of ^{13}N are taken into account as explicit degrees of freedom. The elastic scattering amplitudes are expressed in terms of the effective-range parameters, and the parameters are determined by the experimental differential cross sections. The calculation results are compared with the existing experimental data.
[1] S. I. Ando, Eur. Phys. J. A (2016) 52: 130

Keywords:

elastic p + 12C scattering, differential cross section, cluster effective field theory

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B3.02

Proton decay of ^{21}Na states

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Abstract:

The proton decay of radionuclide ^{21}Na was measurement is measured at Holifield Radioactive Ion Beam Facility(HRIBF) of the Oak Ridge National Laboratory. This measurement is simultaneously measured with the spectroscopic study of ^{21}Na [Cha et al, Phys. Rev. C **96**, 025810 (2017)]. The ^{21}Na nucleus was produced through the ^{24}Mg(p,a)^{21}Na reaction and the proton was emitted from ^{21}Na. Several groups of events related to ^{20}Ne states were identified in decay proton energy versus coincident $₩alpha$ particle energy spectrum. The proton branching ratios of several states of ^{21}Na were obtained. Details of data analysis will be discussed.

Keywords:

An intranuclear cascade model for the $^{12}C(K^-,K^+)$ reaction at 1.8 GeV/c

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Abstract:

The study of double-strangeness systems attracts a lot of attention in nuclear physics to understand hyperon-nucleon and hyperon-hyperon interactions in the strange hadronic matter. A series of S=-2 experiments via (K^-, K^+) reactions are underway with the beam momentum of 1.8 GeV/c at J-PARC. To interpret the experimental data, it is crucial to understand the reaction mechanism of the (K^-, K^+) reaction on nuclei. In addition to quasi-free $K^-p \rightarrow K^+\Xi^-$ and $K^-p \rightarrow \Lambda\phi$ reactions, two-step strangeness exchange processes involving Ξ^- and intermediate-meson induced reactions could contribute to the (K^-, K^+) reactions. We have developed the intranuclear cascade (INC) generator in C++, in which all the possible reactions are implemented. In this talk, we will introduce the details of the INC model and the validation of the INC generator with J-PARC experimental data.

Keywords:

Intranuclear cascade, Double strangeness exchange reactions, J-PARC

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B3.04

Cross-section measurement for K^-p interactions at 1.8 GeV/c

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Abstract:

We report Geant4 simulation results on the cross-section measurement for K^-p interactions at 1.8 GeV/c with the Hyperon Spectrometer. During beam commissioning of the H-dibaryon search experiment E42 at J-PARC, we plan to measure cross-sections for K^-p inelastic scattering processes involving K(892)* and Lambda hyperon. We have dedicated to a Geant4 simulation with a full geometry of the Hyperon Spectrometer consisting of a superconducting dipole magnet and a time projection chamber(HypTPC) enclosed by a trigger hodoscope (HTOF) of 32 fast plastic scintillator slats. The HTOF is a key detector component for the online trigger with the hit multiplicity. In this talk, we would like to present preliminary simulation results on the cross-section measurement for K^-p interactions at 1.8 GeV/c.

Keywords:

Simulation, HypTPC, HTOF, E42, J-PARC

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B3.05

$₩beta$ delayed $₩alpha$ emission from ^{16}N in effective field theory

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Abstract:

The $₩alpha$ particle energy distribution from the $₩beta$ delayed $₩alpha$ emission from ^{16}N is studied in effective field theory up to next-to-next-to leading order. Secondary lower energy peak in the observable is known to be important to determine an interference pattern between the subthreshold 1_1^- state and the broad resonance 1_2^- state, along with a background state, of ^{16}O in R-matrix or K-matrix analysis, which provides a crucial constraint for an estimate of the astrophysical S-factor of radiative $₩alpha$ capture on ^{12}C through the $E1$ transition at stellar energies. We derive an expression of $₩alpha$ decay amplitudes for the $₩beta$ delayed $₩alpha$ emission from ^{16}N in the theory and fit the parameters to available two sets of the experimental data. We find that in the present approach that the secondary peak in the $₩alpha$ particle energy distribution is well reproduced by an interference between the amplitudes from a non pole diagram and a pole diagram. We also find that values of the two sets of the fitted parameters are significantly different and call for a new experiment for the $₩beta$ delayed $₩alpha$ emission from ^{16}N in the future.

Keywords:

$₩beta$ delayed $₩alpha$ emission from ^{16}N, interference between 1^- states of ^{16}O, effective field theory

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B3.06

H-dibaryon productions with the Lambda-baryon beam off the proton target

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Abstract:

In this talk, we provide recent results on H-dubaryon productions in the Lambda-baryon beam off the proton target via $\Lambda p \to K^+\Lambda\Lambda$ and $\Lambda p \to K^+\Xi^- p$ reaction processes, using the effective Lagrangian method. We provide possible shapes of the invariant-mass plots, which depend on the H-dibaryon properties, such as the mass and decay width. We also provide the polarized cross sections, which enable tp reduced the signal-background ratios.

Keywords:

H-dibaryon, Hyperon beam, effective Lagrangian method, final state interactions.

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B3.07

Electroproduction of vector mesons in an effective Lagrangian approach

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Abstract:

We investigate the reaction mechanism of light vector-meson electroproductions based on the gauge invariant effective Lagrangians. We include Pomeron and various meson exchanges in the t-channel Feynman diagrams and calculate the transverse-, longitudinal- and
interference-cross sections at the low photon virtualities Q^2 and low photon energies W. Various spin-density matrix elements are also examined in the helicity frame. The role of each contribution is clarified by using our effective hadronic model.

Keywords:

vector-meson electroproductions, separated cross sections, spin-density matrix elements

B3.08

QCD phase diagram via the canonical method in the PNJL model with complex quark chemical potential

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Abstract:

In this talk, we present recent results on the QCD phase diagram via the canonical method in the PNJL model with finite complex quark chemical potentials $\mu_{R,I}$ in order to overcome the sign problem in lattice QCD sumulations. We verified that, employing an appropriate parameterization of the quark number density in the imiginary quark chemical potential μ_I, we successfully describe the QCD phase diagram as a function of T and μ_R. We also explore the CEP in the PNJL model as well.

Keywords:

QCD phase diagram, PNJL, canonical method, complext quark chemical potetntial.

B4.01

Tellurium: 1D Helical Atomic Chains to 2D Tellurene

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Abstract:

Two-dimensional (2D) materials are of significant interest for various technical applications. Since the discovery of graphene, various 2D materials are of substantial interest due to their tunable properties. In contrast, group VI elements such as tellurium or selenium have yet to be stabilized in purely 2D forms, which may be due to its stable crystal structure, which consists of covalently bonded Te atomic chains that spiral along its c-axes. These 1D helical chains are van der Waals bonded into a hexagonal lattice. A typical exfoliation technique to produce 2D monolayers would not work in this case.

Here, we report the synthesis of various forms of elemental tellurium, i.e., 1D atomic chains to 2D tellurene, which is the first 2D group VI tellurium allotrope. Bundles of 1D helical tellurium (Te) atomic chains were directly grown at low temperatures by molecular beam epitaxy (MBE). Its integrated nanostructure devices exhibit room temperature field-effect hole mobilities as high as 420 $cm^2V^{-1}s^{-1}$, significantly higher device performance than other low-temperature grown materials. These bundles of 1D atomic chains of tellurium were successfully isolated by carbon nanotube (CNT) or boron nitride nanotube (BNNT) encapsulation. By the encapsulation of a BNNT, 1D coaxial Te/BNNT heterostructure enables a large current density. Then, we used a wafer-bonding assisted self-assembly process, a new approach to synthesize and stabilize the low-dimensional structure, to synthesize a single layer tellurene. Each monolayer Te atom has four nearest neighbors within the plane with inter-atomic distances of 0.31 – 0.32 nm. First-principles calculations found tellurene to be metallic, with electronic band structures containing Dirac-cone-like features and exhibiting significant asymmetric spin-orbit band splitting. These findings enable further research into the suitability of tellurene for device applications, such as spintronics and quantum computing.

Keywords:

Tellurium, atomic chain, Tellurene

B4.02

Advanced scanning probe microscopy studies in ferroelectric oxide films

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Abstract:

For the last three decades, scanning probe microscopy (SPM) has emerged as one of the most powerful tools to investigate physical properties of materials on the nanometer level. It allows us to measure not only surface morphology but also current, forces, mechanical displacement, and so forth. Especially, it is widely used to characterize physical properties in functional oxide films. Typical examples are piezoresponse force microscopy (PFM) and conductive-atomic force microscopy (c-AFM) studies in ferroelectric oxide films.

Here, I will talk about my recent SPM studies in ferroelectric oxide films. Mainly, I present PFM-based studies of nanoscale ferroelectricity and flexoelectricity. Regarding ferroelectricity, I will introduce several studies of ferroelectric domain switching dynamics and the recent study of nanoscale ferroelectricity in ultrathin films [1]. About flexoelectricity, I will stress that trailing flexoelectric field generated by SPM tip pushing is a simple but very effective way to deterministically control ferroelectric domains in low-symmetry materials [2].

References:
[1] S. M. Yang, A. N. Morozovska, R. Kumar, E. A. Eliseev, Y. Cao, L. Mazet, N. Balke, S. Jesse, R. K. Vasudevan, C. Dubourdieu, and S. V. Kalinin, *Nature Physics*, **13**, 812 (2017)
[2] S. M. Park, B. Wang, S. Das, S. C. Chae, J.-S. Chung, J.-G. Yoon, L.-Q. Chen, S. M. Yang, and T. W. Noh, *Nature Nanotechnology*, **13**, 366 (2018)

Keywords:

Scanning probe microscopy, Oxide, Ferroelectric, Piezoresponse force microscopy, flexoelectricity

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B4.03

Visualization of the inhomogeneous superfluid in an iron-based superconductor

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Abstract:

Inhomogeneous superconductivity has been one of the long-standing conundrums in unconventional superconductors. Scanning tunneling microscopy and spectroscopy (STM/STS) has been indispensable to investigate their inhomogeneous electronic structure with unparalleled spatial and energy resolution. However, a metallic tip commonly used in STM does not probe superconducting ground state but single electron excitation spectrum. In the light of this limitation, it seems desirable to employ a superconducting tip to measure Cooper pair tunneling (Josephson) current that is directly related with the superconducting order parameter. In this talk, I will present our Josephson STM study that reveal a strongly inhomogeneous superfluid in the iron-based superconductor $FeTe_{0.55}Se_{0.45}$. By simultaneously acquiring the topographic and electronic properties, we find that this inhomogeneity in the superfluid is not caused by structural disorder or strong inter-pocket scattering, and does not correlate with variations in the energy of the Cooper pair-breaking gap. Instead, we see a clear spatial correlation between superfluid density and the quasiparticle strength, defined as the height of the coherence peak, on a local scale. Our results shed light on the interplay between superconductivity and quasiparticle character that has been observed by photoemission experiments across the critical temperature in the unconventional superconductors.

Keywords:

unconventional superconductors, iron-based superconductor FeTe0.55Se0.45, inhomogeneous superfluid, Cooper pair tunneling

B4.04

Topological superconductivity at the edge of bismuth bilayer

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Abstract:

Ferromagnetic chains of Fe atoms on a superconducting Pb substrate have proven to be a platform to host Majorana zero modes(MZM). By combining ferromagnetism, strong Rashba spin-orbit coupling and superconductivity, engineering a new platform is highly desirable to further study the emergence of MZMs and to find systems with the largest topological gap. We have successfully grown epitaxial Bi(110) and Bi(111) thin film on a superconducting substrate that shows robust proximity induced superconductivity with a hard gap. We've characterized the electronic structure of bismuth films and examined the proximitized superconductivity. Using high-resolution STM spectroscopy, we observed distinct localized zero-bias peaks at the interface of both the experimental system. I will discuss two driving mechanisms for developing MZMs in each system.

Keywords:

Topological superconductivity, Majorana, Scanning tunneling microscopy

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B5.01

Thickness-Controlled Black Phosphorus Tunnel Field-Effect Transistor for Low Power Switches

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Abstract:

The continuous transistor down-scaling has been the key to the successful development of the current information technology. However, with Moore's law reaching its limits the development of alternative transistor architectures is urgently needed. Transistors require at least 60 mV switching voltage for each 10-fold current increase, i.e. subthreshold swing (SS) 60 mV/dec. Alternative tunnel field-effect transistors (TFETs) are widely studied to achieve a sub-thermionic

SS and high I_{60} (current where SS becomes 60 mV/dec) . Heterojunction (HJ) TFETs bear promise to deliver high I_{60}, but experimental results do not meet theoretical expectations due to interface problems in the HJs constructed from different materials. Here, we report a natural HJ-TFET with spatially varying layer thickness in black phosphorus (BP) without interface problems. We

achieved record-low average SS over 4–5 decades of current, $SS_{ave\_4dec} \approx$ 22.9 mV/dec and $SS_{ave\_5dec} \approx$ 26.0 mV/dec with record-high I_{60} (= 0.65–1 μA/μm), paving the way for the application in low power switches.

Keywords:

tunnel FET, Moore's law, power consumption, subthreshold swing, black phosphorus

B5.02

Emerging electronic and thermal properties of two-dimensional oxidized black phosphorus

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Abstract:

A single layer of black phosphorus or phosphorene has attracted much attention from researchers studying two-dimensional materials due to its high carrier mobility. It has, however, been observed that its oxidation may be unavoidable since its high surface reactivity. Thus, we explore the electronic and thermal properties of oxidized phosphorene using first-principles density functional theory. Intriguingly, a certain stable phosphorene oxide (PO) exhibits symmetry-protected electronic structures including the band degeneracy and Dirac fermions guaranteed by two nonsymmorphic symmetries with the inversion symmetry broken. Even more intriguingly, we reveal that the PO can undergo topological phase transition induced by strain. We also find that due to its unique structural configuration, PO exhibits a much lower thermal conductivity than its pristine counterpart as well as other two-dimensional materials. We present a fundamental understanding of these emerging properties of the PO.

Keywords:

phosphorene oxide, nonsymmorphic symmtry, topological phase transition, thermal conductivity, density functional theory

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B5.03

Observation of Excitonic Structure in Atomically Thin Black Phosphorus

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Abstract:

Atomically thin 2D semiconductors provides a fascinating platform where novel excitonic quantum phenomena can be realized at higher temperature due strongly enhanced Coulomb interaction at the atomically thin thickness. Black phosphorus is a unique direct bandgap semiconductor where the size of band gap can be drastically modified by thickness and electric field. The strong structural anisotropy further provides interesting electronic properties such as anisotropic effective mass and pseudospin. Few-layer black phosphorus, therefore, can offer exciting opportunities to explore the excitonic phenomena with different symmetry and tunability. Here, we study the excitonic structure of few-layer black phosphorus with optical spectroscopy. The absorption and photoluminescence spectra reveal tightly bound excitonic states in high quality few-layer samples with hBN encapsulation

Keywords:

Black phosphorus, Excitonic structure

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B5.04

Optical and transport properties of few-layer black phosphorus

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Abstract:

In recent years, few-layer black phosphorus (BP) has attracted considerable attention due to its tunable energy gap and highly anisotropic electronic structure, which shows a gapped insulator phase, gapless semi-Dirac transition point, or gapless Dirac semimetal phase depending on the sign of the band gap. In this talk, first we discuss the optical conductivity of few-layer BP, showing a characteristic frequency dependence in each phase [1]. Next, we present the dc conductivity within the semiclassical Boltzmann transport theory fully considering the anisotropy of the system [2], which can alternatively be proved by a many-body diagrammatic method including the vertex corrections [3]. Finally, we discuss the quantum interference corrections by calculating the Cooperon operator considering the anisotropy and Berry phase of the system, demonstrating a crossover between weak localization and weak antilocalization depending on the phase and the intranode/internode scattering strength in few-layer BP [4].

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[2] Sanghyun Park, Seungchan Woo, and Hongki Min, Semiclassical Boltzmann transport theory of few-layer black phosphorus in various phases, 2D Mater. **6**, 025016 (2019).
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[4] Sunghoon Kim and Hongki Min, Tunable quantum interference effect on magnetoconductivity in few-layer black phosphorus, Phys. Rev. Research **2**, 022045(R) (2020).

Keywords:

few-layer black phosphorus, optical conductivity, Boltzmann transport theory, weak localization

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B6.01

Determining the spin Nernst effect in platinum from magnetic-field-dependent differential voltage measurements

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Abstract:

Since the spin Seebeck effect was observed, a group of effects coupling spin current with heat or thermal gradient has drawn considerable attention due to their large potential for applications in spincaloritronics. Recently, a new member of the family, named the spin Nernst effect, was reported to be observed. Spin Nernst effect converts thermal gradient into pure spin current in nonmagnetic conductors, which is expected to have many applications such as energy harvesting. Here, we report a magnetic-field-dependent differential voltage (< 25 nV) across two permalloy contacts on a platinum thin-film channel patterned into a cross shape, while in the orthogonal channel, electrical current bias up to 5.5 mA is utilized to create a significant local thermal gradient through the Joule heating effect. From finite element analysis as well as local electrical transport thermometry measurements, we estimate thermal gradients to be 6 K/micron near the permalloy contacts at electrical bias current of 5.5 mA. We averaged the voltage from current in both directions so that any voltage with electrical origin cancels out by its odd dependence, while thermal effect survives since it is even in current. We will further discuss the origins of the large observed voltage by measurements with different interface condition which we strongly feel rules out any other thermomagnetic effects such as anomalous Nernst effect in ferromagnetic metal contacts.

Keywords:

Spin Nernst effect, Spin Hall effect, Thermomagnetic effect, Spin current

2020 KPS Spring Meeting
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B6.02

Magnetoelectric Response of Antiferromagnetic Van der Waals Bilayers

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Abstract:

Spintronics is the study of the interplay between electrical and magnetic properties, and underlies an important technology, based so far almost exclusively on the properties [1–2] of magnetic metals. There has long been interest in expanding spintronics to semiconductors, which tend to have properties that are more subject to electrical control [3]. We predict that antiferromagnetic bilayers formed from van der Waals (vdW) materials, like bilayer CrI_3, have a strong magnetoelectric response that can be detected by measuring the gate voltage dependence of Faraday or Kerr rotation signals, total magnetization, or anomalous Hall conductivity [4]. Strong effects are possible in single gate geometries, and in dual-gate geometries that allow internal electric fields and total carrier densities to be varied independently. We comment on the reliability of density-functional-theory estimates of interlayer magnetic interactions in van der Waals bilayers, and on the sensitivity of magnetic interactions to the pressure that alters the spatial separation between layers.

Acknowledgements
Support from the Korean NRF is acknowledged for B.L.C. through Basic Science Research Program of the National Research Foundation of Korea (NRF) funded by the Ministry of Education Grants No. 2018R1A6A1A06024977 and No. NRF-2017R1D1A1B03035932, and for J.J. through Grant No. NRF-2020R1A2C3009142.

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4. C Lei, BL Chittari, K Nomura, N Banerjee, J Jung, AH MacDonald, arXiv:1902.06418 (2019)

Keywords:

Antiferromagnetism, Magnetoelectricity, Mean Field Theory, Denisty Functional Theory, Monte Carlo Simulations

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B6.03

Spin-dependent thermoelectric power of nanoislands

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Abstract:

The Seebeck effect explains the generation of electric voltage as a result of a temperature gradient. Its efficiency, defined as the ratio of the generated electric voltage to the temperature difference, is sensitive to local inhomogeneities that alter the scattering rate and the density of the conduction electrons. Spin-polarized Seebeck tunneling generates a distinct thermovoltage in spin-up and spin-down charge transport channels, and is a key to spin caloritronics, which focuses on transport phenomena related to spin and heat. Here, we report spatially resolved measurement of the spin-dependent thermovoltage in a tunneling junction formed by ferromagnetic Co layers and a Ni tip of a scanning tunneling microscope. The data acquired in
spin-dependent scanning tunneling thermovoltage microscopy (SP-STV$_{th}$M) resolve the nanoscale thermoelectric powers with respect to spin polarization, nano-island size, and stacking order of Co layers on a Cu substrate, as well as the local heterogeneities introduced by intermixing of Co with Cu or merged islands. The observed thermally generated spin voltages are supported by first-principles and model calculations, which help disentangle electrostatic effects from spin-dependent thermovoltage.

Keywords:

Scanning tunneling thermovoltage microscopy (STVthM), Thermovoltage, Spin-polarized scanning tunneling microscopy, Thermoelectric power, Seebeck coefficient

B6.04

Magnetic eld induced quantum phases in a tensor network study of Kitaev magnets

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Abstract:

Recent discovery of the half quantized thermal Hall conductivity in a-RuCl3, a candidate material for the Kitaev spin liquid, suggests the presence of a highly entangled quantum state in external magnetic elds. This eld induced phase appears between the low eld zig-zag magnetic order and the high eld polarized state. Motivated by this experiment, we study possible eld induced quantum phases in theoretical models of the Kitaev magnets, using the two dimensional tensor network approach or innite tensor product states. We nd various quantum ground states in addition to the chiral Kitaev spin liquid occupying a small area in the phase diagram. They form a band of emergent quantum phases in an intermediate window of external magnetic elds, somewhat reminiscent of the experiment. We discuss the implications of these results in view of the experiment and previous theoretical studies.

Keywords:

Kiteav spin liquid, Kitaev magnet, Tensor network

Study of thin molecular spin qubit layers using a surface-sensitive electron spin resonance spectrometer

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Abstract:

Over the last several years, research has revealed that electron spins in molecular structures are potential candidates to realize nanometer-size qubits with long coherence time (T_2) even at high temperature. Examples of molecular spin qubits are copper phthalocyanine with T_2 = 1 μs at 80 K [1] and vanadyl phthalocyanine with T_2 = 1 μs at room temperature [2].

Understanding how the molecule properties are perturbed when adsorbed on a substrate is crucial to realize integrated molecular devices. In order to investigate the quantum coherence properties of molecular spins adsorbed on surface, a tailored instrument with suitable surface sensitivity is required.

In this work, we use a home-built surface-sensitive electron spin resonance (ESR) spectrometer to characterize thin films of molecular spin qubits. The spectrometer utilizes a coplanar waveguide resonator designed for two-dimensional spin distributions. We investigate the magnetic and quantum properties of electron spins in mononuclear metal-organic complexes via continuous-wave and pulsed ESR spectroscopy. The present results on thin molecular films will pave the way to the measurement of a single molecular qubits layer and its interaction with suitable substrates.

[1] Warner *et al.*, Nature **503**, 504 (2013).
[2] Atzori *et al.*, J. Am. Chem. Soc. **138**, 2154 (2016).

Keywords:

Electron spin resonance, Quantum coherence, Surface magnetism, Molecular spin qubit

High-temperature itinerant antiferromagnetism in a iron-based magnetic van der Waals metal

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Abstract:

Antiferromagnets, due to their negligible stray field, robustness against perturbation and ultrafast dynamics, have great potential for spintronics. Among them, synthetic antiferromagnets, where two ferromagnetic (FM) layers are stacked alternately with non-magnetic layers in-between, are versatile system for antiferromagnetic (AFM) spintronics. Since their diverse spin configuration and functionalities are based on the interlayer exchange coupling mediated by conduction electrons, they are extremely sensitive to material compositions and interlayer distance. Taking this approach and using a metallic van der Waals (vdW) magnet Fe_4GeTe_2 as a model system, we show that the interlayer exchange coupling and magnetic anisotropy is significantly modulated with Co doping, leading to the AFM order with the highest Neel temperature of T_N ~ 210 K among vdW antiferromagnets. The resulting spin configurations and orientations are sensitively controlled by magnetic field, temperature, and thickness and effectively read out by their coupling to the electrical conduction. These findings manifest metallic vdW antiferromagnets as intrinsic synthetic anti-ferromagnets, which can serve as a tunable component for AFM spintronics

Keywords:

Antiferromagnet, Spintronics, Synthetic antiferromagnet, van der Waals magnet

Effect of growth temperature on magnetism of $GdFe_{12}$ epitaxial thin films

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Abstract:

Alloys of rare-earth elements and transition metals are promising composition of permanent magnet materials. Especially, $ThMn_{12}$ structured alloys are expected to have both high saturation magnetization and large coercivity. Since Gd element has its own unpaired electrons, we choose $GdFe_{12}$ to study magnetic properties. In this presentation, we present effect of growth temperature on structure and magnetism on $GdFe_{12}$ epitaxial thin films from $GdFe_{12}$ target. Amorphous Mo / (110) Gd-Fe / (110) Mo were deposited by RF and DC magnetron sputtering on (001) Al_2O_3 substrates. This sandwiched structure prevents potential oxidation of $GdFe_{12}$ films. The films were characterized by an x-ray diffractometer (XRD) and an atomic force microscopy (AFM) to study structural property and surface morphology. In addition, a vibrating sample magnetometer (VSM) and x-ray magnetic circular dichroism (XMCD) were used to determine magnetism. From growth condition optimization, we could get epitaxial (110) Mo on (001) Al_2O_3. From AFM and XRD results, we obtained $GdFe_{12}$ films with smooth surface and epitaxial stabilization by growth temperature in between 200^{o}C and 500^{o}C. From XRR fitting analysis, growth rate of epitaxial $GdFe_{12}$ films are strongly affected by growth temperature. From VSM and XMCD results, growth temperatures of 400^{o}C and 300^{o}C provide similar magnetic moments as a function of magnetic fields.This work is supported by the National Research Foundation of Korea (NFR) (NRF-2018M2A2B3A01071859).

Keywords:

REFe12

Angle-resolved photoemission spectroscopy study of Kondo insulators of CeRhX (X=As, Sb) and CeNiSn

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Abstract:

Kondo insulators (KI's) exhibit unique properties due to the Kondo effect. In the case of rare-earth-based Kondo insulators, the localized 4f electrons and valence electrons interact strongly with each other to form a hybridized gap. Recently, KI's have attracted renewed attention because a theoretical study predicted that Kondo insulators with the non-symmorphic symmetry become Möbius Kondo insulators (MKI's) [1]. However, the experimental confirmation of the MKI's is still controversial. In this study, we have performed angle-resolved photoemission spectroscopy (ARPES) study of CeNiSn, CeRhAs, and CeRhSb, which have the same crystal structures and are considered to be the candidates for the MKI. According to the band calculations of these materials (CeNiSn, CeRhAs, CeRhSb)[2], the hourglass-type band structures are predicted along X-S-X between the Fermi level and -0.5 eV, which arise from the non-symmorphic glide and screw axis symmetries. We measured the Fermi surfaces and band structures for the (100), (010), and (001) planes, respectively, for each of them. We will present the ARPES results on CeNiSn and CeRhX (X=As, Sb) and discuss on their electronic structures as well as the possibility of the MKI.

[1] Po-Yao Chang, et al., Nature Physics, **13**, 794 (2017).
[2] T.-S. Nam, et al., Phys. Rev. B, **99**, 125115 (2019).

Keywords:

Topological Insulator, Möbius Kondo insulator, ARPES

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B7.01

Electonic structure and device properties of hybrid perovskite

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Abstract:

Fundamental understanding of hybrid perovskite material is a key for their critical application in (opto)electronic device. One of the most important material properties is the electronic structure, which governs the electrical and optical properties. However, the detailed electronic structure of hybrid perovskite is not very clear, especially on the band structure. In this study, the relationship between the electronic structure and device properties will be explained and recently measured (clear) band structure will be introduced.

Keywords:

hybrid perovskite, electronic structure

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B7.02

Ion transport in lead halide perovskites in the dark and under light

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Abstract:

Organic-inorganic lead halide perovskites are considered as most promising photovoltaic materials due to high performance. Lead halide perovskite has some anomalies properties such as a huge apparent low frequency dielectric constant and severe hysteretic current-voltage behavior. These properties are closely related to ionic transport. In order to understand the key features of its performance, not only electronic, but also ionic transport properties need to be considered. This talk will present the finding that confirmed methylammonium lead iodide (MAPI) is mixed conductor and the mobile carriers are iodine vacancies, holes and conduction electrons [1,2]. Besides, providing the surprising finding that light enhances not only electronic but also ionic conductivities of MAPI by several orders of magnitude [3]. The mechanism of ion conduction enhancement by light is thus based on the interaction of electronic into ionic defects. I will also demonstrate this photo effect on ion transport for perovskites with mixed anions and cations. Such mixed perovskite based solar cells have shown reasonable stability and excellent photovoltaic performance. Unlike the iodide, the bromide perovskite does not show this photo-ionic effect [4]. These studies could lead to new insights of implications for photo-decomposition in halide perovskites and also new opto-ionic devices.

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3. G. Y. Kim, A. Senocrate, T. –Y. Yang, G. Gregori, M. Grätzel, J. Maier, *Nature Mater.* **17**, 445-449 (2018).
4. G Y. Kim, A. Senocrate, Y. Wang, D. Moia, J. Maier, *arXiv preprint arXiv:1912.09777* (2019).

Keywords:

Lead Halide Perovskite, Ionic Transport

B7.03

Ion migration and suppression in perovskite light-emitting diodes

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Abstract:

Metal halide perovskites are promising candidates for use in light emitting diodes (LEDs), due to their potential for color tunable and high luminescence efficiency. While recent advances in perovskite-based light emitting diodes have resulted in external quantum efficiencies exceeding 20.3% for the green emitters and 21.6% for infra-red emitters, the external quantum efficiencies of the pure red and blue emitters still lag behind. Moreover, a critical issue to date is creating highly emissive and stable perovskite emitters with the desirable emission band gap to achieve full-color displays and white LEDs. Here, we report mixed halide perovskite nanocrystals passivated with multi-dentate ligands that suppress halide segregation resulting in stable red emission and a quantum yield near unity. Our work eliminates the problem of bandgap instability in mixed halide perovskites and minimizes non-radiative losses, alleviating the limits of perovskite nanocrystals for use in light-emitting diodes.

Keywords:

Perovskite, PeLEDs, Ion migration, Ion suppression

B7.04

Photoelectron Spectroscopy Study on Electronic Structure of Organolead Halide Perovskite

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Abstract:

Recently, organolead halide perovskites have shown excellent performance in solar cell and light-emitting diode applications. In the perovskite optoelectronic devices, charge transport and recombination play a crucial role in the device efficiency and lifetime. These properties are highly related to the electronic structure. Thus, the understanding of the electronic structure of perovskite is of great importance in analyzing the device characteristics. In this study, we performed photoelectron spectroscopy measurements on methylammonium lead triiodide ($MAPbI_3$) perovskite films. The ion migration and chemical interaction of the $MAPbI_3$ perovskite film with the charge transport layer or metal electrode are analyzed. Our results provide key information to build an efficient strategy in increasing the efficiency of perovskite optoelectronic devices.

Keywords:

perovskite, photoelectron spectroscopy, electronic structure

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B7.05

Deep level defects of organic lead halide perovskite single crystals and organic-inorganic heterojunction structures

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Abstract:

Defect states in the methylammonium (MA, CH_3NH_3) and formamidinium (FA) lead halide perovskites materials were investigated by using capacitance and conductance transient spectroscopy such as deep level transient spectroscopy (DLTS) and conductance DLTS. From the $MAPbX_3$ (X= Br, I) single crystals grown by an inverse temperature crystallization, the deep level traps of E_v+1.24 eV and E_v+0.84 eV were measured from $MAPbBr_3$ and $MAPbI_3$, respectively. The deep level traps of organic lead halide may have decreased the reactivity between iodide and bromide ions in the crystal lattice. Varying the ratio of halides in the perovskite can change the defect species in the crystals and can increase the photoconversion efficiency by decreasing the density of deep level traps. In the perovskite solar cells containing formamidinium (FA) with multiple cations and mixed halide anions, the concentration of defect states can be responsible to reduce the cell's performance by decreasing the open-circuit voltage and short-circuit current density. The defect states in an organic-inorganic hybrid solar cell containing Sb_2S_3 quantum dots (QDs) and TiO_2 nanoparticles (NPs) were studied also. The activation energy and capture-cross section of an interface state between the Sb_2S_3 QDs and the TiO_2 NPs were found to be about 0.78 eV and 2.21×10^{-9} cm^{-2}, respectively.

Keywords:

Deep level defects, organic lead halide perovskite, organic-inorganic heterojunction, organic lead halide perovskites

B8.01

Defect engineering for metal halide perovskite optoelectronics

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Abstract:

The solution processed metal halide perovskite thin films are polycrystalline. The polycrystalline perovskite films inevitably possess grain boundaries with structural disorders. The grain boundaries in the polycrystalline thin films were found to have significant impact on both optoelectronic properties and stability of the perovskite films and devices. Furthermore, the defective grain boundaries are vulnerable to environmental degradation, which results in poor operational stability of the optoelectronic devices. Defect-mediated environmental degradation of the material and ion migration have been reported to contribute largely to the operational instability of perovskite-based optoelectronic devices including light-emitting diodes (LEDs) and solar cells. We present the manipulating strategies of grain boundaries in perovskite grains by controlling nucleation and growth of solution-processed perovskite thin film. The effective mitigation of such drawbacks resulted in significantly reduced charged trap densities, environmental stability, and ion migration immune surface of the perovskite nanograins, thereby having improved operational stability in optoelectronic devices.

Keywords:

metal halide perovskite, light-emitting diodes, solar cells

2020 KPS Spring Meeting
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B8.02

Enhanced Charge Transport in Doped Conjugated Polymers for Higher Thermoelectric Properties

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Abstract:

Recently, organic thermoelectric devices have been intensively investigated not only for improving the device performance but also for understanding the charge transport mechanism in doped polymers. Doping with donor or acceptor molecules are one widely used method to increase the electrical conductivity of conjugated polymers; however, it decreases the Seebeck coefficient. Thus, it is important to enhance the morphology of the polymer film to retain the thermoelectric performance. The arrangement of polymer chains also affects the charge transport properties of the polymer. We quantatively analyze the charge transport properties with a few reported models to find out the origin of the improvements in doped polymers.

Keywords:

charge transport, organic thermoelectric, polymer, doping, morphology

Soft x-ray spectroscopy study of the element and orbital contributions to the electronic structure of organic semiconductors

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Abstract:

We have studied the element and orbital-specific electronic structure of thin films of hexaazatriphenylene hexacarbonitrile (HAT-CN) and other organic semiconductors using a combination of synchrotron radiation-exited resonant x-ray emission spectroscopy, x-ray absorption spectroscopy, x-ray photoelectron spectroscopy, as well as density functional theory calculations. Resonant and non-resonant x-ray emission spectroscopies were used to measure the C and O 2*p* partial densities of state in HAT-CN and other organic semiconductors. Furthermore, resonant x-ray emission at the C and O *K*-edges is shown to be able to measure the partial densities of states associated with individual atomic sites. In flexible organic light-emitting devices, the HAT-CN acted as an efficient charge-generation layer due to its deep-lying lowest unoccupied molecular orbital level. We support it by comparison of our calculation to measurements of the electronic structure using element-, site-, and orbital-selective C and O *K*-edge resonant x-ray emission spectroscopy.

Keywords:

XES, XAS, HAT-CN, organic semiconductors, electronic structures

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B8.04

Visible light detectable quantum-dot light emitting diode with an inorganic hole injection layer

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Abstract:

Quantum-dot light emitting diodes (QLEDs) have been fabricated with an inorganic hole injection layer (HIL) of vanadium oxide (V_2O_5) to be used as a bi-functional optoelectronics, which can be operated as a visible-light photodetector as well as a light emitting diode. When the device was operated in a forward-bias mode, a bright green light was observed at 520 nm. The maximum luminance was 31,668 cd/m^2. By applying a reverse-bias, the device works as a photodiode. Basically, the QLEDs was turned-off due to the reverse-bias. However, an increase of photocurrent was observed during the illumination of the light on to the device at the reverse-bias mode. X-ray and ultraviolet photoelectron spectroscopy was measured to analyze the interfacial electronic structure of the device with different thickness of V_2O_5 HIL. According to increase the concentration of vanadium solution, we observed a change of the gap states in V_2O_5, which are related to the photon-electron transform efficiency. A detail analysis and device performance will be discussed in this talk. Our result would be provide a useful way to fabricate a dual-functional QLEDs, which can applied as a photosensor as well as a display.

Keywords:

Quantum-dot light emitting diode

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B8.05

The various optical logic circuits for visible light communications based on highly transparent phototransistors with oxide semiconductor and quantum dots

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Abstract:

An active channel such as oxide semiconductor (ZnO) with high electrical property and visible light absorption layer such as quantum dots (QDs) with size dependent tunable absorption in visible light spectrum have studied as promising materials for the photodetector because of their solution process, high transparency, and flexibility. However, ZnO with a wide bandgap (~3.3 eV) cannot the low energy photons with visible light, while the QDs with a small bandgap can absorb visible light. Therefore, highly transparent phototransistors for visible light detection composed of QDs/ZnO heterojunctions structure were fabricated for absorbing visible light. When QDs absorbs visible light, photoexcited charge carriers can be generated on the conduction band of QDs, transferred to conduction band of ZnO and flow photocurrent at the device. The mechanism of effective transfers by photoexcited charge carriers was identified and interpreted using SKPM, UPS, and TRPL spectroscopy. These results showed that charge carriers can effectively transfer the barrier between ZnO and QDs interface with a change in the Fermi energy level by incident low photons energy. Moreover, the optical logic circuits (NOT, NAND, and NOR), which were composed of highly transparent QDs/ZnO phototransistors, were demonstrated with operating under various visible light signals. This work offers a new confirmation for photo-mechanism of photoexcited charge carriers and a useful guide of the next-generation visible light communication technology.

Keywords:

Quantum dot, Phototransistor, ZnO

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

B9.01

Effect of social structure on perception bias

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Abstract:

People’s perceptions about intra and inter groups behaviors in social networks can be biased, often showing systematic over- or underestimation. These social perception biases are often attributed to biased cognitive or motivational processes. However, it also can be caused by social structure. We have investigated how the over- and underestimation of an attribute for intra and inter groups can emerge from the structural properties of social networks. Using a generative network model, results show that these biases depend on the level of homophily and the size of the minority group. Our model predictions correspond well with empirical data from a cross-cultural survey. We also identify a crucial role of a multi-layered characteristic of social networks to understand in-group biases on group members' addictive behavior. This work advances our understanding of the impact of network structure on social perception biases and offers a quantitative approach for addressing related issues in society.

Keywords:

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B9.02

Thermodynamic uncertainty relation in overdamped Langevin systems with a magnetic field

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Abstract:

The thermodynamic uncertainty relation (TUR) provides a universal lower bound on the relative error of nonequilibrium currents such as heat dissipation. The TUR is valid for overdamped Langevin dynamics when the time-reversal symmetry is not broken. To investigate the effect of broken time-reversal symmetry on the TUR, we study the Langevin dynamics with a magnetic field in the overdamped regime. The system is described by an anomalous Langevin equation with a singularly correlated noise. To find a generalized TUR, we derive the explicit expressions of the path probability, the average nonequilibrium current, and the average entropy production. By applying the approach based on the Cramer-Rao inequality, we obtain a TUR generalized by a magnetic field. We find that the magnetic field always reduces the lower bound. In the small magnetic field limit, the original TUR is recovered. We verify the generalized bound for work and heat in a solvable case, analytically and numerically.

Keywords:

thermodynamic uncertainty relation, stochastic thermodynamics, Langevin dynamics

Work fluctuation, entropy, and time's arrow in time-asymmetric engine cycles

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Abstract:

We derive a thermodynamic uncertainty relation that governs the work yield and the entropy production of an engine operating with a time-asymmetric cycle such as the Carnot cycle.
The relation shows an intercorrelation between one engine cycle and its time-reversed cycle, disclosing the role of time-asymmetry of an engine cycle.
It also illustrates that entropy production and the arrow of time appear as the central quantities controlling the average and the fluctuation of work.

Keywords:

time-asymmetric engine cylces, thermodynamic uncertainty relation, entropy production, fluctuation of work

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B9.04

Brownian heat engine with active reservoirs

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Abstract:

Microorganisms such as bacteria are active matters which consume chemical energy and generate their unique run-and-tumble motion. A swarm of such microorganisms provide a nonequilibrium active environment whose noise characteristics are different from those of thermal equilibrium reservoirs. One important difference is a finite persistence time, which is considerably large compared to that of the equilibrium noise, that is, the active noise is colored. Here, we study a mesoscopic energy-harvesting device (engine) with active reservoirs harness- ing this noise nature. For a simple linear model, we analytically show that the engine efficiency can surpass the conventional Carnot bound, thus the power-efficiency tradeoff constraint is released, and the efficiency at the maximum power can overcome the Curzon-Ahlborn efficiency. We find that the supremacy of the active engine critically depends on the time-scale symmetry of two active reservoirs.

Keywords:

active matter, heat engine, efficiency enhancement

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B9.05

Neural estimator for entropy production

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Abstract:

We present a Neural Estimator for Entropy Production (NEEP) which learns entropy production (EP) from time-series data without any data pre-processing step and prior knowledge of the system dynamics. We prove that the estimator built with deep neural network learns EP when it maximizes our proposed objective function. Our experiments on two nonequilibrium systems, bead-spring, and ratchet model show that NEEP can estimate EP of the Markov process for both continuous and discrete phase space. We also demonstrate that our method is applicable to non-Markovian systems.

Keywords:

Entropy production, Nonequilibrium, Machine learning, Deep neural networks, optimization

2020 KPS Spring Meeting
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B9.06

Thermodynamic Learning of Neural Networks

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Abstract:

Although deep learning has been applied in various fields with remarkable results, fundamental principles under their success are still unknown. As a part of developing intuitively understandable deep learning for the generation of physical model, a new architecture with stochastic parametrization of learning parameters has recently been proposed. For stable learning in the hierarchical structure of the learning variables, we performed statistical analysis dominating learning dynamics. We also experimentally confirmed that the thermodynamic analysis and its application to neural networks improved the performance.

Keywords:

machine learning, neural network, stochastic parametrization, physical model, thermodynamic learning

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B9.07

Intermittent search with stochastic resetting

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Abstract:

Search strategies based on random walk processes with stochastic restart on the one hand and intermittent behavior switching between local search and ballistic relocation phases on the other, have been known to be beneficial in target searching problems. Besides, stochastic resetting has also been proven to enhance the searching time under certain conditions. In this study, we analyze the interplay between the intermittent process and the resetting. To characterize this problem, we investigate the mean first passage time to find a fixed target in the system. We show that intermittent strategies combined with resetting can be efficient strategies that allow the minimization of the search time.

Keywords:

first passage time, Intermittent process, resetting

B9.08

Topological Defect in Janus Colloidal Crystal

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Abstract:

Particles and molecules composing real materials generally contain anisotropic properties such as a spin or an electric dipole. To understand their roles in material phase states, we observed colloidal crystals comprised of Janus spheres whose anisotropic properties can be controlled. Here, we found a BKT transition by tuning an interparticle interaction and could see dynamics of topological defects in real time. We think that this model system can eventually give an insight to apprehend roles of molecular and atomic orientational dynamics in 2D crystal phases.

Keywords:

Topological defect, Janus particle, Colloid, Crystal

2020 KPS Spring Meeting
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C1.01

SM and BSM results from Higgs-boson to a pair of W-boson at CMS

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Abstract:

A report is presenting for the result of Standard Model and Byond Standard Model through Higgs boson decaying to a W-boson pair at CMS detector. The results have been measured from the proton-proton collision at CERN with sqrt(s) = 13 TeV RunII data set.

Keywords:

Higgs-boson, W-boson, CMS, SM, BSM

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C1.02

Search for new resonances decaying two muons in the bottom fermion fusion process with Run 2 CMS data

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Abstract:

The current major challenge for the LHC is to search for new physics beyond the standard model. One of most interesting current issues in high-energy physics, is an B anomaly reported by the LHCb collaboration. A massive gauge boson Z' with a flavor changing bottom-strange coupling, and a nonuniversal coupling to leptons could accommodate the B-anomaly. The Z’ boson is produced by the bottom fermion fusion (BFF) process where the bottom quark arising from gluon splitting and the Z' boson decays to two muons in the final state. Therefore, we investigate a scenario which can satisfy the B-anomaly constraints in a dimuon final state. The main goal is to conduct analysis for the Z' model with full CMS Run 2 data. At present, Run 2 year-by-year data are compared with background event samples generated by Monte-Carlo simulations. In this talk, the status of the search for Z’ in the BFF process will be presented.

Keywords:

LHC, B-anomaly, Z', CMS Run 2, Bottom Fermion Fusion

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C1.03

Search for long-lived charginos based on disappearing-track signature with the CMS detector at LHC

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Abstract:

This study aims to explore new physics signatures with long-lived particles to search for dark matter at the CERN Large Hadron Collider (LHC) and suggest new methods of discovery. We search for new physics with long lived particles in final states with one or two short tracks, missing hadronic transverse momentum and multiple jets.

Keywords:

CMS, Long-lived, chargino, disappearing

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C1.04

Search for excited leptons in llγ final states at 13 TeV

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Abstract:

A search for excited leptons (electrons and muons) is presented using 2017+2018 data collected by the CMS experiment at a center-of-mass energy of 13 TeV and corresponding to an integrated luminosity of 101 /fb. Excited leptons are predicted by various theoretical models beyond the standard model (SM) that quarks and leptons are not elementary but instead are made of unknown fundamental constituents never observed yet. Excited leptons ($l^* = e^*, \mu^*$) in $ll\gamma$ ($l = e, \mu$) final states where the excited lepton decays to a SM lepton and a photon ($l^* \rightarrow l\gamma$) are studied. We select events which have two same-flavor leptons and one photon and we apply Z-veto which dilepton mass should be larger than 116 GeV due to $Z\gamma$ process. This presentation indicates recent progress on the search.

Keywords:

CMS, excited lepton

2020 KPS Spring Meeting
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C1.05

RPV SUSY search in single-lepton final state in CMS

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Abstract:

A search for RPV SUSY in proton–proton collisions at a center-of-mass energy of 13 TeV will be discussed. The search uses a signature of a single lepton, large jet and bottom quark jet multiplicities, and high sum of large-radius jet masses, without any requirement on the missing transverse momentum in an event. Using the full Run2 data, the expected limit on gluino mass for g->tbs model is expected to reach 2 TeV, which poses a tension for naturalness argument even in the RPV scenario. In this talk signal region optimization for full Run2 data and background estimation strategy will be presented

Keywords:

RPV, SUSY, CMS, Run2, gluino

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C1.06

Background study for Monotop events at CMS

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Abstract:

One of the important goals of the Large Hadron Collider (LHC) is to find the dark matter signature. Since the dark matter doesn't leave the measurable signature in the detector, one way to observe them is when they are produced in association with visible Standard Model particles, called MET+X where MET is the missing transverse energy. If the spin-1 mediator has flavor-changing couplings to top and light quarks, dark matter particles can be produced with a single top quark, called the monotop final state. The signal study of monotop signatures is conducted from 2016, 2017 and 2018 samples. The background study will be presented using a new analysis framework, Columnar Object Framework For Effective Analysis (COFFEA).

Keywords:

Monotop, Dark matter, CMS

C1.07

Search for high mass spin-0 resonances in semileptonic WW to lvqq final state at √s=13TeV in CMS experiment

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Abstract:

We present a study of search for high mass scalar particle in the semileptonic WW to lvqq final state at LHC with CMS p-p collision data at the center of mass energy 13 TeV. The mass range of the renonances is extended from 200 GeV/c2 to 5000GeV/c2. In this mass region hadronically decaying W-boson is boosted enough to produce a merge jet. A technique to tag the merge jet from the W boson decay is used. Also, events with hadronic W decay to resolved jets are investigated.

Keywords:

LHC, CMS

Search for pair production of heavy neutrinos via Z' based on the left-right symmetric extension of the Standard Model at CMS using Full LHC Run2 data of proton-proton collisions at sqrt(s) = 13 TeV

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Abstract:

The existence of neutrino masses established by discovery on neutrino oscillations is one of the most clear evidence for physics beyond the Standard Model (SM). The left-right symmetric (LRS) extension of the SM can provide answers to many unsolved questions of the universe including parity violation of weak charged current, mass generation mechanism of neutrinos and its small values compared to other fermions, and matter/anti-matter asymmetry. Additionally, many experimental signatures targeting physics beyond the SM (BSM) such as muon to electron and gamma decay, B-meson anomalies, and flavor changing neutral current (FCNC) can be interpreted. In this talk, search for pair production of heavy neutrinos mediated by new gauge boson Z' introduced by the LRS of the SM at same-flavor dilepton channel with at least two jets using LHC Full Run2 proton-proton collision data at sqrt(s) = 13 TeV, corresponding to 137 /fb, collected by the CMS detector will be presented.

Keywords:

LHC, Neutrino, Majorana, CMS, LRSM

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C11.01

Electrostatic-electromagnetic wave interaction via cold-hot wave coupling

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Abstract:

We examine the interaction between electrostatic (ES) and electromagnetic (EM) waves in a flowing plasma by analyzing the coupling between cold and hot waves. For propagation parallel to the background magnetic field (or in an unmagnetized plasma), the ES and EM waves attain separate linear dispersion relations. However, by a nonlinear cold-hot wave coupling, the ES and EM waves can interact and generate wave harmonics. We reveal that the EM waves can be modulated by ES waves using a kinetic theory and particle-in-cell simulations. The coupling of EM waves to ES waves implies that the EM waves measured outside the plasma can provide information about the density and flow perturbations.

* This work was supported by the National Research Foundation of Korea under BK21+ program, Grant No. NRF-2017M1A7A1A03064231 and Grant No. NRF-2019M1A7A1A 03088456.

Keywords:

wave-wave interaction, cold-hot coupled wave, plasma flow

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C11.02

FLYCHK Opacity Calculation of Aluminum, Iron, Copper, and Gold Plasmas

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Abstract:

The opacity information is essential to interpret the spectrum of a finite density and temperature plasma. A lightweight collisional radiative code, FLYCHK, has been widely used to research the spectroscopic properties of the plasma in a wide temperature and density range. In the presentation, we report FLYCHK calculation on Planck Mean Opacity (PMO) of aluminum, iron, copper, and gold in wide temperature and density range ($T = 10^0 \sim 10^4$ eV, $\rho = 10^{-6} \sim 10^2$ g/cc). It is also shown that other opacity calculation code, including PROPACEOS and ATOMIC, calculates PMO in the same range which is analyzed and compared with the FLYCHK's result quantitatively. In conclusion, FLYCHK calculation provides a similar trend of PMO calculated by other codes, and it shows the potential to generate opacity of high-Z material like Gold with complicated atomic states.

This work is supported by National Research Foundation of Korea (No. 2015R1A5A1009962 and 2019R1A2C2002864), and the Defense Research Laboratory Program of the Defense Acquisition Program Administration and the Agency for Defense Development of Republic of Korea.

Keywords:

Opacity, FLYCHK, High Energy Density Physics, Radiation Transport

C11.03

Nonthermal electron dynamics in warm dense gold plasma

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Abstract:

The study of ultrafast electron dynamics has attracted much interest recently to understand warm dense matter (WDM) condition which is a high-density strongly coupled plasma with near the Fermi temperature and solid density. The femtosecond laser is used to generate WDM conditions in laboratory. For pump laser-heated samples, at first, a highly non-equilibrium state is generated, and it leads to two competing processes which are ballistic motion and electron collision. Hot electrons of ballistic motion go into deeper parts of the target with approximately Fermi velocity (~10^6 m/s), the other process is developed an electron temperature by collisions between excited electrons and electrons around the Fermi level.

In this work, we present the study of ultrafast electron dynamics of nonthermal hot electrons from a comparison between experiment measurement and theoretical calculation. Nonthermal hot electrons are lead to abnormal electron distribution in d-band and s-band for the gold, it causes a variation of the optical properties such as dielectric function. For monitoring of the change of physical properties, we measured reflectivity and transmissivity of 30 nm gold as intensity increase using 1TW Ti; sapphire laser system (~ 30 mJ, ~ 30 fs) at the HEDP laboratory of the GIST.

Preliminary modification of the theoretical calculation such as the two-temperature model for temperature calculation and the Drude model for dielectric function calculation is progressed and compared with experimental results.

* This work is supported by National Research Foundation of Korea(No. NRF-2015R1A5A1009962, NRF-2016R1A2B4009631 and NRF-2019R1A2C2002864)

Keywords:

Warm dense matter, Hot electron, Plasma

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C11.04

Design of Beam Shaping Device for Accelerator based BNCT

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Abstract:

Beam shaping device (BSA) plays an important role in the boron neutron capture therapy (BNCT). In this study, the BSA design for accelerator based BNCT system is investigated by means of simulation method. The fast neutron transport is simulated by using the GEANT4 tool kit. Optimization study was conducted on BSA material candidates. The design of BSA is suggested in terms of the International Atomic Energy Agency(IAEA) techincal document.

Keywords:

BSA, BNCT, Simulation, GEANT4, Accelerator based

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C11.05

Monte Carlo study of imaging plate response to laser-driven aluminum ion beams

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Abstract:

We measured the response of BAS-TR imaging plate (IP) to energetic aluminum ions up to 222 MeV, and compared it with predictions from a Monte Carlo simulation code using two different IP response models. Energetic aluminum ions were produced with an intense laser pulse, and the response was evaluated from cross-calibration between CR-39 track detector and IP energy spectrometer. For the first time, we obtained the response function of the BAS-TR IP for aluminum ions with a kinetic energy as high as 222 MeV. Upon close examination of the two IP response models, we confirm that the exponential model fits our experimental data better.

Keywords:

imaging plate, Monte Carlo simulations, laser plasma, laser driven ion beam

2020 KPS Spring Meeting
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C11.06

Property change of radiation generated by plasma dipole oscillations in the magnetic field.

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Abstract:

Diagnostics of magnetic field with tubulent plasmas is essential for various plasma applications. We are investigating the validity of applying plasma dipole oscillation (PDO) for magnetic field measurement. Radiations are radially emitted from PDO. Vertical and horizontal radiation have different polarizations each; circular and linear polarization. We traced center of mass of PDO and probed spectrum of radiation signal generated from PDO. If the magnetic field is parallel to the rotational axis of PDO motion, spectrum of radiation is X-mode cut-off. We can measure magnetic field to use this spectral change of radiation from magnetized PDO.

Keywords:

X-mode cut-off, Diagnostics of magnetic field, Plasma Dipole Oscillations, Spectral changes of radiation

C12.01

Temporal Characterization of a Two-color Laser Field using the Tunneling Ionization Method

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Abstract:

We investigate the temporal characterization of a two-color laser field using the TIPTOE (Tunneling ionization with a perturbation for the time-domain observation of an electric field) method. A Ti:sapphire laser pulse at 800 nm is used as a fundamental pulse, and its second harmonic is produced using a type-I BBO crystal. The temporal profiles of a two-color laser pulse at different relative phases are measured. The spectra obtained from the TIPTOE measurements agrees well with the spectra obtained using a spectrometer, supporting the validity of the measurement. The reconstruction of a two-color laser pulse is also performed for the theoretical results obtained by solving the time-dependent Schrodinger equation. The accuracy of the reconstruction results is discussed.

Keywords:

temporal characterization, TIPTOE, two-color laser field, tunneling ionization

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C12.02

Spatiotemporal characterization of a femtosecond laser pulse using tunneling ionization

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Abstract:

An ultrashort femtosecond laser is an essential tool in many scientific applications. Since an ultrashort laser pulse can have a space-time coupling[1], which may significantly degrade the quality of the laser pulse, it is important to characterize the laser pulse both in space and in time. In this work, we investigate the spatiotemporal characterization of an ultrashort laser pulse using new pulse characterization method called TIPTOE (Tunneling ionization with a perturbation for the time-domain observation of an electric field) [2]. TIPTOE is a method that can be applied in a wide wavelength range. The temporal profiles are measured by sampling the different part of the laser beam. The complete information of the laser pulse is obtained in space and time using an appropriate reconstruction algorithm.

Keywords:

Optics, tunneling ionization, spatiotemporal characterization

C12.04

Polymer-based colloidal composite with tunable permittivity

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Abstract:

In this study, we designed a polymer/colloid composite to modulate refractive index of effective medium at millimeter wave frequency (76 ~ 81 GHz). If a high refractive index material is mixed with a low refractive index material, this composite can have a desired refractive index. In this work, titanium dioxide (TiO_2) colloid was used for its high permittivity and moderate loss at millimeter wave frequency (ε ~ 92, tanδ ~ 0.05).
If the diameter of the TiO_2 sphere is very small compared to the operating wavelength, the refractive index of the TiO_2 mixed medium follows the Maxwell-Garnett relation. According to this, a wide range of refractive index can be adjusted according to the volume percent. However, since the volume percent at the maximum compression of the sphere particles is 74%, it is no longer possible to increase the volume percent. Therefore, using a small TiO_2 colloid, the maximum epsilon is about 20. To achieve higher refractive index, sphere particle of similar size to wavelength should be used. This is explained by the energy-density coherent-potential approximation (ECPA) model. According to the ECPA model, a unit cell of a medium in which particles are randomly dispersed in a volume fraction f is defined as a coated sphere. The requirement that the energy content of a coated sphere embedded in the effective medium and being hit by a plane wave should be the same as the energy stored by a plane wave in the same volume of the effective medium can be formulated quantitatively by the self-consistency equation. Consequently, scattering efficiency of a single sphere affects the refractive index. Therefore, with Mie resonance, a relatively high effective refractive index can be achieved even at a low volume fraction.

Keywords:

Millimeter Wave

Electrically tunable amplitude only spatial light modulator

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Abstract:

본 연구는 단축 복굴절 물질을 기반으로, bi-phase 공간 상에서 진폭의 조절이 가능한 일반화된 공간 광 변조기 (A-SLM) 및 진폭, 위상의 조절이 가능한 일반화된 공간 광 변조기 구조 (C-SLM)를 제시하고 있으며, Jones matrix 기반의 시뮬레이션을 통하여 입증하였다. 두 구조 모두 복굴절 물질 분포의 대칭성을 이용하며, 대칭성 조건을 만족하는 수직 또는 수평전계를 사용하여 진폭과 위상을 조절하다.
기존 공간 광 변조기의 경우 진폭과 위상의 조절을 위하여 여러 공간 광 변조기, 여러 화소 또는 beam splitter, wave-plate 등 추가적인 광학 소자가 필요하지만, 본 구조들의 경우, 하나의 화소 및 공간 광 변조기를 통하여 구현이 가능하며, 일반화된 구조로, VA (Vertical Alignment)와 IPS (In-Plane Switching)와 같은 모든 LC mode 및 단축 복굴절 물질 분포에 적용이 가능하다.
본 연구의 공간 광 변조기 구조는 양자 광학, 홀로그램, OAM 등 다양한 electro-optical 실험 및 application에서 큰 역할을 할 것으로 보인다.

Keywords:

공간 광 변조기, Spatil Light Modulator, 복소수 공간 광 변조기, SLM, birefringence material

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

C16.01

Capturing protein cluster dynamics and gene expression output in live cells

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Abstract:

To address biological processes upstream of transcription, we developed a live-cell assay to observe cooperative dynamics of enhancers, which are gene-expression regulatory DNA elements, and transcription sites. Gene activation is thought to involve a multistep process whereby transcription factors bind to distal enhancer sites and recruit a Mediator protein complex which contacts the Pol II protein at the gene loci. The interaction of Mediator and Pol II has yet to be observed in the nucleus of living cells and the dynamics of this interaction are not yet elucidated. We used quantitative PALM (photo-activated localization microscopy) imaging and lattice-light-sheet imaging to study the organization and dynamics of Mediator and Pol II. We found that Mediator and Pol II form large stable clusters and also observed that these clusters have properties expected for phase-separated bimolecular condensates. Moreover, labeling a specific gene, we observed protein condensates dynamically contact with the active gene.

Keywords:

Transcription, Super-resolution, Protein dynamics

C16.02

Listening to lipid membranes

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Abstract:

Fluctuations of giant unilamellar vesicle and cell membranes are detected with exceptional resolution. The motion of localized membrane (<1 μm cross-section) is resolved with 5 decades in both frequency (1 Hz - 100 kHz) and amplitude (0.01 nm - 100 nm). This allows to listen to surprises in underlying membrane mechanics

Keywords:

Giant unilamellar vesicle, free standing, mebmrane, liposome

C16.03

Three-dimensional large-area label-free examination of cell migration using optical diffraction tomography

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Abstract:

Cell migration is one of the fundamental processes in many biological phenomena including embryonic development, wound healing and cancer metastases. The wound-healing assay is commonly used for studying collective cell migration and is acknowledged as an undemanding method with low-cost in therapeutics for testing the effect of chemical treatments on wound healing. Optical diffraction tomography (ODT) allows quantitative imaging of low-scattering samples in three-dimension (3D) based on the optical characteristic of the sample. Its label-free and quantitative phase imaging capability suit the purpose of investigating the cell migration from a unique viewpoint through an extended time without concerning photobleaching.
In this study, ODT is assisted with a custom-written stitching algorithm to cover the large field of view for analysis and the wound healing process is observed in a time-lapse mode. It gives a fresh perspective for studying the 3D quantitative properties of the cells, in particular, the thickness, refractive index histogram of the nuclei and the migration velocity vectors on various heights. Several differences in these characteristics were found when a cell is treated with a chemical or is on the wound boundary leading the collective cell migration.

Keywords:

optical diffraction tomography, cell migration, wound healing assay

2020 KPS Spring Meeting
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C16.04

Non-invasive three-dimensional (3D) imaging and quantitative characterisation of vasculogenesis of 3D cultured endothelial cells inside a microfluidic chip using optical diffraction tomography (ODT)

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Abstract:

Recent advances in organ-on-a-chip and three-dimensional (3D) cell culture technology have allowed for successful reconstitution of in vivo microenvironments and their functions inside a microfluidic channel, such as gut, eye, and the vasculature. Unlike conventional 2D static culture dishes, these three-dimensional (3D) in vitro cell culture platforms enable to preserve in vivo property of cells in their in-vivo mimicking microenvironments, suggesting diverse potential applications such as 3D multicellular bioassays and drug discovery.

Despite this significant advances in organ-on-a-chip technology, current microscopes for the observations of cells cultured in on-chip devices and the evaluations on their functionalities mostly require the use of exogenous labelling agents. Of those, confocal fluorescence microscopy (CFM) is a well-established imaging technique for on-chip applications due to its 3D imaging capability and high molecular specificity. However, the requirement of fluorescent labelling procedures accompanies several drawbacks such as phototoxicity and photobleaching, which ultimately limits the long-term imaging of 3D multicellular dynamics inside a microfluidic chip.

To address these issues, here we introduce a 3D label-free imaging technique optical diffraction tomography (ODT) for daily tracking of 5-day vasculogenesis of endothelial cells that were 3D cultured inside a microfluidic chip. Owing to 190 nm lateral resolution of ODT, it is possible to obtain 3D refractive index map of multicellular activities and subcellular organelles of the cells throughout the vasculogenesis. To further characterise mature vascular networks, the vascular structures and the microvascular permeability of the endothelium were quantified.

Keywords:

vasculogenesis inside a microfluidic chip, multicellular dynamics, 3D label-free imaging, optical diffraction tomography, refractive index

2020 KPS Spring Meeting
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C16.05

혈액암 세포의 PPI 관측을 통한 BH3 mimetic drug 동반진단기술 개발

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Abstract:

Apoptosis는 암과 같은 이상 증식 세포를 안전하게 제거하는 중요한 기전이다. 이에 대응하여 암세포는 apoptosis에 관여하는 proteome의 변화를 통해 apoptosis 신호를 극복하고 사멸을 회피한다. 내인성 apoptosis 경로에서 핵심적인 역할을 하는 BCL-2 family는 암세포에서 변화가 일어나는 주된 단백질군으로, 혈액 또는 골수에 종양이 발생하는 AML(acute myeloid leukemia, 급성골수성백혈병) 세포는 BCL-2 family의 antiapoptotic 기능을 이용한다. 따라서 BCL-2 family의 활성도를 측정하는 것은 암 진단의 중요한 과제이다. 한편 단백질의 활성도는 각 단백질의 번역 후 변형 과정으로 인하여 단순한 발현량으로는 측정할 수 없고, 반드시 PPI(protein-protein interaction, 단백질-단백질 상호작용)를 통해야만 정량적인 측정이 가능하다. 따라서 본 논문은 SM co-IP(single molecule co-immunoprecipitation, 단분자공동면역침강) 기술을 통하여 U937 세포주 및 실제 AML 환자의 세포에서 apoptosis가 일어날 때의 주요 BCL-2 family들의 PPI 변화를 측정하였다. 먼저 proapoptotic 단백질인 BIM, tBID, BAD를 각각 probe로써 개발하여 이들과 antiapoptotic 및 pore-former 단백질 사이의 PPI를 확인했다. 각 probe를 U937 세포주에 적용하였을 때 세포주의 apoptosis 상태에 따라 유의미한 PPI 변화를 확인했으며, 세포로부터 선별 분리한 미토콘드리아에서 특이적인 PPI에서 큰 변화가 발생했다. 실제 AML 환자의 경우, 환자별로 PPI가 크게 변하는 antiapoptotic 단백질이 서로 달랐으며, FACS 분석을 통해 측정한 venetoclax(BCL-2 PPI 저해제)의 반응성도 다양하게 나타났다. 이때 BCL-2의 PPI가 크게 변한 환자의 경우 venetoclax에 민감하게 반응하였다. 이는 같은 AML 환자일지라도 각 환자의 세포가 addiction된 단백질이 서로 달라 특정 항암제의 효과가 다르게 나타날 수 있음을 의미하며, 나아가 PPI 분석이 환자별로 적절한 항암제의 진단에 응용될 수 있음을 시사한다.

Keywords:

Apoptosis, BCL-2 family, Acute myeloid leukemia(AML), Venetoclax(ABT-199), Single molecule co-Immunoprecipitation(SM co-IP)

2020 KPS Spring Meeting
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C16.06

Heterogeneous diffusion of purinosomes in live cells: application of machine learning and its stochastic modeling

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Abstract:

Purinosome is a dynamic multi-enzyme complex of typically sub-micron size, responsible for *de novo* purine synthesis through which raw material of DNA (purin) is produced. A single-particle experimental study reported that purinosomes tend to be colocalized with subcellular structures, such as mitochondria and microtubule networks in living LND cells [1], but the transport mechanism remains elusive. To deal with a spatiotemporal heterogeneity in live cells, we perform a novel analysis technique, namely cluster analysis for single-particle time-series, and we get insights on the intracellular transport mechanism of purinosomes. A majority of purinosomes interact with both microtubule and mitochondria networks, showing subdiffusive mean squared displacement. However, they can probabilistically be transported along microtubule branches in a ballistic manner. To understand the physical mechanism underlying the anti-correlation at short time scales, two models are suggested: fractional Brownian motion with diffusing diffusivity and Brownian motion in a periodic potential field. The former explains the anti-correlation in terms of self-similar noise caused by the crowded network environment and the latter describes the colocalization phenomena as obstructed states arisen by uneven potential field. Meanwhile, a small portion of particles undergoing the ballistic motion (9 %) shows a power-law probability density function of displacement and superdiffusive mean squared displacement. The dynamics are modeled by a two-state continuous-time Markov chain in which subdiffusive and ballistic phases alternate. In addition, if we introduce angle persistence to the ballistic states, a two-point correlation function fits better to the experiment, which suggests that the direction of the ballistic states has a positive temporal correlation at the short time regime.

[1] Chung Yu Chan. *et al.,* Microtubule-directed transport of purine metabolons drives their cytosolic transit to mitochondria, Proc. Natl. Acad. Sci. U.S.A. **115**, 51 (2018).

Keywords:

Heterogeneous diffusion, Unsupervised machine learning, Purinosome, Active transport, Run-and-tumble particle

2020 KPS Spring Meeting
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C16.07

Transition path times and shapes: Theory and examples

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Abstract:

The transition path time has been drawing attention not only for the sake of a better theoretical understanding of rare barrier crossing events, but also as an important observable in single-molecule experiments with the advent of a high resolution in space and time. We first present an analytical model focusing on deriving the shape of the transition path, i.e., the kinetic profile in the space spanned by the mean time and the position, thereby leading to the transition path time. The mean shape of the transition path turned out to be related to the first-passage path by a constant time shift, and the mean transition path time scales inverse-proportionally with increasing energy barrier. We then present several examples of the transition path times and shapes in systems with various free energy profiles, ranging from a simple harmonic barrier to the complex profile of polypeptide folding-unfolding events.

Keywords:

Transition path time, Barrier crossing, Peptide folding, Rare events

C16.08

Log-normally distributed velocity distribution of immature dendritic cell in 1D channel

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Abstract:

Modeling of cell migration is still an unexplored area because cellular locomotion is an outcome of complex micro machinery.
Here, we analyze the single-cell tracking datasets of an immature dendritic cell, known as antigen-presenting cells in the mammalian immune system,_confined to a one-dimensional microchannel.
We find that the motion of the dendritic cells has three dynamic states: forward run, reverse run, and pause.
It is also found that the velocity distribution is well-fitted with a lognormal distribution, and the lognormally distributed velocity is robust against various conditions. We propose a possible scenario for explaining this lognormal velocity distribution, along with speculation about its biological consequence.

Keywords:

modeling cellular migration, lognormal distribution, immature dendritic cell

2020 KPS Spring Meeting
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C2.01

Bulk Clockwork Standard Model

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Abstract:

We consider the bulk Standard Model in the continuum Clockwork model. We obtain the Kaluza-Klein masses and wave functions for bulk fields in 5D dilaton background and compare them with those in Randall-Sundrum model. Furthermore, we discuss the phenomenological applications of the results.

Keywords:

1293

Beyond the Starobinsky model for inflation

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Abstract:

We single out the Starobinsky model and its extensions among generic f(R) gravity as attractors at large field values for chaotic inflation. Treating a R^3 curvature term as a perturbation of the Starobinsky model, we impose the phenomenological bounds on the additional term satisfying the successful inflationary predictions. We find that the scalar spectral index can vary in both the red or blue tilted direction, depending on the sign of the coefficient of the R^3 term, whereas the tensor- to-scalar ratio is less affected in the Planck-compatible region. We also discuss the role of higher order curvature term for stability and the reheating dynamics for the unambiguous prediction for the number of efoldings up to the R^3 term.

Keywords:

inflation, curvature:higher order, stability

2020 KPS Spring Meeting
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C2.03

Primordial Black Holes in Higgs-R^2 Inflation as a whole dark matter

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Abstract:

Primordial black holes are produced in a minimal UV extension to the Higgs inflation with an included R^2 term. We show that for parameters consistent with Standard Model measurements and Planck observation results lead to $M_{PBH} \in (10^{-17}, 10^{-15}) M_{\odot}$ primordial black holes with significant abundance, which may consist the majority of dark matter.

Keywords:

Primordial Black Holes, Inflation, Higgs Inflation, Dark Matter

2020 KPS Spring Meeting
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C2.04

Detecting keV-Range Super-Light Dark Matter with a Graphene-based Josephson Junction Detector

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Abstract:

We propose a new dark matter detection strategy that will enable the search of super-light dark matter $m_\chi \simeq 0.1$ keV, representing an improvement of the minimum detectable mass by more than three order of magnitude over the ongoing experiments. This is possible by integrating intimately the target material, π-bond electrons in graphene, into a Josephson junction to achieve a high sensitivity detector that can resolve a small energy exchange from dark matter as low as ~ 0.1 meV. We investigate detection prospects with mg-scale and g-scale detectors by calculating the scattering rate between dark matter and the free electrons confined in two-dimensional graphene with Pauli blocking factors included. We find not only that the proposed detector can serve as a complementary probe of super-light dark matter but also achieve higher experimental sensitivities than other proposed experiments, i.e. in having a low detectable threshold provided the same target mass, thanks to the extremely low energy threshold of our Josephson junction sensor.

Keywords:

Super-Light Dark Matter, Dark Matter Direct Detection, Graphene-based Josephson Junction

C2.05

Neutrino self-interaction in the signals from blazar TXS 0506+056

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Abstract:

Even though conventional leptonic or lepto-hadronic models of blazar successfully explain the observed electromagnetic component of the flaring signal from the Blazar TXS 0506+056 in a large range of energy window $E\gamma\in$(10−1eV,102 GeV), the predicted neutrino flux is too small to be consistent with the IceCube observation at $E\nu$~300 TeV. We show that a sizable self-interaction of neutrinos with a light messenger resolves the discrepancy. Interestingly, the same physics can relieve the cosmological tension in $H0$ and $\sigma8$.

Keywords:

Neutrino Secret Interaction, , High-Energy Neutrinos, Multi-Messenger Astrophysics

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C2.06

Lightening Gravity Mediated Dark Matter

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Abstract:

We consider a massive spin-2 particle as the mediator between dark matter and the Standard Model particles in the effective theory. In this scenario, dark matter can annihilate into a pair of the spin-2 particles via allowed or forbidden channels as well as into a pair of the Standard Model particles. For both WIMP and light dark matter cases, we show the parameter space that is consistent with the correct relic density and experimental bounds. Moreover, when the spin-2 mediator is light enough, it generates a Yukawa potential for dark matter and it leads to a large Sommerfeld effect on dark matter self-scattering. As a result, we explain how both the Born cross-section and the Sommerfeld effect can make the self-scattering cross-section of dark matter velocity-dependent to be consistent with the observed rotation velocities of galaxies and galaxy clusters.

Keywords:

Dark matter, self-interaction, spin-2 mediator, Sommerfeld

C2.07

New reactor experiments to search for a new decay channel

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Abstract:

A new reactor experiment searching for the dark sector is suggested using the dark photon production from a reactor in the presence of the dark axion portal which can be a decay channel for a dark photon into a photon and an axion. First, we will present the expected sensitivity with the current reactor experiments such as Reactor Experiment for Neutrino Oscillation (RENO) and Neutrino Experiment for Oscillation at Short baseline (NEOS). Then we will propose a new detector design with a decay chamber which would have a better sensitivity.

Keywords:

reactor, dark photon, hidden photon, dark axion portal

C2.08

Size Separations in Higher Dimensional Anisotropic Gravity

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Abstract:

We consider five dimensional massive vector-gravity theory which is based on the foliation preserving diffeomorphism and anisotropic conformal invariance. It does not have an intrinsic scale and the only relevant parameter is the anisotropic factor z which characterize the degree of anisotropy between four dimensional spacetime and the extra dimension. We assume that physical scale M_* emerges as a consequence of conformal symmetry breaking in vacuum solution. It is demonstrated that a very small mass for the vector particle compared to M_* can be achieved with a relatively mild adjustment of the parameter z. At the same time, it is also observed that the motion along the extra dimension can be highly suppressed and the five dimensional theory can be effectively reduced to four dimensional spacetime.

Keywords:

massive photon, higher dimensional theory and modified gravity

2020 KPS Spring Meeting
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C2.09

Gluon-Photon Signatures for color octet at the LHC (and beyond)

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Abstract:

We consider a color octet scalar particle and its exotic decay in the channel gluon-photon using an effective Lagrangian description for its strong and electromagnetic interactions. Such a state is present in many extensions of the Standard Model, and in particular in composite Higgs models with top partial compositeness, where couplings to photons arise via the Wess-Zumino-Witten term. We find that final states with one or two photons allow for a better reach at the LHC, even for small branching ratios. Masses up to 1.21.2 TeV can be probed at the HL-LHC by use of all final states. Finally, we estimate the sensitivity of the hadronic FCC.

Keywords:

BSM, composite Higgs, gluon-photon resonance, LHC, FCC

C2.10

Boosting Invisible Higgs Search with a Gluon Jet

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Abstract:

We propose that tagging the jets emitted by initial state radiation (ISR) can help search invisible Higgs decays. Quark and gluon composition of ISR jets of the signal process is different from that of the background and we can enhance the signal to background ratio using flavor information of the ISR. By using jet substructure variables as inputs containing flavor information, neural network-based classifier is found to be very powerful for boosting the discrimination of gluon jet rich signal events from the other quark jet rich backgrounds. On top of the conventional missing transverse energy (MET) in mono-jet analysis, we show that Higgs produced from the gluon fusion constrains the invisible Higgs decay the most, over the vector boson fusion traditionally known as the most constraining, and the limit on the branching ratio of the Higgs invisible decay is significantly improved. We summarize with emphasizing that our method has wider implications in search for new resonances.

Keywords:

invisible Higgs decay, jet substructure, LHC

C2.11

Measuring the trilinear Higgs boson self{coupling at the 100 TeV hadron collider via multivariate analysis¯-

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Abstract:

We perform a multivariate analysis of Higgs-pair production via the decay channel HH → b¯bγγ at the future 100 TeV pp collider to determine the trilinear Higgs self–coupling (THSC) λ3H,
which takes the value of 1 in the standard model. We consider all known background processes. For the signal we adopt the most recent event generator of POWHEG-BOX-V2 to exploit the NLO distributions for Toolkit for Multivariate Data Analysis (TMVA). Through the technique of Boosted Decision Tree (BDT) analysis trained for λ3H = 1, compared to the the conventional cut-and count approach, the signal-to-background ratio improves tremendously from about 1/10 to 1 and the significance can reach up to 20.5 with a luminosity of 3 ab−1 without including systematic uncertainties. In addition, by implementing a likelihood fitting of the signal-plus-background Mγγbb distribution with optimized bin sizes, it is possible to determine the THSC with the precision of 7.5% at 68% CL even at the very early stage of 100 TeV hadron collider with 3 ab−1.

Keywords:

Higgs-pair production, 100 TeV pp collider, Booted Decision Tree(BDT), Trilinear Higgs self coupling

Random bond Ising model and quantum error correction of a toric code

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Abstract:

Understanding the threshold probability for possible quantum error correction is important in determining whether quantum computing is achievable in realistic environment. Previously, such a understanding was illustrated using the fact that the quantum error correction model for 2 dimensional toric code can be mapped into classical random bond Ising model and was based on the possibility that all three quantum errors (qubit error, measurement error and quantum gate error) may occur independently. In contrast to this simplified assumption, we try to understand the case for the correlated quantum errors via random bond Ising model with correlated quenched probability. Here we discuss our preliminary result.

Keywords:

lattice gauge theory, quantum computing, 2d random bond Ising model, threshold theorem

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C3.01

Production of Hyperon Resonances in Lambda_c -> p K_s pi^0 decays in the Belle experiment

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Abstract:

We analyzed Monte Carlo simulation data of the Lc -> p Ks pi0 channel in order to measure the relative branching ratio of Γ(Lc -> p Ks pi0)/Γ(p K- pi+) and sub-branching ratios using 980.6 fb^{-1} data sample collected in the Belle detector at KEK. This study also aims to test the isospin symmetry in the Lc -> pKpi decays. The I = 1 Σ* resonances appear only in the Lc -> pKspi0 decays, while I = 0 Λ resonances are dominant in the Lc -> p K- pi+ decays. A recent observation of a narrow peak structure in the Lc -> p K- pi+ decays can be tested in the Lc -> p Ks pi0 decays. we will report a preliminary result of the Monte Carlo study with regard to the branching fraction measurement.

Keywords:

Lambda_c, Hyperon

2020 KPS Spring Meeting
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C3.02

The σ and ρ coupling constants for charmed and bottom mesons from bootstrap method

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Abstract:

In this talk, we evaluate the σ and ρ coupling constants for the $D(D^{*})$ and $B(B^{*})$ mesons. We first calculate $D\bar{D}(D^{*}\bar{D}^{*})\to\pi\pi$ amplitudes in the pseudophysical region. Combining the $\pi\pi$ transition amplitudes with the $D\bar{D}(D^{*}\bar{D}^{*})\to\pi\pi$ amplitudes by using the Blankenbecler-Sugar equation, we construct the 2π correlated amplitudes based on a meson-exchange model. The S- and P-channel spectral functions are derived from the two-body unitarity of S-matrix. We obtain the $DD(D^{*}D^{*})$ partial amplitudes from the dispersion integral along the unitarity cut$(4m_{\pi}^{2}\leq t\leq 52m_{\pi}^{2})$ which corresponds to the $D\bar{D}(D^{*}\bar{D}^{*})\to\pi\pi$ reaction. Employing the zero-width approximation, we provide the σ and ρ coupling constants for $DD(D^{*}D^{*})$ as the function of the physical t. As for the σ couplings, we examine the dependence of the σ coupling on the mass of the σ meson. We also compute the BB and $B^{*}B^{*}$ coupling constants in a similar way. Finally, we discuss our results compared with those of other models.

Keywords:

Exotic hadron, DDσ coupling constant, DDρ coupling constant, D*D*σ coupling constant, D*D*ρ coupling constant

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C3.03

Color-octet heavy quark potential from the instanton vacuum

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Abstract:

In the present talk, we investigate the color-octet heavy-quark potential from the instanton vacuum. We discuss the instanton effects on the masses and hyperfine mass splittings of the color-octet heavy quarkonium systems. In addition, we deal with the polarization of the quarkonia, which can be used to describe the heavy pentaquarks, P_c's.

Keywords:

Instanton-induced interactions, quarkonia, pentaquarks, color-octet, heavy-quark potential

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C3.04

Axial-vector transition form factors of the baryon decuplet

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Abstract:

In this talk, we present the results of the axial-vector transition form factors of the baryon decuplet to the octet within the framework of the SU(3) self-consistent chiral quark-soliton model. We take into account the
$1/N_c$ rotational corrections and the effects of SU(3) flavour symmetry breaking. In order to compare our results with the lattice results, we evaluate the axial-vector transition form factors employing the various unphysical pion masses such that we are able to compare the present results directly to those from the lattice calculations.

Keywords:

Photoproduction of a new Σ*(1400) resonance with $J^P=1/2^-$ off the nucleon target

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Abstract:

We investigate photoproduction of a new Σ*(1400) resonance with $J^P=1/2^-$ off the nucleon. A hybrid framework is utilized by combining an effective Lagrangian method with a Regge approach. The parallel and perpendicular parts of the cross sections and beam asymmetries for Σ*(1400) are examined and compared with those for Λ(1405) photoproduction. We rely on the chiral unitary model (ChUM) for the strong couplings. We find that the magnitudes of Σ*(1400) cross sections are about 5 times smaller than those of Λ(1405) ones.

Keywords:

new Σ*(1400) resonance, effective Lagrangians, photoproduction

Gravitational form factors of the singly heavy baryon Σ_c

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Abstract:

In this talk, we present results of the gravitational form factors of the singly heavy baryon Σ_c within the framework of a pion mean-field approach. We discuss how the pressure of the Σ_c can nontrivially vanish in the pion mean-field approach. We computed three different form factors, i.e., the mass form factor, D-term form factor, and the form factor of the angular momentum. In order to compare future results from lattice QCD, we employ the values of the unphysical pion mass and discuss the dependence of the form factors on it. We also present the mechanical equation of the states, i.e. the relation between the pressure and mass densities.

Keywords:

Gravitational form factors, Chiral quark-soliton model, Singly heavy baryons, Pion mean fields

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C3.07

The baryon octet and decuplet masses in nuclear matter within the model-independent approach

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Abstract:

We studied the baryon octet and decuplet masses in nuclear matter using the model-independent chiral soliton approach. The modifications in nuclear matter are performed by reproducing the ordinary matter properties at the saturation density. We also discuss the possible applications of the model to neutron and strange stars.

Keywords:

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C3.08

Axial-vector form factors of the baryon decuplet

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Abstract:

We present in this talk the axial-vector form factors of the baryon decuplet within the framework of a mean field approach, also known as the chiarl quark-soliton model (χQSM). We take into account the 1/Nc rotational corrections and the effects of flavor SU(3) symmetry breaking. We present the results of the flavor singlet, triplet and octet axial-vector form factors of the baryon decuplet. In order to compare the present results with those from the lattice calculations, we employ the values of the unphysical pion mass. Moreover, we also present the axial-vector constants and the axial radii in comparison with those from other models.

Keywords:

Axial-vector form factors, pion mean fields, the chiral quark-soliton model, the baryon decuplet

2020 KPS Spring Meeting
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C4.01

Impurity-induced magnetism in FeSe: Atomic scale imaging and spectroscopy using scanning tunneling microscopy

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Abstract:

Understanding of emergence of magnetism in high temperature superconductors is one of the fundamental keys to reveal the secret of the unconventional superconductivity. For most iron-based superconductors, the parent state of materials shows stripe antiferromagnetic (AFM) ordering which breaks the C_4 symmetry of the lattice. However, such long range magnetism is absent in FeSe which has been one of the mysteries in iron-based superconductors. Recently, theories suggest FeSe is close to the magnetic quantum critical point and thus weak impurities could induce local magnetism in FeSe. Here, we show the local magnetism is directly induced by impurities of FeSe using scanning tunneling microscopy (STM). More interestingly, the induced magnetism was consistent with the (pi,0) magnetic ordering, showing that this material falls into the category of Hund's metal in which orbital selectivity plays an important role.

Keywords:

FeSe, STM, Superconductivity, Impurity

C4.02

STM investigation of unexpected charge-density waves in thin flakes of 1T-TaS_2

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Abstract:

In strongly correlated electronic systems, an interplay between the degrees of freedom of electrons can induce versatile phase transitions among various intermediate phases. To investigate such an electron correlation effect on phase transitions, the study of intermediate phases is significantly important. Despite its importance, experimental results have been limited to macroscopic-scale studies due to the inevitable instability of intermediate phases. One of well-known transition metal dichalcogenides, 1*T*-TaS_2, is a prototypical model system because of its various metastable intermediate phases between coexisting charge-density-wave (CDW) and Mott insulating phases, which compete with superconductivity. The previous scanning tunneling microscopy studies on metastable phases of bulk 1*T*-TaS_2 revealed a correlation between smaller CDW domains and Mott gap closing. However, it was very difficult to control such metastable phases in bulk 1*T*-TaS_2, which limits further research on the correlated phases.
In this work, we prepared thin, clean 1*T*-TaS_2 flakes in order to investigate metastable CDW phases by STM. We found unexpected CDW phases on very thin flakes of 1*T*-TaS_2 as opposed to thick ones. While thick flakes show the isotropic, nearly commensurate CDW like bulk 1*T*-TaS_2 at room temperature, these novel CDW phases have anisotropic symmetry on thin flakes. Finding such unexpected CDW phases will provide fresh insight into the interplay among strongly correlated intermediate CDW phases at the thin limits.

Keywords:

STM, charge-density wave, 1T-TaS2, phase transition, superconductivity

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C4.03

TEM Imaging of Molecular Structures and Dynamics Enabled by Graphene Membrane

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Abstract:

Graphene, one-atom-thick layer composed of carbon atoms, is an ultimate membrane with various superior properties such as remarkable mechanical/chemical stability and ultra-high electrical/thermal conductivity. In particular, graphene can serve as an ideal platform for transmission electron microscopy (TEM) imaging owing to these unique physical properties. In this talk, I will discuss the applications of graphene membrane for atomic and molecular resolution TEM imaging of various structure and dynamics. The molecular assembly with one-dimensional atomic chains or zero-dimensional fullerene molecules are studied on graphene and two-dimensional crystals. Moreover, molecular dynamics under e-beam stimulation is monitored, which can provide direct observation on molecule-graphene interaction. Two-dimensional crystals supported by graphene membrane also exhibit prolonged stability under e-beam, enabling successful imaging of crystal structure and atomic-scale defects.

Keywords:

graphene, transmission electron microscopy (TEM), e-beam- stimulation, atomic structure, molecular structure

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C4.04

Single-Atom Level Determination of Complex 3D Atomic Structure via Electron Tomography

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Abstract:

Modern science and technology rely on functional materials, and the physical properties of these materials often strongly depend on defects, local disorder, nanoscale heterogeneities, and grain structures at the atomic scale. Traditional crystallography, which is reliant on periodicity, has been the main method for determining crystal structures, but cannot determine defects or other non-crystalline features. Without any prior assumption of underlying structure, atomic electron tomography (AET) is now able to locate the 3D coordinates of individual atoms and their dynamics with picometer precision and with elemental specificity [1-4]. A variety of complex atomic structures have been measured with 3D atomic-level details; including grain boundaries, dislocations, point defects and related strain and lattice distortions. Understanding the atomic resolution structural dynamics together with the relationship between atomic structure and physical properties will open up new avenues in condensed matter physics and allow the rational design of novel materials at the atomic scale.

[1] Zhou et al., Nature 570, 500 (2019).
[2] Yang et al., Nature 542, 75 (2017).
[3] Xu et al., Nat. Mater. 14, 1099 (2015).
[4] Tian et al., Nat. Mater., in press (2020) arXiv:1901.00633.

Keywords:

Electron Tomography, Atomic Scale Imaging, 3D Structure

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C5.01

Gate-tunable topological flat bands in graphene moire superlattices

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Abstract:

Periodic moiré patterns in the length scale of a few tens of nanometers can give rise to moiré mini Brillouin zones whose zone corners are at energy ranges accessible by conventional field effects in gated transistor devices. Recent experiments have shown resistance peaks as a function of carrier doping indicative of Mott-like phases in twisted bilayer graphene at the first magic twist angle [1,2] and in ABC trilayer graphene (TLG) nearly aligned with hexagonal boron nitride (BN) [3,4] when the Fermi energy is brought near the superlattice flat bands. The possibility of tailoring narrow flat bands through moire patterns is an attractive pathway to engineer novel correlated artificial materials. In this talk we discuss about the flat bands that can be found in twisted multilayer graphene systems. In twisted bilayer graphene (tBG), the flat band magic angles are found to grow linearly with interlayer coupling and decrease with Fermi velocity [5] showing an interdependence between twist angle and vertical pressure. Another related system of interest is twisted double bilayer graphene (tDBG) whose bandwidth is generally flatter than in tBG by roughly up to a factor of 2 in the same parameter space of twist angle and interlayer coupling, making it in principle simpler to tailor narrower bandwidths [6]. A related system where flattening of the low-energy bands is facilitated by the presence of a vertical electric field induced band gap is the ABC trilayer graphene on hexagonal boron nitride (TLG/hBN) [7]. We show that narrow bandwidths of ~10 meV are achievable for a continuous range of twist angles $\theta \leq 0.6^{\circ}$ with moderate interlayer potential differences of ~50 meV making of TLG/BN a promising platform for the study of electric-field tunable flat bands. Moreover, the valley resolved moire flat bands acquire a finite valley Chern number when they are isolated through avoided crossings in k-space which impacts the character of the ground-state Hall conductivity when the degeneracy is lifted by Coulomb interactions.

Acknowledgments:
This work was supported by the Samsung Science and Technology Foundation under Project Number SSTF-BA1802-06.

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2. Y. Cao et al., Nature 556 (2018) 43.
3. G. Chen et al., Nat. Phys 237 (2019) 15.
4. G. Chen et al., Nature 572 (2019) 215.
5. B. L. Chittari et al., Electron. Struct. 1 (2018) 0150012.
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7. B. L. Chittari et al., Phys. Rev Lett, 122 (2019) 016401.

Keywords:

moire bands, graphene, topological bands, flat bands, anomalous Hall effect

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C5.02

Ferroelectricity-driven Berry curvature dipole in SnTe monolayers

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Abstract:

In symmetry-broken crystalline solids, pole structures of Berry curvature (BC) can emerge, and they have been utilized as a versatile tool for controlling transport properties. For example, the monopole component of the BC is induced by the time-reversal symmetry breaking, and the BC dipole arises from a lack of inversion symmetry, leading to the anomalous Hall and nonlinear Hall effects, respectively. In this talk, we show that the ferroelectricity in a SnTe monolayer produces a unique BC distribution, which indeed offers charge- and spin-controllable photocurrents. We verify the fundamental relation between the ferroelectricity and the BC dipole, which is a counterpart of the well-known ferromagnetism and BC monopole coupling. By manipulating the photon handedness and the ferroelectric polarization, charge and spin circular photogalvanic currents are generated in a controllable manner. The ferroelectricity in group-IV monochalcogenide monolayers can be a useful tool to control the BC dipole and the nonlinear optoelectronic responses.

Keywords:

ferroelectricity, Berry curvature dipole, nonlinear optoelectronic response

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C5.03

Quantum Distance and Anomalous Landau Levels of Flat Bands

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Abstract:

We uncover the novel roles of the band-crossing singularities in flat bands. While the singularity of the flat band is topologically trivial, it can be characterized by a pseudo-spin canting around the touching point. We propose that the strength of the singularity is defined as the maximum canting angle between two pseudo-spins, or equivalently, the maximum quantum distance between two Bloch wave functions. This bulk's singularity guarantees the existence of two topological objects in real space, one is the non-contractible loop states under the periodic boundary condition, and the other is the robust boundary modes under the open boundary condition. Then, we show that when the flat band has a singularity, its Landau levels develop in the energy gap, and their spreading into the gap is determined by the maximum quantum distance around the band crossing point. This is a new rule for the Landau level quantization, and completely beyond the conventional semi-classical paradigm. Moreover, the Landau levels corresponding to the flat band exhibit 1/n dependence, where n is the Landau level index. This behavior leads to the divergence of the orbital magnetic susceptibilities.

[1] J.-W. Rhim, K. Kim, B.-J. Yang, accepted in Nature (2020); [2] J.-W. Rhim and B.-J. Yang, Phys. Rev. B **99**, 045107 (2019); [3] J. Ma, J.-W. Rhim et al., Phys. Rev. Lett. **124** 183901 (2020)

Keywords:

Flat band, Landau level, Quantum distance, Band-crossing, Real-space topology

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C5.04

Uncovering pseudospins and its polarization in black phosphorus

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Abstract:

Pseudospin is a key of Dirac fermions in a two-level quantum system which shows the chirality with exotic geometrical phase. Because Dirac fermions in black phosphorus can be created by tuning bandgap [1] and protected by crystal symmetry [2], it has been studied for the topological phase diagram with a simple parameter. Although these attractive benefits of black phosphorus, however, there is a few knowledge about pseudospin textures depending on the topological phase of matter. In this presentation, we will introduce our study of pseudospins in black phosphorus by employing angle-resolved photoemission spectroscopy (ARPES) and the tight-binding calculation [3]. By comparing intensity modulation in ARPES and sublattice interference model [4], we probed pseudospin textures of black phosphorus as the process of merging Dirac fermions. Especially, We found the strong pseudospin polarization in semiconducting black phosphorus, which is topologically trivial. Our finding suggests the potential of semiconducting black phosphorus for the pseudospintronics.

References

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[2] J.Kim et al., Physical Review Letters 119, 226801 (2017)
[3] S.W.Jung et al., Nature Materials 19, 277-281 (2020)
[4] S.W.Jung et al., Physical review letters 116, 186802 (2016)

Keywords:

Pseudospin, Merging Dirac fermions, Two-level quantum system

2020 KPS Spring Meeting
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C6.01

Control of ferromagnetic Curie temperature and topological Hall effect in chromium telluride thin films

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Abstract:

Chromium telluride ($Cr_{1-x}Te$) has been known as a p-type ferromagnetic metal with varied Curie temperatures (T_c = 170 K – 340 K). Recent report of topological Hall effect (THE) suggested the skyrmion phase formation (Nano Research, 11, 3116 (2017)). However, the origin of THE as well as the various T_c among the Cr_2Te_3 phases was not clearly understood yet. Here, we investigate two different types of Cr_2Te_3 thin films with different T_c via different growth conditions to understand the origin of the various T_c. We also discuss the THE-like signal in our Hall measurements, with complementary microscopic and spectroscopic evidences, to address the origin of observed THE-like signal in this peculiar magnetic thin film system.

Keywords:

Chromium telluride, Curie temperature, Magnetic anisotropy, Topological Hall effect

C6.02

Oxygen Vacancy Engineering for Highly Tunable Ferromagnetic Properties: A Case of $SrRuO_3$ Ultrathin Film with a $SrTiO_3$ Capping Layer

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Abstract:

Oxide heterostructures have great potential for spintronics applications due to their well-defined heterointerfaces and vast functionalities. To integrate such compelling features into practical spintronics devices, effective control of the magnetic switching behavior is key. Here, continuous control of the magnetic coercive field in $SrTiO_3/SrRuO_3$ ultrathin heterostructures is achieved by oxygen vacancy (V_O) engineering. Pulsed laser deposition of an oxygen-deficient $SrTiO_3$ capping layer can trigger V_O migration into the $SrRuO_3$ layer while avoiding the formation of Ru vacancies. Moreover, by varying the thickness and growth conditions of the $SrTiO_3$ capping layer, the value of the coercive field (H_C) in the ferromagnetic $SrRuO_3$ layer can be continuously tuned. The maximum enhancement of H_C at 5 K is 3.2 T. Such a wide-range tunability of H_C may originate from a V_O-induced enhancement of perpendicular magnetic anisotropy and domain wall pinning. This study offers effective approaches for controlling physical properties of oxide heterostructures via V_O engineering, which may facilitate the development of oxide-based functional devices.

Keywords:

oxygen vacancies, oxide heterostructures, SrRuO3 thin films, coercive field, perpendicular magnetic anisotropy

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C6.03

Superconductivity emerging from a stripe charge order in $IrTe_2$

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Abstract:

Unconventional superconductivity often appears in the vicinity of competing charge or spin orders, when these parent orders are suppressed by doping or pressure. For transition metal dichalcogenides (TMDCs) hosting such orders in van der Waals structure, thickness control offers another effective means to tune their ground states and also to stabilize the otherwise hidden phases. Here using Raman spectroscopy, scanning tunneling microscopy and transport property measurements, we report the observation of two-dimensional (2D) superconductivity emerging from the preexisting stripe charge order in $IrTe_2$ nanoflakes. This contrasts to the doped bulk $IrTe_2$ whose superconductivity appears only after melting the stripe charge order. We found that this intrinsic coexistence of superconductivity and the stripe charge order in $IrTe_2$ nanoflakes significantly increases the out-of-plane superconducting coherence length and the superconducting gap ratio, much larger than those of the doped bulk crystals. These findings manifest the collaborating relationship, not competing one, between two orders in $IrTe_2$, distinct from other superconducting TMDCs.

Keywords:

IrTe2 nanoflake, charge order, 2D superconductivity

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C6.04

Effect of local density of states on the impurity-induced many-body ground states in superconductivity

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Abstract:

Magnetic impurities on s-wave superconductors locally break time reversal symmetry and thus provide exchange potential to break Cooper pairs. As a result, impurity-induced bound states appear inside superconducting gap, which is called Yu-Shiba-Rusinov (YSR) bound states. It is well known that the YSR bound states depend on the impurity spin (S), exchange coupling energy (J), and the local density of states (LDOS) at Fermi energy (E_F). Theory and experiments have shown that the YSR bound states indeed depend on the exchange coupling energy J. However, experimental evidence of showing their electron densities dependence has been lacking. In this study, we used Ar-induced nano-cavity in Pb(111) substrate to control the LDOS at E_F. We systematically discuss the way the YSR bound states respond to the variation of LDOS at E_F.

Keywords:

s-wave superconductor, Yu-Shiba-Rusinov state, local density of states

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C6.05

Multiband Nature of the Room-Temperature Superconductivity in Compressed LaH_{10}

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Abstract:

Recently, the discovery of room-temperature superconductivity (SC) was experimentally realized in the fcc phase of LaH_{10} under megabar pressures. This SC of compressed LaH_{10} has been explained in terms of strong electron-phonon coupling (EPC), but the detailed nature of how the large EPC constant and high superconducting transition temperature T_c are attained has not yet been clearly identified. Based on the density-functional theory and the Migdal-Eliashberg formalism, we reveal the presence of two nodeless, anisotropic superconducting gaps on the Fermi surface (FS). Here, the small gap is mostly associated with the hybridized states of H *s* and La *f* orbitals on the three outer FS sheets, while the large gap arises mainly from the hybridized state of neighboring H *s* or *p* orbitals on the one inner FS sheet. Further, we find that compressed YH_{10} with the same sodalite-like clathrate structure has the two additional FS sheets, enhancing EPC constant and T_c. It is thus demonstrated that the nature of room-temperature SC in compressed LaH_{10} and YH_{10} features the multiband pairing of hybridized electronic states with large EPC constants.

Keywords:

LaH10, Multiband pairing, Anisotropic superconducting gaps

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C6.06

Superconducting Hydrogen Cages Stabilized by Anionic Electrons in Compressed LaH_{10}

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Abstract:

The lanthanum hydride LaH_{10} with a sodalitelike clathrate structure was experimentally realized to exhibit a room-temperature superconductivity under megabar pressures. Although the building block of this metal hydride is the cage of 32 H atoms surrounding a La atom, the bonding nature between the H_{32} cage and La atom has not yet been clearly identified. Based on first-principles density-functional theory calculations, we reveal that the face-centered cubic (fcc) lattice of La atoms without H atoms has the unbound electrons residing at interstitial regions. Such anionic electrons in the La lattice stabilizes formation of the H_{32} cages containing the covalent H_1-H_1 and H_1-H_2 bonds with two H species. Here, the interaction between the La lattice and H_{32} cages induces a charge transfer from H_2 to H_1 and La atoms, leading to a strong hybridization of H_1 *s* and La *f* orbitals near the Fermi energy. The charge analysis illuminates that the bonding nature between the H_{32} cage and La atom is characterized as a mixture of ionic and covalent. Our findings demonstrate that the anionic electrons of the La lattice play an important role in determining the bonding and electronic properties of superconducting H_{32} cages in compressed LaH_{10}.

Keywords:

Room-temperature superconductivity, Metal hydride, Electride

2020 KPS Spring Meeting
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C7.01

Overcoming lifetime limitation on metal halide perovskite emitters and their display applications

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Abstract:

Organic/inorganic halide perovskites (OIHPs) have been emerged as promising candidates for next-generation display material because of their advantages regarding luminescent properties such as high photoluminescence quantum efficiency, high color purity (FWHM ~ 20 nm), and low material cost, and easy color tunability. Additionally, intense progress on perovskite light-emitting diodes (PeLEDs) resulted in drastic increase of external quantum efficiency, exceeding 20 % in less than 5 years since the first efficient EL operation.[1] However, the operational stability of PeLEDs is limiting their practical application due to the easy device breakdown and poor lifetime less than several hours. Especially, the effect of ion migration in perovskite under electric field is known to destroy the crystal structure and cause device breakdown.[2]
Here, we suggest new strategies to overcome the stability limitation of PeLEDs. First, we introduced the proton-transfer-induced 3D/2D hybrid structure with low defect density and extremely suppressed ion migration. Especially, the electrical stability of perovskite emitter can be greatly improved with self-assembled 3D/2D structure, enabling long-term stable operation. Also, we could further prolong the operational stability of PeLEDs with mixed-cation system, realizing minimum defect states in bulk perovskites. Our work will provide a promising guideline to overcome the instability of PeLEDs assisted by the ion migration in perovskite.

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(2) Cho, H.; Kim, Y.-H.; Wolf, C.; Lee, H.-D.; Lee, T.-W. Improving the Stability of Metal Halide Perovskite Materials and Light-Emitting Diodes. *Adv. Mater.* **2018**, *30* (42), 1704587.

Keywords:

Metal halide perovskites, Light-emitting diode, Stability, Ion migration, Display application

2020 KPS Spring Meeting
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C7.02

Raman scattering study of structural phase transitions in methylammonium lead halide perovskite single crystals

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Abstract:

We present Raman scattering spectroscopic study of methylammonium (MA) lead halide perovskite materials, focusing on structural phase transition behaviors. By measuring temperature-dependent Raman spectra, we observed anomalous changes in phonon frequencies and phonon linewidths across the phase transition temperatures from which we could effectively monitor phase transitions, from cubic to tetragonal and successively to orthorhombic structure. We could also study contributions from each vibration species to the phase transitions whose influence to the phase transitions differs significantly. Moreover, from analyzing polarization dependence and temperature dependence of phonon modes, we could get information regarding the mechanism of the phase transitions. From our results, we claim that Raman scattering spectroscopy is a very effective research mean that can sensitively monitor structural phase transition behaviors and their mechanism from studying local structural environment.

Keywords:

methylammonium lead halide perovskite, Raman scattering, structural phase transition

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C7.03

Cation engineering of mixed-halide perovskite solar cells for improved photo conversion efficiency and long-term stability

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Abstract:

Hybrid organic-inorganic perovskite solar cells (PSCs) have recently emerged as a highly promising and inexpensive solution for sustainable energy. PSCs also showed a rapid increase in efficiency for a short period time due to its excellent optical and physical properties, wide light absorption coefficient, low defect density, and excellent carrier diffusion. The PSCs were initially researched based on the use of methyl ammonium lead iodide ($MAPbI_3$) material as a light absorber layer. Since methyl ammonium (MA) based materials have long-term stability problems, many studies recently have been performing to improve efficiency and long-term stability using absorber materials that MA are partially substituted with cation such as formamidinium (FA), Cs, and Rb. In this research, we report the fabrication of multiple cation engineered perovskite absorber layer and the characteristics of the PSCs using these absorber layers. In addition, evaluation of long-term stability using damp heat (85 degree, 85 % relative humidity 1000 hour for the PSCs will be described in detail.

Keywords:

Mixed halide perovskite solar cells, Cation engineering, Long-term stability, Damp heat test

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C7.04

Interfaces in perovskite solar cells: influence of functional materials on electronic structures and performances

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Abstract:

Perovskite solar cells have achieved a high power conversion efficiency (PCE) over 26% in 2020. For now, it is important to understand in detail the working mechanism of these devices. In special, the interface between perovskite film and the charge extraction layers is the most critical factor in determining both the CPE and stability of perovskite solar cells. This contribution will be presented our recent achievements in the fundamental understanding of how these interfaces influence the electronic structures and performance of devices. First, an overview will be provided on the various strategies for the interfaces in perovskite solar cells. Then the study on the thickness of perovskite films will be discussed as a way to optimize the device performance. At the end, the interfaces and interfacial materials such as Ag nanoparticles and ionic polymers will be provided how to influence the electronic structures and device performance.

Keywords:

perovskite, electronic structure, interface

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C7.05

First-principles studies of the surfaces, interfaces, and junctions of hybrid halide perovskites

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Abstract:

In this talk, I will present several recent works within our group that are concerned with the surfaces, interfaces, and junctions based on hybrid halide perovskites. First, based on the combined density functional theory (DFT) calculations and atomic force microscopy measurements, we study the stability and degradation mechanisms of the $MAPbI_3$ (MA: $CH_3NH_3^+$) and $MAPbBr_3$ surfaces [1]. We propose a degradation pathway that initiates even at a low humidity levels and leads to the formation of surface $PbBr_2$ species. Possibilities of surface stabilization and work function control via the ligand exchange approach are discussed. Next, performing DFT calculations, we consider the interfaces between $MAPbI_3$ light absorber and TiO_2 electron transfer layer and predict that a strain-induced atomically thin metallic layer can be created at the $MAPbI_3/TiO_2$ interface by forming an interdigitated interface. Experimental realizations of the interdigitated interface by substituting Ti sites at the TiO_2 surface with Pb atoms show that the emergent interfacial metallic layer provides a volcano-type photovoltaic activity curve with the optimal photovoltaic efficiency appearing at the monolayer PbO limit [2]. If time permits, I will also discuss the prediction of semimetallicity and ultrahigh negative differential resistance that can be achieved from the nanowires derived from recently synthesized one-dimensional (1D) halide perovskites [3].

References

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2. [2] M. E. Khan *et al.* (in preparation); N. Tsvetkov *et al.* (submitted).
3. [3] M. E. Khan, J. Lee, S. Byeon, Y. -H. Kim, *Adv. Funct. Mater.* **2019**, 29, 1807620.

Keywords:

Halide perovskite, Ligand exchange, MAPbI3/TiO2 interface, First-principles approaches, Negative differential resistance (NDR)

2020 KPS Spring Meeting
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C7.06

Structural and optoelectronic properties of $CH_3NH_3PbX_3$ Perovskite Crystals (X = I, Br, and Cl) for fundamental understanding and device applications

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Abstract:

We report growth and structural characteristics of organic-inorganic hybrid lead halide perovskite crystals for elucidating optical and electrical properties. Eventually, we like to find out application platforms of this new and unique material for photonic and photovoltaic devices itself and bottom substrates as a building foundation. Three halides including I, Br, and Cl allow us to study a variety of spectral range which is a key characteristic due to the bandgaps of the materials. Unfortunately, the materials are not stable in the ambient air with water molecules. Basic properties of structural identity and phase purity were confirmed by transmission electron microscopy and x-ray diffraction. This structural analysis also gives a clue for decomposing or degrading process of the parts of the crystals. Bandgaps and workfunctions of the materials were obtained by optical transmission and Kelvin probe force microscopy. From this tool, an electronic structure was built for comprehensive views on the carrier type and electronic capability of materials, which are essential to device applications. We will show some preliminary results of photonic devices and growth of hetero-epitaxial halide perovskites on the crystals.

Keywords:

Perovskite, Semiconductor, Optoelectronics

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C8.01

Single-molecule force sensor for molecular tension measurement in living cells

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Abstract:

Every time we see, hear, touch, and taste, cells in our body sense and respond to their environment. Mechanical/physical interactions between the cell and their microenvironment regulate various cell behaviors such as morphology, adhesion, and migration. To characterize the mechanical forces, we utilized a novel single molecule technique, referred to as tension gauge tether (TGT). This technique allows us not only to measure tension thresholds to activate signaling pathways, but also to investigate how mechanical cues influence cell behaviors. In this seminar, detailed information about the TGT assay will be introduced, and then our new discoveries acquired from the TGT assay will be described; Characterization of integrin tensions during 1) cancer metastasis, 2) muscle cell shortening, and 3) immune cell migration.

Keywords:

Mechanobiology, single molecule technique, molecular tension

C8.02

DNA computing and storage system by electric field

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Abstract:

DNA-based systems could potentially be developed to solve highly complex computational problems such as medical diagnosis using big data and artificial intelligence. Due to the highly specific Watson-Crick pairings of complementary nucleobases, DNA can be used to process information at the molecular level. This enables DNA-based systems to be exploited for parallel molecular computation, and massive memory and data storage. DNA-based systems have been developed for solving combinatorial problems, construction of logic gates, and memory storage. One common critical limitation of these systems is related to the slow hybridization kinetics, hindering their operating speed. In this talk, we discuss the construction and operations of a DNA-based non-volatile memory (NVM) system and the use of electric field induced hybridization (EFH) to drastically accelerate the operations of the system. The efficiency of EFH was confirmed by modeling using the finite-element method. First, we demonstrated a 1-bit or single-level cell NVN (SLC-NVM) system using an array of 6 x 6 individually addressable electrodes. Using three segments with different sequences on a single DNA molecule to encode 3 bits and an array of 3x3 electrodes, we demonstrated the parallel 3-bit write operations on the addressable cells by 3-step EFH and parallel read operations by using 3-channel optical imaging. We demonstrated the ability for rapid parallel write and read of 2^3 DNA memory effects. Moreover, we have also demonstrated bit shifting by EFH DNA sequence displacement. Furthermore, we will discuss about the molecule level computing system and storage system in biochip.

Keywords:

DNA computing, DNA storage, displacement effect, electric field hybridization

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C8.03

Nuclease-free detection of DNA methylation via the B-Z transition

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Abstract:

DNA methylation is one of the most frequent and critical epigenetic modifications. Abnormal DNA methylation has been implicated in various metabolic syndromes and cancers. It is therefore not only of fundamental interest but also of practical significance to probe the degree of DNA methylation by DNA methyltransferases (DNMT). Here, we propose a new single-molecule-based approach to measure the degree of DNA methylation. The B-to-Z-DNA transition is sensitive to the extent of DNA methylation: CG repeat sequences with methylated cytosines are easier to convert to Z-DNA than unmethylated, otherwise, identical sequences. Thus, we monitored the B-Z transition occurring to individual DNA molecules in various methylation states by single-molecule FRET and could quantitate DNA methylation in a facile manner and establish the relationship between Z-DNA forming capability and the degree of DNA methylation. Besides, we also tested the effects of various DNMT inhibitors, some of which are clinically tested as anti-cancer drugs, discovering that our technique provides a convenient way to evaluate the efficacy of such drugs. Our work clearly demonstrates that the new method is a sensitive, selective, versatile, and viable sensor platform to detect DNMT activity and screen DNMT inhibitors.

Keywords:

Epigenetics, DNA methylation, DNA methyltransferase, DNMT inhibitors, single-molecule FRET, B-Z transition, nuclease-free assay

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C9.01

Multiplexing induced first order transition (explosive) synchronization in multilayer networks

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Abstract:

The multilayer nature of networks has broadened the landscape of network science. In this multilayer description, different kinds of relationships or interactions between the nodes are modeled by allowing the units to be arranged in several layers, either simultaneously or in an alternating fashion. An example of multilayer systems is the transport system of a country or state in which cities or towns would be the nodes, and a distinct network of each bus, train and flight connectivity among the nodes (cities) denote different layers.
Furthermore, a close relationship between structure and dynamics in the process of synchronization in complex networks have been the object of study for a long time; however, it has proved to be particularly important in the case of the “explosive synchronization,” where the ensemble reaches suddenly to a fully coherent state through a discontinuous, irreversible First-order like transition, often in the presence of a hysteresis loop. This first-order discontinuous transition to synchronization, popularly known as explosive synchronization (ES), in a the network has been shown to be originated from considering either degree-frequency correlation, frequency-coupling strength correlation, inertia or adaptively controlled phase oscillators. We show that ES is a generic phenomenon, and show that through appropriate multiplexing, one can achieve explosive synchronization in those networks that are incapable of exhibiting explosive synchronization in isolation.

Keywords:

Mulilayer networks, Synchronization, Phase transition

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C9.02

Phase transition and entropy flux in majority-vote dynamics on multiplex networks

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Abstract:

Phase transition is studied with different voting rules of majority-vote model on multiplex networks. Following [1], we consider two types of voting rules for multiplex networks, OR- and AND-model. In OR-model, agent follows an averaged majority opinion among layers and in AND-model, agent takes a common majority, imitating prudent manner in decision making process. OR-model shows continuous transition on multiplex networks consisting of random regular (RR) networks. Overlaps in two neighboring degrees are found in magnetization but distinguished in entropy flux. Mean-field approach is taken giving a physical understanding on the overlaps. For AND-model, continuous transition occurs with odd number of degree and discontinuous transition with even number of degree on RR duplex networks. Hysteresis is found as known to be in first-order transition in both magnetization and entropy flux. These are studied in more details with pair-approximation of approximate master equation.

[1] Jeehye Choi and K-I Goh 2019 New J. Phys. 21, 035005

Keywords:

majority-vote model, multiplex network, majority-vote model

C9.03

The multi-scale landscape of community inconsistency in networks

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Abstract:

A community structure of a network reveals various important mesoscale characteristics of the network. The community partition depends on the resolution parameter and finding the adequate resolution has been one of the toughest challenges of the modularity-maximization-based community detection. Since there is no unanimous rule in deciding the resolution parameter to diagnose the structure of the network, many previous studies have used the parameter in a rather ad-hoc way to obtain reasonable community partitions. In this work, we harness the heterogeneity from multiple results generated from stochastic community detection algorithms in order to overcome the ambiguity in determining the resolution parameter and shed light on overall processes of stochastic community detection algorithms. We develop a series of measures to systematically quantify the inconsistency in an ensemble of community partitions in the whole-network point of view (partition inconsistency, PaI) and the nodal inconsistency of companionship (membership inconsistency, MeI; companionship inconsistency, CoI). By the numerical simulation on synthetic multi-community models with different levels of participation to communities and real networks, we find that PaI, MeI, CoI are useful to determine the legitimate range of resolution parameters for given networks. We also show that the results can explain the process of overlapping and merging dynamics of community structures.

Keywords:

network, inconsistency, resolution, community detection, modularity

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C9.04

Modeling temporal networks with bursty activity patterns of nodes and links

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Abstract:

The concept of temporal networks provides a framework to understand how the interaction between system components changes over time. In empirical communication data, we often detect non-Poissonian, so-called bursty behavior in the activity of nodes as well as in the interaction between nodes. However, such reconciliation between node burstiness and link burstiness cannot be explained if the interaction processes on different links are independent of each other. This is because the activity of a node is the superposition of the interaction processes on the links incident to the node and the superposition of independent bursty point processes is not bursty in general. Here we introduce a temporal network model based on bursty node activation and show that it leads to heavy-tailed inter-event time distributions for both node dynamics and link dynamics. Our analysis indicates that activation processes intrinsic to nodes give rise to dynamical correlations across links. Our framework offers a way to model competition and correlation between links, which is key to understanding dynamical processes in various systems.

Keywords:

temporal network, bursty behaviour

2020 KPS Spring Meeting
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C9.05

The origin of bursty pattern in Wikipedia editing

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Abstract:

To understand bursty time series with metadata or contextual information, we study human activity patterns observed in the English Wikipedia editing dataset. In particular, we are interested in the origin of bursty editing behavior of individual editors, i.e., whether such bursty behavior is intrinsic to the individual editors or driven by the interaction between editors. We assume that the intrinsic behavior of editors and interactions between them could correspond node burstiness and link burstiness, respectively. We analyzed Wikipedia editing information using the general method of human bursty dynamics. Precisely, for a given article in the Wikipedia dataset, each edit or event is recorded with the edit timing as well as with contextual information on the editor who generated the edit. The sequence of edit timings is used to detect bursty trains for a given time window: Every pair of consecutive events in a bursty train are separated by the time interval shorter than the time window, while events between different bursts are separated by the time interval longer than the time window. The detected bursty trains are classified according to the contextual information, for which we distinguish a particular editor from others. We define types of bursts by classifying them as initiated, involved, and non-involved bursts. (i) If the first event in a bursty train is edited by the particular editor, it is called the initiated burst. (ii) If a bursty train is not initiated by the particular editor but some following events are edited by the particular editor, it is called the involved burst. (iii) All other bursty trains are called non-involved bursts. Then to quantify the degree of initiation (DOI) of a particular editor in a given article, we define a ratio of the number of initiated bursts to that of initiated or involved bursts for a given time window. This ratio is calculated for the entire range of time window, leading to the DOI curve as a function of the time window. The normalized area under the DOI curve (AUC) can be interpreted as the degree to which the particular editor initiates bursty trains in a given article: The larger (smaller) AUC value implies the tendency of node burstiness (link burstiness). We empirically find various behavioral patterns of editors in terms of the DOI curves. To investigate which features in the edit sequence are most relevant to predict the DOI of a particular editor, we adopt the randomized reference models (RRMs). Based on the results of RRMs, we devise a simple mechanical model considering the inter-event time distributions of the particular editor and of others as well as the contextual correlations in terms of the probability of the edit being generated by the particular editor given the information on the editor for the previous edit in a given article. The analytic solution of the model is successfully compared with the simulation results.

Keywords:

Human bursty dynamics, Wikipedia editing

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C9.06

Optimizing hospital distribution across districts for reducing tuberculosis fatalities

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Abstract:

The spatial distributions of diverse facilities are often understood in terms of the optimization of the commute distance or the economic profit. Incorporating more general objective functions into such optimization framework may be useful, helping the policy decisions to meet various social and economic demands. As an example, we consider how hospitals should be distributed to minimize the total fatalities of tuberculosis (TB). The empirical data of Korea shows that the fatality rate of TB in a district decreases with the areal density of hospitals, implying their correlation and the possibility of reducing the nationwide fatalities by adjusting the hospital distribution across districts. Approximating the fatality rate by the probability of a patient not to visit a hospital in her/his residential district for the duration period of TB and evaluating the latter probability in the random-walk framework, we obtain the fatality rate as an exponential function of the hospital density with a characteristic constant related to each district's effective lattice constant estimable empirically. This leads us to the optimal hospital distribution which finds the hospital density in a district to be a logarithmic function of the rescaled patient density. The total fatalities is reduced by 13₩% with this optimum. The current hospital density deviates from the optimized one in different manners from district to district, which is analyzed in the proposed model framework. The assumptions and limitations of our study are also discussed.

Keywords:

Optimization, Facility distribution

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C9.07

First passage time of searchers in the presence of strong attractions

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Abstract:

We study how the first passage dynamics change when we consider the strong attraction between searchers in the random target search. We perform a molecular dynamics simulation that makes the searchers form clusters as they approached each other. The simulation gives us how the distribution of first passage time (FPT) changes when the searcher's initial density, critical distance to make a cluster, and cluster's diffusion reduction rate change. As a result, we observe that the cluster formation between searchers and stagnation of diffusion drastically lengthen the tail of FPT distribution, and it causes an increase in the mean first passage time (MFPT) above the critical density. This phenomenon is in stark contrast to the result of a non-interacting system where the MFPT steadily decreases as the searcher density increases. In addition, by introducing a model that handles the cluster formation and searching dynamics as Poisson events, we suggest a more analytical understanding of the effects of cluster formation and stagnation on the first passage dynamics of the system.

Keywords:

Random Target Search, Cluster Formation, First Passage Dynamics

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C9.08

Automata representation of successful strategies for social dilemmas

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Abstract:

In a social dilemma, cooperation is collectively optimal, yet individually each group member prefers to defect. A class of successful strategies of direct reciprocity were recently found for the iterated prisoner's dilemma and for the three-person iterated public goods game: By a successful strategy, we mean that it constitutes a cooperative Nash equilibrium under implementation error, with assuring that the long-term payoff never becomes less than the co-players' regardless of their strategies, when the error rate is small. Although we have a list of actions prescribed by the successful strategies, the rationale behind them has not been fully understood. In this work, we provide a better understanding for the successful strategies by converting them into automata with a minimal number of states. Each of the states becomes interpretable in this representation, whereby one can gain insight into the underlying mechanism.

Keywords:

Evolution of cooperation, Reciprocity, Prisoner’s dilemma, Public-goods game

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D1.01

Search for a right-handed W boson and heavy neutrino in proton-proton collisions at sqrt(s)=13 TeV

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Abstract:

A search for a right-handed W boson and a heavy neutrino, in a final state consisting of two same-flavor leptons (e or μ) and two quarks, is presented.
The search is performed by the CMS experiment at the CERN LHC using a data sample of proton-proton collisions at a center-of-mass energy of 13₩TeV corresponding to an integrated luminosity of 137 fb^{-1}.
The search covers both regions of phase space where the heavy neutrino is produced with sufficiently high transverse momentum that its decay products are merged into a single large-area jet and where the decay products are well-separated.
The signal is characterized by an excess above the standard model expectation in the invariant mass distribution of the final-state objects.

Keywords:

CERN, LHC, CMS, Left-right symmetry, Heavy neutrino

D1.02

Search for new physics in the monophoton final state in proton-proton collisions at √s=13 TeV with full Run II dataset

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Abstract:

Dark matter (DM) is one of the most compelling piece of evidence for physics beyond the standard model (BSM) and is one of goals of a diverse, multi-pronged research program at the large hadron collider (LHC). A traditional dark-matter signature at a proton-proton collider is one where one or more SM particles, X, are produced and detected recoiling against missing transverse momentum with magnitude associated with the non-interacting DM candidate. One such signature is the production of a photon and missing transverse energy. We present the theoretical motivation for the monophoton final state with different models and will present the status of different background studies to the monophoton final state.

Keywords:

Dark matter, Monophoton, CMS, LHC

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D1.03

Performance of high-momentum muons at CMS

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Abstract:

High-momentum muons are one of the crucial keys for exploring new regimes in physics beyond the standard model. In 2016 and 2017, the CMS detector recored 78 /fb of proton-proton collisions at $\sqrt{s}$=13 TeV. These data contain a large number of sufficiently energetic muons with momenta reaching up to 1.8 TeV allowing us to better understand their performances which are different from their lower momentum counterparts. In this talk, we will present dedicated studies of efficiencies, momentum assignment, resolution, scale, and showering of very high momentum muons produced at the LHC.

Keywords:

muon, high momentum

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D1.04

Identification of a pair of di-lepton with boosted signature in the CMS experiment

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Abstract:

A heavy resonance such as hypothetical Z' boson may decay into a pair of di-lepton system indirectly if the direct coupling between the boson and leptons is not allowed. In such a case, the di-lepton system can be highly boosted, which makes proper detection of the lepton pair difficult. Efforts to identify boosted lepton pairs, mainly electrons, using Monte-Carlo samples of the CMS experiment are introduced.

Keywords:

Z', CMS, Identification, LHC, Lepton

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D1.05

Background estimation for Dark Higgs searches with Coffea framework

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Abstract:

The conventional Dark Matter (DM) searches at the LHC based on the missing transverse energy (MET) results as the recoil of the DM particles against the Standard Model (SM) particles from initial state radiation. If the SM state consists of one or more jets in association with the MET, it refers to the “monojet”. The constraints of parameter space in a monojet-based DM search at the LHC can be relaxed by opening up a new annihilation channel with a dark Higgs boson. The presence of the dark Higgs boson is motivated simultaneously by the need to generate the masses of the particles in the dark sector. If the dark Higgs boson decays into SM states via a small mixing with the SM Higgs boson, one would observe large-radius boosted jets containing a pair of b quarks in association with the MET. Background estimation of the dark Higgs searches will be reported based on the new analysis framework using columnar objects.

Keywords:

CMS, Dark Higgs, Coffea framework

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D1.06

MET Resolution Study of the Level-1 MET Trigger for CMS Phase-2 Upgrade

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Abstract:

The High-Luminosity LHC (HL-LHC) will give us a new window on the nature of the universe, providing high precision measurements of the Standard Model and maximizing search potential for new physics. Though the upgrade of the LHC for the HL-LHC enables information-rich datasets for such precision measurement and searches, it also entails a severe pileup environment of upto 200 proton-proton interactions per bunch crossing. To collect datasets efficiently in such a harsh environment is one of the challenges for the CMS Phase-2 upgrade. The CMS trigger system presently comprises two levels, which are the Level-1 (L1) trigger and High-level trigger (HLT) based on hardware and software respectively. The L1 correlator trigger (L1 CT) is a new trigger system for the L1 trigger proposed for CMS Phase-2 upgrade. The traditional L1 trigger is vulnerable to large pileup effects since it reconstructs jet and missing transverse energy (MET) using exclusively by calorimeters only. To resolve this problem, the best performing reconstruction and pileup mitigation technique, named particle-flow (PF) and PileUp Per Particle Identification (PUPPI) which are currently used only in HLT and offline reconstruction, will be implemented by the L1 CT. The PF and PUPPI algorithms incorporate all information from all the detector subsystems including track trigger, endcap and barrel calorimeter triggers and the muon trigger systems so that they are able to reduce pileup effect based on the collected information. In this talk, we present the MET response and resolution studies based on the PF and PUPPI algorithms for the L1 CT.

Keywords:

HL-LHC, CMS Phase-2 Upgrade, Level-1 Trigger, Missing Transverse Energy, Pileup mitigation

2020 KPS Spring Meeting
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D1.07

MET regression with machine learning for CMS Level-1 Trigger Upgrade

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Abstract:

The LHC has prepared and approved a major upgrade of the accelerators to increase the sensitivity for new physics searches and high precision measurements, the so-called High Luminosity Large Hadron Collider (HL-LHC) period. In order to fully exploit the scientific potential of the HL-LHC, the CMS collaboration is upgrading detector and to improve the ability of the apparatus to isolate and precisely measure the products of the most interesting collisions. To deal with harsh pile-up conditions i.e., 140 – 200 proton-proton interactions per bunch crossing and extreme size of data, the trigger level plays an important role to collect interesting physics data. And as part of this, the efforts are being carried to improve the Level-1 trigger of CMS detector by using machine learning to reduce the resource usage of hardware and reduce computation time. A study based on missing transverse energy (MET) calculated from particle flow and PUPPI algorithm for the level -1 correlator trigger and compared using regressed in machine learning is presented in this talk.

Keywords:

machine learning, LHC

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D1.08

Development of MET HLS algorithm on the FPGA for CMS Phase-2 Level-1 trigger

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Abstract:

The LHC will be upgraded for the high-luminosity LHC (HL-LHC) with an increasing luminosity by a factor of 10 in order to maximize the potential for the discovery of new physics. This brings significant increasing data and needs for improvement of the CMS detector performance and trigger algorithms. The Level-1 (L1) missing transverse energy (MET) trigger algorithm based on the field programmable gate array (FPGA) is being developed for newly introduced L1 correlator trigger for the HL-LHC. This talk will present the optimization of the MET algorithm for latency and resource usages and present the result of testing in a machine.

Keywords:

L1 trigger, HL-LHC, MET, FPGA

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D10.01

딥러닝 및 머신러닝을 활용한 물리교육의 활용 방안

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Abstract:

최근 머신러닝과 딥러닝 등 SW기술의 급격한 발전과 Tensorflow, Pytorch, Keras 등 범용 프로그래밍 언어에서 사용가능한 공개 패키지들이 보급되면서 이에 대한 활용이 다양한 분야에서 적극적으로 이뤄지고 있다. 특히, 자연어 처리와 컴퓨터 비전, 음성 인식 등을 중심으로 활발하게 나타나고 있는데 이러한 분야에서의 활용은 물리 교수학습 영역에서도 유용하게 쓰일 수 있다. 본 발표에서는 간단한 예시와 함께 이러한 기술을 접목한 물리교육의 형태와 활용 방안에 대해 소개하고 논의하고자 한다.

Keywords:

머신러닝, 딥러닝, 파이썬, 4차 산업혁명

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D10.02

물리교육과 텍스트 네트워크 분석

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Abstract:

개인의 사고는 언어를 통해 표현되고, 표현된 언어를 통해 발화자의 사고를 분석할 수 있다. 같은 맥락에서 특정 집단에서 공유되는 독특한 사고 체계는 집단 내에서 통용되는 언어에 반영되고, 특정 집단에서 사용하는 언어를 분석하면 집단에서 통용되는 사고 체계를 복원할 수 있게 된다. 이에 본 고에서는 물리학자 및 물리교육자들 사이에서 공유되는 지식의 체계가 물리 교과서를 통해 표현된다는 것을 이론적 바탕으로 하고, 물리 교과서 분석을 통해 이를 정량적이고 가시적으로 복원하는 연구 방법을 소개한다.
인간의 지식 체계는 수많은 단어들의 조합으로 구성된다 (Miller, 1996). 이에 물리학의 지식 체계 역시 많은 단어들의 복잡한 연결 관계를 통해 구성된다고 할 수 있다. 따라서 물리 교과서 텍스트에서 단어들의 연결 관계를 복원해 낸다면, 이는 물리 분야의 전문가들이 동의하고 공유하는 지식 체계를 표상하게 된다. Yun & Park (2018)에서는 이를 scientific semantic network라 부른 바 있다. 텍스트를 구성하고 있는 단어들의 연결 관계를 추출하는 방법으로 텍스트 네트워크 분석을 꼽을 수 있다. 텍스트 네트워크 분석 방법은 복잡계 이론을 언어에 적용하여 단어 사이의 관계를 살펴보는 방법으로서(Shin et al., 2010) 단어들 사이의 관계 및 네트워크를 시각적으로 들여다볼 수 있다는 점, 텍스트 내에서 개별 단어들의 영향력 혹은 중요성을 정량적으로 살펴볼 수 있다는 점 등을 특징으로 꼽을 수 있다. 본 고에서는 텍스트 네트워크 분석 방법을 이용하여 물리 교과서로 부터 scientific semantic network를 추출하는 방법을 소개하고, 고등학교 물리 교과서와 대학 물리 교과서의 비교, 물리 교과서 텍스트와 물리 교사 발화와의 비교, 국가간 물리 교과서 비교 등의 연구 사례를 소개한다.

Keywords:

텍스트 네트워크 분석, scientific semantic network, 교과서 분석

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D10.03

2020 발명교육 현황과 물리교육에의 시사점

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Abstract:

1980년대부터 시작된 발명교육은 2017년 제정된 "발명교육의 활성화 및 지원에 관한 법률"(발명교육법)에 힘입어 미래 시민 개개인의 창의력 증진을 위한 교육 혁신을 제공하기 위해 수행되어 왔다. 지난 40년간 정부주도의 top-down 방식 위주로 지원된 발명교육 지원사업은 교과교육(과학교육)에서 관심 증대와 일선 학교 등 민간에서 인식이 개선되어야 할 시대적 필요성을 갖고 있다. 2020년 교육부의 "창업체험교육백서"에서는 발명교육의 성과를 진로/창업교육의 기반으로 포함시켜 그 가치를 인정하고 있으며, 국내외 성공한 과학기술기반 발명가 CEO들의 성공사례가 축적되며 과학교육의 실천 활동으로 발명의 역할이 부각되고 있다. 본 발표에서는 특허청과 한국발명진흥회에서 주도적으로 수행하고 있는 일반학생교육, 직업교육, 영재교육, 교원교육의 대상별 발명교육지원 내용을 요약하며 각각의 성공사례를 탐색하였다. 마지막으로 강점-약점-기회-위협(SWOT) 분석을 통해 과학-발명교육 발전을 위한 시사점을 제시하였다.

Keywords:

발명교육, 진로/창업교육

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D13.01

Probing the superfluid order parameters via dc Josephson supercurrents

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Abstract:

The dc Josephson effect provides a formidable tool for investigating superfluid order parameters. We exploit controlled Josephson currents to probe condensation in strongly correlated fermionic superfluids of ultracold atoms, weakly coupled through a tunable tunneling barrier. We map out the current-chemical potential characteristics along the BCS (Bardeen Cooper Schrieffer)-BEC (Bose Einstein condensate) crossover by imparting a controlled current, thereby extracting the Josephson critical current. We find good quantitative agreement between the observed critical current behaviour and an analytic model throughout the crossover region, enabling an explicit connection to the pair condensate density (rather than the superfluid density) in strongly interacting Fermi gases. This work demonstrates the effectiveness of coherent Josephson transport for pinning down the condensate fraction of the strongly interacting superfluid.

Keywords:

condensate, Josephson current, superfluid, order parameter, strongly interacting, strongly correlated

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D13.02

Progress in investigating a universality in vortex shedding dynamics in a superfluid

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Abstract:

An intriguing feature in a classical fluid is a universal behavior in their fluid dynamics, which is characterized by the Reynolds and Strouhal number (St-Re relation). A superfluid, which has no viscosity, is expected to show similar universality in vortex shedding dynamics [1]. In previous work, the regular vortex cluster shedding in a superfluid was reported [2]. Although a clear transition to turbulence was observed, it was insufficient to verify a universal behavior due to lack of cluster shedding events. For multiple events of cluster shedding, a long stirring distance and homogeneous density is definitely beneficial.
In this talk, I present our progress in studying a universal characteristic of vortex shedding dynamics in an elongated ^{87}Rb Bose-Einstein condensate (BEC). To obtain a long stirring distance, we use a clipped Gaussian optical dipole trap (ODT) [3]. By truncating a 1070nm ODT beam, the BEC length along the beam direction is significantly increased. The vortex cluster shedding and turbulence are observed by moving an optical obstacle. For various obstacle size and its potential height, we measure the superfluid Reynolds number and investigate its universal behavior with the Strouhal number.

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Keywords:

Bose-Einstein condensate, 87Rb, vortex shedding dynamics, universality

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D13.03

Emission of entangled matter-wave jet from spinor Bose-Einstein condensates

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Abstract:

In this talk, we present the observation of entangled matter-wave jets from spin-1 spinor Bose-Einstein condensates, resembling recent ‘bose fireworks' experiment [1]. Similar to the Chicago group’s experiment [2,3], the underlying mechanism of the jet emission is the dynamic instability of our initial spin state [4], where the condensate in spin-0 state emits matter-wave jets consist of (+1, -1) and vice versa. The quadratic Zeeman energy was transformed into the kinetic energy, and the angular spin correlation shows a peak at 180 degree because of momentum conservation. These results suggest that the created pairs could be a macroscopic Einstein-Podolsky-Rosen (EPR) pairs [5], and we confirm the presence of entanglement by interfering with the two spin states. Remarkably, these jets are spatially resolvable, improving the addressability of entangled state so that we might be able to show non-locality with moving objects of massive particles.

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Keywords:

Bose-Einstein condensate, Entaglement, Matter-wave jet, Dynamic instability, Spinor condensate

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D13.04

Crossover of early quench dynamics from weak to strong quench in a spinor Bose-Einstein condensate.

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Abstract:

We report our observation that early-time quench dynamics of a quasi-two-dimensional spin-1 antiferromagnetic Bose-Einstein condensate shows a crossover behavior depending on quench strength. We quench a condensate in the easy-plane phase to the easy-axis phase by changing quadratic Zeeman energy q, which determines initial excitation energy per particle. We characterize quench strength as $\tilde{q} = q/(c_2 n)$, where $c_2 n$ is the characteristic spin excitation energy. For a weak quench where $\tilde{q} < 1$, long wavelength spin excitation occurs and leads to irregular spin domains. As $\tilde{q}$ increases, the initial spin excitations show shorter length scales leading to speckle patterns and for $\tilde{q} > 2$, long-wavelength instability is highly suppressed. The observed crossover from weak to strong quench is accounted for by Bogoliubov description of dynamic instability of the initial condensate.

Keywords:

Quench, Bose-Einstein condensate

Progress towards development of a quantum simulator based on ultracold Yb atoms at KRISS

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Abstract:

We report a novel approach to ^{174}Yb atom transport using a compact optically compensated zoom(OCZ)-lens. The laser cooled atoms in a magneto-optical trap are loaded into an optical dipole trap(ODT) via focused laser beam at 532 nm through an OCZ lens which keeps the numerical aperture value constant while zooming. By controlling the zoom position within 3 cm, i.e., interspacing distance between the lens groups of the OCZ lens, the atoms loaded into the ODT are transported over a distance of 60 cm to a custom designed science chamber(SC) with better optical accessibility for a quantum gas microscope. The experiments show that 2.1x10^6 number of atoms are successfully transported in the SC.

Keywords:

Quantum simulator, Quantum gas microscope, Yb quantum gas

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D13.06

Review on recent development in quantum walk and search in Markov chains

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Abstract:

Quatum walk and search in Markov chains has been developed for 20 years. In 2016, Krovi et al suggested replacement of an original Markov chain by a linear combination of the original Markov chain and its modification in which marked vertices are changed to absorbing ones. In March 2019, Ambainis et al announced a conjecture that the quantum walk based on Krovi et al's suggestion can find arbitrary number of marked vertices within time of square root of classical hitting time for any reversible Markov chains. And then, in December 2019, Apers et al. asserted they proved the conjecture by using the quantum fast forwarding technique that was developed by themselves in 2018. We review their proof and analyze numerical examples to grasp underlying physical mechanism.

Keywords:

quantum walk, quantum search, Markov chain, quantum fast forwarding

D14.01

NaF layer insertion for improving efficiency of flexible solar cells in kesterite $Cu_2ZnSn(S,Se)_4$ solar cells

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Abstract:

$Cu_2ZnSn(S,Se)_4$ (CZTSSe) has suitable optical and electrical properties for low-cost and high-efficient thin-film solar cells. Unfortunately, the photo-conversion efficiency of kesterites solar cells is still 12.6% with hydrazine process and recently vacuum process. For making flexible CZTSSe solar cells, it is indispensable to add NaF layers during the growth or after the deposition, since the open circuit voltage (V_{OC}) is one of the significant issues in kesterite solar cells. Na incorporation in kesterites has been reported to surpass the formation of secondary phases and passivate deep-level defects. To optimize the Na-doing, NaF layer was deposited as one of the precursor stacks, during the sputtering. The highest efficiency of the flexible CZTSSe solar cells on Mo with NaF layers is 11.4% so far. Depending on the growth conditions, grain boundary (GB) properties can be changed because Na segregation and defect formation can affect the surface electrical properties and carrier behavior. By Kelvin probe force microscopy, we were able to measure the local variation of surface potential barrier at the vicinity of the GBs. Also, using photo-assisted conductive atomic force microscopy, we can image the photo-current maps, inducing the recombination position at local-scale. We figured out that Na plays a role for passivation of Cu-Zn related defects and enhance efficiency substantially via photoluminescence spectroscopy. The results can help enhancing the efficiency of kesterites on flexible substrates better than kesterites on rigid glasses.

Keywords:

Flexible CZTSSe thin-film solar cells, NaF layer insertion, Kelvin probe force microscopy, Micro-Raman spectroscopy, Defect passivation

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D14.02

에너지 저장소자를 위한 금속 황화물 나노 입자의 합성 및 특성 분석

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Abstract:

최근, 증가하는 에너지 수요를 충족시키기 위해 친환경적이고 재생 가능한 대체 에너지 자원의 개발에 대한 광범위한 연구가 진행되고 있다. 의사커패시터는 산화 환원 반응을 수행함으로써 전하를 극적으로 저장한다. MnO_4, RuO_4 및 전도성 중합체는 의사커패시터를 위한 가장 일반적으로 사용되는 재료이다. 의사커패시터형 재료와 비교하여, 최근 배터리형 재료는 높은 전기 전도성, 개선된 산화 환원 화학 및 저렴한 비용으로 인해 전극 재료로서 큰 관심을 끌고 있다. 배터리형의 재료 중에서, 금속 황화물은 우수한 전기 전도성, 높은 비정전 용량 및 풍부한 전기 화학 사이트로 인해 큰 주목을 받고 있다. 활물질 이외에도 형태는 슈퍼커패시터의 에너지 저장 특성에 중요한 역할을 한다. 저온 조건에서 용이한 습식화학법을 사용하여 황화니켈 활성물질을 합성하였다. 제작된 물질은 나노 입자로 형성되었다. 독특한 형태를 갖는 제작된 재료는 우수한 전기 화학적 성능을 보여주었다. 따라서, 비용 효과적인 방법을 사용하여 제작된 나노 스케일 범위에서 유리한 형태를 개발하는 것은 고성능 슈퍼커패시터의 개발에 새로운 방향을 제시할 수 있다.

Keywords:

슈퍼커패시터, 황화니켈, 습식화학법, 전기화학적특성

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D14.03

리튬이온 배터리의 양극 재료로서 $CeVO_4$/탄소나노튜브 하이브리드 나노 구조의 합성

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Abstract:

흑연은 리튬이온 배터리용으로 가장 상업적으로 사용되는 양극 재료이며, 리튬 삽입 전위가 낮기 때문에 리튬 dendrite 형성 문제가 있다. 안전 문제를 위해, dendrite 형성없이 양극 재료를 구성해야 한다. 리튬 dendrite 형성을 피하기 위해서는 Li/Li^+에 대해 ~ 1 V의 충전/방전 전위를 갖는 이상적인 새로운 부류의 양극 재료가 필요하다. 여기서, 새로운 $CeVO_4$ 및 $CeVO_4$/CNT는 oil-bath법을 사용하여 성공적으로 제조되었다. 제작된 샘플의 상 순도는 X-선 회절법을 사용하여 확인하였다. $CeVO_4$/CNT 물질의 화학적 조성 및 화학적 상태는 X선 광전자 분광법에 의해 분석되었다. 제작된 $CeVO_4$ 및 $CeVO_4$/CNT를 리튬이온 배터리의 양극 물질로서 추가로 시험하였다. $CeVO_4$ 및 $CeVO_4$/CNT 전극은 우수한 방전 용량을 제공하였다. 이러한 결과는 특정 $CeVO_4$/CNT 하이브리드 구조가 향상된 가역 용량 및 속도 성능을 나타낸다는 것을 시사한다.

Keywords:

리튬이온 배터리, Oil bath법, 전기화학적특성

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D14.04

졸겔 방법으로 제작한 IGZO TFTs에 PMMA코팅이 소자특성에 미치는 영향

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Abstract:

Induim Galium Zinc oxide(IGZO)는 Amorphous Silicon (a-Si) 보다 높은 전자이동도 특성을 가지며 Low Temperature Polysilicon (LTPS)보다는 낮은 off 전류로 차세대 thin-film transistors(TFTs) 채널 물질로 각광받고 있는 대표적인 물질이다. 하지만 소자 신뢰성이 취약하여 이를 해결하기 위하여 passivation layer를 이용한 방법이 많이 연구되었다. 본 발표에서는 그동안 passivation 물질로써 많이 사용된 Polymethyl Methacrylate (PMMA)을 이용한 IGZO TFT의 전기적 특성 영향에 대하여 연구하였다. 이를 위하여 우선 Sol-gel 방법으로 Si/SiO2 기판위에 IGZO TFT를 제작 하였으며 초기 TFT 특성에서 PMMA 코팅에 역할에 대하여 분석하였다. 또한 공기 중 오랜 시간 노출된 소자에 대한 PMMA 효과를 분석하였다. 이러한 연구를 위하여 공정적으로는 PMMA를 이용해 채널 에칭과 passivation을 통합하여 공정을 단순화 하였으며 채널 두께, 길이, 전극 종류에 따른 PMMA 영향 변화에 대해 연구하였다.

Keywords:

IGZO, Thin film transistor, Passivation, PMMA,, etching

2020 KPS Spring Meeting
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D14.05

Growth and drug reaction monitoring of NIH 3T3 cells using impedance biosensor

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Abstract:

Impedance biosensor is manufactured on slide glass using semiconductor process to monitor cell growth and cell-drug reactions. Impedance pattern deposited by using 80 nm thick Platinum for the biocompatibility using sputtering system. After the formation of Pt electrode, PDMS well is attached for cell culture. After sterilization and coating inside of the well with Poly-L-Lysine, NIH 3T3 cells (~10K cells/well) are added in the well and cultured during about 43 hours. Impedance signals are continuously monitored for each 10 minutes during 43 hours with the variations of frequency from 500 Hz to 150 kHz. The capacitance values show gradual increase with the increase of NIH 3T3 cells numbers. After 43 hours growth, 10 μg/ml puromycin (Gibco, A11138-03) is injected for the monitoring of cell-drug reaction. After the injection of puromycin, the capacitance is almost fixed during about 10 hours then rapidly decrease within about 9~10 hours. In this study, we could monitor the state of cells and the cell-drug reactions using the developed impedance biosensor chip by using Electrical Cell-substrate Impedance(ECIS) technique. The developed impedance biosensor could be applied in wide bio-medical area, for example, non-destructive real time cell growth/cell-drug reaction monitoring.

Keywords:

Biosensor, Impedance, Real-time monitoring, Cell growth, Cell-drug reaction

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D14.06

Highly asymmetric optical properties of β-Ga_2O_3 as probed by linear and nonlinear optical excitation spectroscopy

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Abstract:

: β-Ga_2O_3 is a highly promising semiconductor for a deep ultraviolet emitter owing to its wide bandgap, which significantly varies in the range of 4.49 eV to 4.74 eV due to its optical trirefringence in the monoclinic crystal structure (C_{2h}). However, dominant photoluminescence (PL) emissions in this semiconductor occur far below the bandgap, where the underlying PL mechanism has been under intense debate; namely, intrinsic polaron effects vs. extrinsic defect effects. In this presentation, we demonstrate that the below-the-gap PL arises basically from excitons bound to Ga vacancy (V_{Ga}) and O vacancy (V_O), based on the series of optical experiments performed at room temperature. Firstly, we show that the PL of β-Ga_2O_3 is highly polarized along the (102) direction regardless of input polarization and essentially the same for one-photon absorption (1PA), two-photon absorption (2PA), and three-photon absorption (3PA). However, absorption polarization dependence is quite distinct for 1PA, 2PA, and 3PA, which is consistent with theoretical selection rules for C_{2h} symmetry. Secondly, we show that excitation power dependence across the 1PA-2PA-3PA range also indicates the case for the defect-induced transition. Lastly[S1] , we show that the 2PA depth scan also support the extrinsic PL model. A broad set of highly asymmetric optical properties clarified in our work is critical for the understanding of this wide-bandgap semiconductor and its potential use for ultraviolet sources especially when band-edge emission is realized.

Keywords:

Ga2O3, Oxide, Semiconductor, nonlinear optics.

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.01

General relativistic three dimensional simulations of the accretion disks onto black holes

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Abstract:

Accretion disks around black holes are very energetic and interesting process in astrophysics. Observationally, they can produce x-ray emission and astrophysical jets. However, they are not fully understood still. In this talk we are going to introduce recent results of the accretion disk around either non-rotating (Schwarzschild) and rotating (Kerr) black hole. In this work, we carry out general relativistic three dimensional numerical hydrydynamic simulation using KISTI 5th generation supercomputer.

Keywords:

General relativity, Numerical, Hydrodynamics, black holes, accretion disks

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.02

Scattering Angles for Encountering Two Black Holes

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Abstract:

Recently, a Hamiltonian describing two massive spinless particles has been obtained at the 3rd Post-Minkowskian (3PM) order in the context of effective field theory. By performing numerical simulations for two black holes, we have studied the validity of this Hamiltonian. Comparisons for scattering angles show that the 3PM results agree well with those in numerical relativity within 0.38% when the range of pericenter distances is r_min = (72.78~15.09)M. As two black holes encounter more strongly in gravitational interaction, e.g., r_min ~ 6.88M, the agreement becomes less acurate, i.e., ~4.51%. We have also considered several Effective One-Body (EOB) Hamiltonians which may improve the accuracy in close encounters. Finally, implications are discussed to the search for EOB Hamiltonians describing two black holes with arbitrary eccentricities.

Keywords:

Scattering angle, Numerical relativitty, EOB Hamiltonian

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.03

Weak Lensing Mass Map Reconstruction of Merging Clusters with Convolutional Neural Network

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Abstract:

We introduce a novel method for reconstructing the projected dark matter mass maps of merging galaxy clusters by applying the convolutional neural network (CNN) to their weak lensing maps. We generate synthesized grayscale images from given weak lensing maps that preserve their averaged galaxy ellipticity. We then apply them to multi-layered CNN with architectures of alternating convolution and trans-convolution filters to predict the mass maps. We train our architecture with 1,000 mock Subaru/Suprime-Cam weak lensing maps, and our method has better mass map prediction than the Kaiser & Squires (1993) method with the following three aspects: (1) better pixel-to-pixel correlation, (2) more accurate finding of density peak position, and (3) free from mass-sheet degeneracy. We also apply our method to actual observations of some known merging clusters and compare their results to the previous studies.

Keywords:

Weak Lensing, Galaxy Cluster, Deep Learning

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.04

Implication of Perturbative Unitarity to Quasi-Single Field Inflation

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Abstract:

Unitarity of the scattering amplitudes gives a upper bound to their behaviors at UV scale, known as the unitarity bound. In this talk, we discuss implications of the unitarity bounds to inflation. While quasi-single field inflation model has been in the limelight as the model which can generate large non-Gaussianities, we show that there exist the cut-off scale if the model parameters belong to the region which can generate large non-Gaussianities.

Keywords:

Unitarity bound, non-Gaussianity, Inflation, Quasi-single field inflation

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.05

Application of geometrothermodynamics to some systems with strong interactions described by the method of holographic dualities

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Abstract:

The geometric properties of the equilibrium manifolds of two thermodynamic systems with strong interactions predicted by the holographic dualities method [1,2] have been studied in this work. Geometrothermodynamics [3,4] was used as the formalism of the study, which allows to obtain results invariant with respect to the Legendre transformations, i.e. independent of the choice of thermodynamic potentials.
In this approach, we considered a new type of quantum liquid with a zero-sound mode at low temperatures in its spectrum and with an exotic temperature dependence of the specific heat [1]. For this liquid, entropy was taken as the thermodynamic potential, depending on the temperature and the baryon density.
Also the thermodynamic systems with a finite baryon density at zero temperature [2] have been considered. For these systems the thermodynamic potentials Ω and Helmholtz free energy F that depend on the chemical potential μ and particle mass m were taken as thermodynamic potentials.
For the systems under consideration, the results of numerical calculations of the corresponding metrics, the metric tensors determinants and scalar curvatures are presented in the form of 3-dimensional graphs. The graphs presented clearly show at what values of thermodynamic variables the scalar curvatures tend to infinity or to zero, which indicates possible phase transitions and possible compensation of interactions by quantum effects, respectively.
The second-order phase transition, defined in [2] at m = μ, have been reproduced by us in the geometrothermodynamic approach.

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3. H. Quevedo (2007) Geometrothermodynamics, J. Math. Phys. 48, 013506, DOI: https://doi.org/10.1063/1.2409524.

4. H. Quevedo, A. Sanchez, S. Taj, A. Vazquez, (2011) Phase transitions in Geometrothermodynamics, Gen. Rel. Grav. 43: 1153. arXiv:1010.5599

Keywords:

geometrothermodynamics, holographic duality, strong interaction

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.06

Quasinormal Modes of Scalar Field in Higher-Dimensional de Sitter Black Holes

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Abstract:

We analytically investigate the quasinormal modes of the scalar field with a nonminimal coupling in the higher-dimensional de Sitter black hole with a single rotation. Under near-extremal conditions, where the outer horizon closes to the cosmological horizon, the quasinormal frequencies are obtained and generalized to universal form in the higher-dimensional spacetime. Here, the real part of the frequency includes the scalar field contents, and its imaginary part only depends on the surface gravity at the outer horizon of the black hole.

Keywords:

Black Holes, Quasinormal Modes

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.07

Deflection of light rays and shadow cast by a rotating black hole

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Abstract:

The black hole has recently attracted the most attention among astrophysical objects in the Universe, thanks to the recent observational reports on the shadow of the black hole by the Event Horizon Telescope. Consequently, the studies on both the physical origin and the mechanism for describing the observed image have also attracted attention. The recent detection of the gravitational waves due to the collision between a pair of black holes has open also the new horizon to the studies of a variety of astrophysical phenomena including the gravitational theory itself. We study deflection of light rays and shadow cast by a rotating black hole to describe the observed phenomena.

Keywords:

deflection of light rays, shadow cast, rotating black hole

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D15.08

Extension of 1+3 formalism and its application to numerical relativity

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Abstract:

In numerical simulations of spacetime, choosing quantities describing spacetime and their governed equation is an important problem. The 1+3 formalism gives a natural method for this problem when a timelike congruence is given in the spacetime. The main difficulty of the 1+3 formalism comes from the diversity of derivatives including Lie, exterior, covariant, and partial derivatives. By introducing linear connections and utilizing their degree of freedom, we can deal with all derivatives collectively. In this presentation, we revisit the 1+3 formalism using linear connections. We also extend the 1+3 formalism using the degree of freedom of linear connections. We discuss the application of this formalism to the numerical relativity.

Keywords:

1+3 formalism, general relativity, numerical relativity

D3.01

Prediction of neutron drip line location in the deformed relativistic Hartree-Bogoliubov theory with continuum

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Abstract:

The location of the neutron drip line has long been of interest. For the description of nuclei close to the drip line, it is important to include the continuum, pairing correlations and deformation effects. Using the DRHBc theory (deformed relativistic Hartree-Bogoliubov theory in continuum) with the relativistic density functional PC-PK1, we investigated whether and how deformation influences the prediction for the neutron drip line location for even-even nuclei with $8 \leq Z \leq 20$. The results are compared with those based on the spherical relativistic continuum Hartree-Bogoliubov (RCHB) theory. The changes of drip lines in nuclei from oxygen to calcium are investigated in detail through the analysis of two neutron separation energies and neutron Fermi energy. Especially, the Ne and Ar drip nuclei are changed after including the deformation effects. We will present our results and introduce the nuclear mass table project with the DRHBc theory.

Keywords:

neutron drip line, DRHBc theory, two neutron separation energy, neutron Fermi energy

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2020-07-13 - 2020-07-15

D3.02

Non-zero transverse single spin asymmetry of very forward pi0 in polarzied p + p collisions at sqrt(s) = 510 GeV

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Abstract:

A possibility of the non-perturbative contribution for the non-zero transverse single spin asymmetry of forward pi0 (2 < eta < 4) has been brought up recently by an event condition dependence study. Bigger asymmetry was observed with more isolated final state which was connected with the non-perturbative event topology. Since the non-perturbative contribution has been studied by only forward pi0 production where the perturbative process was expected to be the major interaction rather than non-perturbative one, the RHICf experiment measured the very forward (eta > 6) pi0 in June 2017 to study the non-perturbative contribution in more detail. A clear non-zero asymmetry was observed even in low pT < 1 GeV/c showing a similar xF dependence with the forward pi0 one as the pT increased from 0 to 1 GeV/c. We present the first measurement of the very forward pi0 asymmetry, Its analysis procedure and final result. A future aspect to more precisely study the non-perturbative contribution will be also introduced.

Keywords:

RHICf, spin, non-perturbative interaction, very forward

D3.03

Microscopic sd-shell effective interaction obtained from NCSM

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Abstract:

We investigate new microscopic effective interaction for the *sd*-shell obtained from the NCSM (no-core shell model) wave-functions using modern nucleon-nucleon potential, Daejeon16. Its monopole property is compared with that of the phenomenological USDB, and theoretical binding energies of oxygen isotopes are presented to show the validness of this effective interaction.

Keywords:

no-core shell model, Daejeon16

D3.04

Quantum Many-Body Calculations using Body-Centered Cubic Lattices

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Abstract:

Lattice simulations have been used to study a variety of different quantum many-body systems in continuous space, including atomic nuclei, nuclear matter, neutron matter, ultracold atoms, and electronic structure. For reasons of simplicity and familiarity, nearly all simulations have been performed on cubic lattices. Since the removal of lattice artifacts is often an important concern, it would be useful to perform calculations using more than one lattice geometry. In this work we show how to perform quantum many-body calculations using auxiliary-field Monte Carlo on a three-dimensional body-centered cubic (BCC) lattice. As a benchmark test we compute the ground state energy of 33 spin-up and 33 spin-down fermions in the unitary limit, which is an idealized limit where the interaction range is zero and scattering length is infinite. As a fraction of the free Fermi gas energy E_{FG}, we find that the ground state energy is $E_0/E_{FG}= 0.368(3), 0.370(3),$ using two different definitions of the finite-system energy ratio. This is in excellent agreement with recent results obtained on a cubic lattice ₩cite{He:2019ipt}. We find that the computational effort and performance on a BCC lattice is approximately the same as that for a cubic lattice with the same number of lattice points. We discuss how the combination of cubic and BCC lattice simulations can be used as a tool for determining the size of lattice artifacts in simulations of continuum quantum many-body systems.

Keywords:

Lattice, Effective Field Theory, Nuclear Structure, Unitary limit

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D3.05

MoO_3 powder measurements with an array of HPGe detectors

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Abstract:

The AMoRE searches for neutrinoless double beta (0νββ) decay of ^{100}Mo using enriched molybdate crystals. AMoRE is preparing for the next stage experimental setup (AMoRE-II) that will be operating with ~ 200 kg of molybdate crystals. AMoRE-II needs ultra-pure crystals with extremely low levels of radioactive contamination in order to achieve the "zero-background" in the region of interest (ROI) around the 0νββ decay energy of ^{100}Mo. In order to make the ultra-pure crystals, the raw materials (enriched ^{100}Mo powder) should be very much low in radioactive contamination. We have an array of fourteen high purity germanium (HPGe) detectors with 70% of relative efficiency each, named the CUP Array of Germanium (CAGe). The CAGe is located in the Yangyang underground laboratory that is ~ 700 m deep underground. The latest background level of the CAGe is ~ 0.07 Hz in the energy range between 40 keV to 4000 keV, and we could measure a sample activities as low as hundreds of uBq/kg. ^{100}Mo can have double-beta-decay (ννββ, DBD) to several excited states of ^{100}Ru. When ^{100}Mo decays to the 2nd excited state of ^{100}Ru, it de-excites to the ground state emitting both 540 keV and 591 keV gammas. When the decay is to the 1st excited state, it emits only 591 keV. By measuring those gammas, we can estimate DBD half-life of ^{100}Mo to each of excited states of ^{100}Ru. Two enriched $^{100}MoO_3$ powder samples were measured together with their background data using the CAGe. We confirmed several contaminant radioisotopes, such as ^{226}Ra,^{228}Th, ^{40}K and ^{88}Y, that can make background signals in the ROI for AMoRE-II. We also measured the DBD of ^{100}Mo to the excited states of ^{100}Ru. We will present results on contaminant activities and DBD half-life of ^{100}Mo in the two enriched ^{100}Mo powder samples.

Keywords:

radioactive contamination, high purity germanium detector, Mo-100 decay, enriched Mo-100 powder

D3.06

Pathways of the emitted free nucleons from heavy-ion collision in the intermediate energy

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Abstract:

The momentum and energy distributions of free nucleons from heavy-ion collision have information of the nuclear matter near the collision center and these are the fundamental observables for the nuclear symmetry energy study. In the quantum molecular dynamics (QMD) model, the main sources of the momentum are the nuclear force from the compressed nuclear matter and the nucleon-nucleon collision in the medium. We track the pathways of emitted free nucleons from heavy-ion collision in the intermediate energy using our QMD code and investigate the volume of the compressed nuclear matter. And then, we estimate the magnitude of momentum change by the nuclear matter on the pathway with different symmetry energy slopes. We discuss the effect of the compressed nuclear matter to the emitted nucleons and the possible observable for the symmetry energy study.

Keywords:

QMD, heavy-ion collision, nuclear matter

D4.01

Pressure-Induced Mott Insulator-Metal Transions in Layered Chalcogenides

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Abstract:

Layered transition metal trichalcogenides, MP{S,Se}$_3$ (M=Mn,Fe,Co,Ni), has been actively studied recently because of possible two-dimensional magnetism and potential applications for resistivity switching devices. Compared to layered oxide compounds, stronger hybridization between transition metal *d*-orbital and chalcogen *p*-orbitals in these layered chalcogenides can yield bigger response of electronic and magnetic properties with respect to external stimuli such as pressure. Here we present our recent computational study of MP{S,Se}$_3$ with M = Mn and Ni under external pressure, employing ab-initio dynamical mean-field theory (DMFT) combined with density functional theory (DFT). It is shown that {Mn,Ni}P{S,Se}$_3$ do show steeper gap closure rate, ~ 50 meV / GPa, compared to conventional correlated oxides. Nature of pressure-driven insulator-metal transitions, which depends on the orbital occupations and structural distortions, is discussed in combinations with experimental observations.

Keywords:

layered chalcogenides, Mott transition, pressure, density functional theory, dynamical mean-field theory

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2020-07-13 - 2020-07-15

D4.02

Identification of a Kitaev Quantum Spin Liquid by Magnetic Field Angle Dependence

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Abstract:

We investigate the characteristic behavior of Kitaev quantum spin liquid under the external magnetic field by using exact diagonalization and thermal pure quantum states formalism. We employ a spin model including Heisenberg and off-diagonal symmetric terms on a honeycomb lattice in addition to the original Kitaev model. Various measurable quantities, such as magnetization and specific heat, are computed as well as low lying energy spectrum. We find extremely sensitive angle-dependence induced by off-diagonal symmetric terms, indicating that the realistic Kitaev systems are considerably distinct from pure Kitaev limit. We further discuss potential implications on the identification of the Kitaev spin liquid based on the calculations.

Keywords:

Kitaev spin liquid

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D4.03

Numerical approach to calculate multipolar interactions in Mott insulators

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Abstract:

Magnetism of the Mott insulators is attributed to the kinetic energy gain of virtual hopping process. In single-band systems, it leads to the antiferromagnetic Heisenberg-type interaction whose strength is proportional to t^2/U where t and U are hopping strength and on-site Coulomb repulsion, respectively. In case of multiorbital systems like d- and f-electron systems, however, it can show more complex behaviors because a few physical parameters like spin-orbit coupling (SOC), Hund's coupling, and lattice distortion are competing each other. They exhibits magnetic interactions beyond the Heisenberg-type interaction like the Dzyaloshinskii-Moriya interaction and pseudodipolar interaction, and so on. Moreover, some systems show the multipolar interactions between spin-orbital entangled states.
In this talk, we introduce numerical way to calculate general superexchange interaction of Mott insulators considering the multiband Hubbard model of two-site cluster. As an example, we derive the magnetic multipolar interactions of double-perovskite Ba_2NaOsO_6.

Keywords:

General superexchange interaction, Multipolar interaction, Ba2NaOsO6

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D4.04

Effect of correlation on nearly flat bands in twisted bilayer graphene

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Abstract:

Recently, correlated insulating phases were observed experimentally in twisted bilayer graphene (TBG) at different doping concentrations. To study possible mechanisms for insulating phases, we investigate electronic and magnetic properties in TBG by performing dynamical mean-field theory calculations based on a minimal tight-binding Hamiltonian. We study variation in the spectral function of the nearly flat bands for a range of local interaction parameters, electron filling, and temperature. We compare our results with experimental reports and discuss the possibility of Mott insulating phase in this system. This work was supported by NRF of Korea (Grant No. 2011-0018306), KISTI supercomputing center (Project No. KSC-2018-CRE-0097), and the Graduate School of Yonsei University Research Scholarship Grants in 2018.

Keywords:

DMFT, Correlation, TBG, Twisted bilayer graphene, Dynamical mean field theory

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D4.06

Ginzberg-Landau-Wilson theory for Kondo lattice from holographic principle

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Abstract:

We consider a holographic theory as a Ginzberg-Landau theory working for strongly interacting system near the quantum critical point: we take the bulk matter field ΦI (r, x) as the order parameter describing the fluctuation of the system from the quantum critical point. The most important order parameters would be the dual of the fermion bilinear, which is responsible for the gaps and transports. We classify the fermion spectral function (SF) in the presence of such orders. Depending on the symmetry class of the order, we found features appearing in strongly interacting system like the pseudo-gap, the flat band. But we also find the spectral feature of topological insulators like the Fermi-arc and the surface modes in the form of ribbon structure in band.

Keywords:

2020 KPS Spring Meeting
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D5.01

Evidence of Higher Order Topology in Multilayer WTe_2 from Josephson Coupling through Anisotropic Hinge States

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Abstract:

The noncentrosymmetric Td-WTe_2, previously known as a type-II Weyl semimetal, is expected to have higher order topological phases with topologically protected, helical one-dimensional (1D) hinge states when their scarcely separated Weyl points get annihilated. However, the detection of these hinge states is difficult in the presence of the semimetallic behaviour of the bulk. Here, we spatially resolved the hinge states by analysing the magnetic field interference of supercurrent in Nb-WTe_2-Nb proximity Josephson junctions. The Josephson current along the a-axis of the WTe_2 crystal, but not along the b-axis, showed sharp enhancements at the edges of the junction; the amount of enhanced Josephson current was comparable to the upper limits of a single 1D helical channel. Our experimental observations provide evidence of the higher order topological phase in WTe_2 and its corresponding anisotropic topological hinge states, in good agreement with theoretical calculations. Our work paves the way for the study of hinge states in the whole class of semimetalic and superconducting transition metal dichalcogenides.

Keywords:

WTe2, Higher order topological insulator, Josephson junction, Fraunhofer pattern

2020 KPS Spring Meeting
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D5.02

Tailoring spin orientation via manipulating electronic structure in two-dimensional magnet CrI3

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Abstract:

The recent discovery of two-dimensional (2D) magnets has not only opened a new realm of low-dimensional materials, but aroused interest in magnetism of reduced dimension and its applications. Despite the Mermin-Wagner theorem that proves the absence of long-range magnetic order in isotropic spin systems, the spin anisotropy induced by the large spin-orbit coupling allows the occurrence of the long-range ferromagnetic order in CrI_3. We investigate how the magnetic anisotropy energy can be controlled in CrI_3. In order to engineer the magnetic properties of CrI3, we utilize a wide range of approaches: electron/hole doping, metal adsorption, composition change, and heterostructure with another 2D material. In addition, we also suggest that carrier excitation via resonant laser pulse can be a versatile tool for manipulating the magnetic anisotropy of CrI3. We also discuss how the band topology is affected by its magnetic properties in the CrI3 monolayer.

Keywords:

Electronic structure, Magentic anistropy energy, Time-dependent density functional theory, two-dimensional magnet, first-principles calculation

A Viscous Graphene Electronic Diode

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Abstract:

Systems in which interparticle interactions dominate can be described by hydrodynamics. For strongly interacting electron systems like graphene, hydrodynamic corrections to conductivity have been observed, such as electron whirlpools, enhanced flow through constrictions or a Poiseuille profile. An electronic device that relies on the viscous behaviour of the electron fluid, and therefore functions as a viscometer, is lacking. We probe the nonreciprocal transport in a viscous electronic diode. Recti∟cation occurs at carrier densities and temperatures consistent with the presence of electron viscosity, and disappears in the ballistic or diffusive transport regimes. In a device with Moiré superlattice, the viscosity of secondary Dirac electrons can be observed as well. This research presents a versatile electron viscometer as a first viscous electronic device.

Keywords:

Graphene, Hydrodynamics, Diode

2020 KPS Spring Meeting
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D6.01

Multiferroicity in Bilayer Perovskites

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Abstract:

Since the giant magnetoelectric effect was found out on $TbMnO_3$ in 2003 and $TbMn_2O_5$ in 2004, there has been plenty of research to understand the physical mechanism of multiferroics, investigate novel/optimized multiferroic materials, and utilize their multifunctionality for applications. Among classes of multiferroic in material-wise, low symmetric perovskite systems, such as $BiFeO_3$, $R$$MnO_3$, $R$$FeO_3$, ($R$ = rare earth), etc., have been the most intensively studied system due to its gorgeous tunability and physical variety for multiferroicity. Recently, the first principle calculations have proposed a new class of multiferroics in the bilayer perovskites, where the geometrical constraints induce ferroelectric polarization, and the combination of two or more of non-ferroelectric structural order parameters mediate the cross-coupling in-between magnetization and electric polarization. Experimentally, the new pathway, so-called hybrid improper ferroelectrics, has been demonstrated on the bilayer perovskites $A_3B_2O_7$ of $(Ca,Sr)_3Ti_2O_7$ single crystal and $(Ca,Sr,Tb)_3(Fe,Ti)_2O_7$ in 2015. Since the pioneering experimental demonstration, there have been numerous investigations on the hybrid improper ferroelectricity. In this talk, I present the recent research progress in the multiferroic bilayer perovskites and introduces our results on the magnetic bilayer perovskites.

Keywords:

Multiferroic, Bilayer Perovskite

2020 KPS Spring Meeting
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D6.02

Harnessing the topotactic transition in oxide heterostructures for fast and high-efficiency electrochromic applications

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Abstract:

The color or opacity of wide band gap materials is determined by defects, as in gemstones such as sapphire and ruby. Searching for a material wherein the color is tunable by electric fields remains a tantalizing challenge. Mobile oxygen vacancies, which are recently attracting attention as a functional defect in complex transition metal oxides, offer a significant potential to broaden the range of optical functionalities due to their mobility and the interplay with correlated electrons. Here, we report a large electro-absorptive optical variation induced by a topotactic transition between the brownmillerite and perovskite structures via oxygen vacancy migration in calcium ferrite. Observing a pronounced change in the absorption spectra in the visible range, to the extent that only a 300-nm-thick layer regulates 99 % of transmitted visible light by electrical switching, we find that the coloration efficiency reaches ~80 $cm^2 \cdot C^{-1}$; recording twice that of a canonical electrochromic material, WO_3. Real-time tracing of the color propagation in an electric bias enables estimating the oxygen vacancy mobility to be 10^{-8} $cm^2 \cdot s^{-1} \cdot V^{-1}$ at 300 °C, which increases the usefulness in terms of the fast switching. This giant mobility is due to the unique mosaic twin structure that facilitates efficient misfit strain relaxation during the transition and in the two competing phases. First-principles density functional calculations reveal that the inter-band optical transitions, according to the selection rule, show a good agreement with the experimental result, indicating that hole charge injection arising from mobile charged defects causes a prominent electron correlation modulation in oxides, resulting in such large optical absorption change. From the comprehensive and combined investigations of the theory and experiments, our findings not only provide a promising material for fast and high-efficiency electro-optic applications, but also offer guiding principles for designing topotactic electrochromic devices in general.

Keywords:

Topotactic transition, Oxide thin film, Electrochromism

2020 KPS Spring Meeting
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D6.03

Ferroelectricity of Si-doped HfO2 for Analog Device

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Abstract:

Ferroelectricity with controllable partial polarization is considered as one of feasible candidates for an analog device for the neuromorphic device in the form of the ferroelectric tunnel junction and ferroelectric transistor. However, in the case of conventional ferroelectric materials, the complex nature of ferroelectric switching mechanism and/or defect mediated uncertainty hinder the deterministic control of ferroelectric subloop switching. This stochastic nature in the control of ferroelectric polarization states are of interest prior to the device application.
Recently, novel ferroelectric HfO_2 thin film has been investigated intensively as an alternative to conventional ferroelectric materials due to the advantages such as good scalability, compatibility with conventional CMOS process technology. In this study, we present the unprecedented stability of sub-loop polarization observed in the subloop switching of ferroelectric HfO_2. We suggest that the enhanced stability and accessibility of intermediate states in HfO_2 can be attributed to the large activation field for ferroelectric switching with small critical volume for the ferroelectric nucleation of HfO_2. We measured switching dynamics and temperature dependence hysteresis of HfO_2 thin films. The characteristic switching time and temperature dependence of hysteresis showed that ferroelectric HfO_2 has large activation energy while the critical size of ferroelectric domain volume is small. PFM results showed large domain wall activation energy due to stable small critical volume. Theoretical calculation demonstrated the stable switching energy path of ferroelectric HfO_2 during single dipole flip. Monte-Carlo simulation confirmed the relation between stable accessibility and the small volume of the ferroelectric domain.

Keywords:

Ferroelectric HfO2

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D7.01

Device Engineering of Sputtered $HfZrO_x$ Ferroelectric Films

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Abstract:

Since polarization switching has been observed in complementary metal-oxide-semiconductor (CMOS) compatible doped HfO_2 materials, interest in ferroelectricity has revived in the semiconductor industry. To realize the ferroelectricity in the materials, an annealing process at high temperatures needs to be carried out to create a specific crystal structure. Considering integration process, this thermal budget can be either negligible or disadvantageous. When the ferroelectric materials are used as the role of capacitor oxides located on top of the drain of the CMOS transistor, strict temperature constraints apply. On the other hand, the ferroelectric materials can be employed as gate oxides in the transistor that requires high temperatures. Rather, in the latter case, the ferroelectric properties that are robust to the thermal budget need to be achieved.
Therefore, in this talk, we present device engineering that allows the ferroelectric switching in $HfZrO_x$ to be used for each process condition. First, we introduce a high pressure annealing technology that not only lowers the process temperature below 550 ^{o}C for the phase transformation but also improves quality of the films. In addition, a trilayer system with $Al_2O_3/HfZrO_x/Al_2O_3$ structure with temperature tolerance will be discussed.

Keywords:

Ferroelectricity, high pressure annealing, trilayer

2020 KPS Spring Meeting
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D7.02

Demonstrations on Nonvolatile Memory and Neuromorphic Synapse Transistors Using Al-doped HfO_2 Ferroelectric Thin Films

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Abstract:

HfO_2-based oxide ferroelectric thin films have attracted huge interests in the suitability for nonvolatile memory applications due to such advantages as non-destructive readout, fast write/read speed, and CMOS compatibility. In these applications, single-transistor-type ferroelectric field-effect transistors (FeFETs) have mainly been developed. The gate stack for the FeFET has been typically composed of a metal-ferroelectric-insulator-semiconductor (MFIS) structure, which was designed to improve the interfacial properties between Si and ferroelectric gate insulator (GI).[1] However, since the insulator and ferroelectric capacitors are serially connected, an applied program voltage is distributed between two layers. This voltage distribution should be carefully considered for the MFIS-FETs using HfO_2 ferroelectric GIs, because they exhibited sound ferroelectric natures with a film thickness as thin as 10 nm. Therefore, during program operations, the electric field applied across the insulator is difficult to be sufficiently reduced, and hence, undesirable charge-injection may be more dominantly activated for the MFIS gate stack. To solve this problem, the metal-ferroelectric-metal-insulator-semiconductor (MFMIS) structure has been introduced, in which intermediate metal layer is inserted between the insulator and ferroelectric layers. In the MFMIS structure, since the areas of MIS and MFM can be individually designed, the program voltage can be sufficiently applied to the ferroelectric layer.[2] Therefore, a larger ferroelectric memory window and a faster program speed can be expected due to fully exploit the ferroelectric properties for the MFMIS-FETs. Furthermore, the MFMIS-FETs using the HfO_2 GIs can also be promising candidates for brain-like adaptive-learning applications due to analog-like memory operations. For these applications, partial polarization switching behaviors of the ferroelectric GIs can be facilitated for emulating biological synaptic functions by gradually modulating the channel conductance of the FeFETs.[3] Thus, in this work, FeFETs with Pt/Al:HfO_2/TiN/SiO_2/Si gate stacks were fabricated to implement nonvolatile memory and artificial synaptic devices. The details of operation mechanisms and device characteristics will be discussed in the presentation. The obtained results provide good guidance to realize high-density ferroelectric memories with higher performance [4] and next-generation artificial synapses with ultra-low power [5] by employing the MFMIS gate stacks for the FeFETs using the HfO_2 ferroelectric GIs.

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[2] S. Y. Na and S. M. Yoon et al. Jpn. J. Appl. Phys. 58(7), 070907, 2019.
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[4] S. J. Yoon and S. M. Yoon et al. IEEE Trans. Electron. Dev. 67(2), pp. 499-504, 2020.
[5] S. J. Yoon and S. M. Yoon et al. Adv. Electron. Mater. (Under review)

Keywords:

Ferroelectric, HfO2, Nonvolatile memory, Synapse device, Field-effect transistor

D7.03

평평한 에너지 밴드에 의해 유닛셀 크기 최소 분극을 개별 조작할 수 있는 새로운 강유전성

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Abstract:

강유전체 내의 유전 분극을 안정화시키고, 스위칭시키기 위해서는 적어도 수 나노에서 수십 나노 정도의 크기를 가지는 도메인을 필요로 하고, 이는 강유전 소자의 집적화를 방해하는 큰 요인 중 하나였다. 하지만 우리는 HfO_2 의 경우 운동량 공간에서 dispersion 이 없는 평평한 포논의 에너지 밴드를 갖는 것을 발견하였고, 이 평평한 밴드에 의해서 도메인 형성 없이 유닛셀 하나 하나의 분극을 완전히 개별적으로 스위칭 시킬 수 있음을 확인하였다 [1]. 이러한 개별적인 분극의 움직임은 거대한 coercive field 나 무척 느린 도메인 속도 등의 HfO_2 만의 독특한 실험적 관측들의 이유를 잘 설명한다. 본 발견은 향후 유닛셀 단위로 조작되는 초집적 메모리 소자 제작에 원동력을 불어넣는 새로운 연구분야를 창출할 것으로 예상된다.

[1] "Scale-free ferroelectricity induced by flat phonon bands in HfO2", Hyun-Jae Lee, Minseong Lee, Kyoungjun Lee, Jinhyeong Jo, Hyemi Yang, Yungyeom Kim, Seung Chul Chae, Umesh Waghmare, Jun Hee Lee* (Accepted in Science).

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D8.01

그래핀으로 감싼 BaTiO3 기반의 유전복합물질의 유전 특성과 이를 활용한 무기 전계발광 특성

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Abstract:

탄소기반의 2차원 나노물질인 그래핀(graphene)으로 강유전체인 BaTiO3 파우더 입자를 감싸게 하였다(encapsulate, wrap). 먼저 BaTiO3 입자를 아민기를 띄게 functionalize하고, graphene oxide(GO)는 phenyl isocyanate로 functionalize를 하였다. 이렇게 +와 -로 functionalize한 두 성분을 N,N-dimethylformamide (DMF) 기반의 용매에 혼합하여, 정전기적 인력을 이용하여 그래핀이 BaTiO3 입자를 감싸게하여 GO@BaTiO3 입자를 합성하였다. 이를 1,1-dimethylhydrazine으로 화학적으로 환원(reduction) 시켜서 reduced graphene oxide(rGO)로 감싸은 BaTiO3 filler 입자(rGO@BaTiO3)를 만들었다. 이를 filler로 사용하여, cyanoethyl pullulan (CEP) 고분자 matrix에 혼합(mixing)하여, 유전체 복합물질을 만들었다. 이를 BaTiO3를 감싸지 않고 단순히 BaTiO3, rGO, CEP를 섞은 3 phase 성분의 단순혼합한 유전체 복합물질도 같이 합성하였다. 스핀코팅 방법으로 (1) BaTiO3와 CEP로 만든 유전 박막, (2) BaTiO3, GO, CEP를 단순히 섞어만든 유전 박막 (3) BaTiO3, rGO, CEP를 단순히 섞어만든 유전 박막, (4) GO@BaTiO3, CEP로 만든 유전 박막, (5) rGO@BaTiO3, CEP로 만든 유전 박막 을 만들어 5 종류의 박막의 유전 특성을 측정하였다. 그래핀이 입자를 잘 감싸고 있음을 SEM, TEM, Raman, FTIR, XPS을 통해 확인하였다. 유전물질 내부에 존재하는 수많은 micro-capacitor에 의한 interfacial polarization 효과에 의해, 그래핀(GO, rGO)으로 감싸은 유전박막이 유전상수값이 1.5~3배 정도 크다. 전도성 나노물질을 섞은 경우에 유전손실율은 percolative connection에 의해 매우 커지는 단점이 있는데, encapsulation을 한 경우에는(특히 rGO@BaTiO3) 단지 6% 정도의 증가로 그 증가세를 억제하는데 성공하였다. 또한 화원시간과 rGO의 농도등의 변화를 통하여, 최적의 rGO@BaTiO3 조건을 찾으려 노력하였다. 이러한 고품질의 유전박막을 이용한 응용의 한 예로 교류 구동 방식의 ZnS:Cu 파우더 형광체를 이용한 무기 전계발광(inorganic electroluminescence) 소자를 구성하여, 고휘도 저전류 구동의 가능성을 보임으로서, encapsulation 유전박막의 우수성을 입증하였다. 이러한 encapsulation을 통한 rGO@BaTiO3 입자를 통한 다른 응용 가능성에 대하여도 발표할 예정이다.

Keywords:

graphene, dielectric, micro-capacitor, encapsulation, interfacial polarization

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D8.02

Interlayer coupled phonons of van der Waals heterostructures

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Abstract:

After the successful isolation of graphene, research on two dimensional (2D) layered crystals has grown considerably because of their unusual physical properties. Such unusual properties have triggered excitement and anticipation to produce emerging optical and electronic devices made of 2D layered crystals. Beyond 2D layered crystals themselves, one can envision new properties and phenomena arising from vertical stacks of 2D layered crystals, called van der Waals heterostructures. The key factor to generate unusual properties is the interaction between the layers so that it is important to investigate the interaction. Raman spectroscopy is the one of successful tools to investigate the interaction between the layers. For examples, the shear and layer breathing modes of 2D layered crystals have been observed by Raman spectroscopy and the mechanical coupling strength between the layers have been estimated from its phonon frequency varying in terms of the number of layers. In this talk, we will discuss about new Raman peaks observed in various van der Waals heterostructures due to strong coupling between the layers.

Keywords:

2D materials, van der Waals heterostructure, Raman spectroscopy, Graphene

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

D8.03

Selective-area remote heteroepitaxy of ZnO microrod arrays on patterned all-graphene surface

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Abstract:

Standard microelectronics processing requires position-controlled semiconductor components to make device architecture arrays easily addressable in manufacturing as well as device operation. Furthermore, for flexible device applications, transferable platform with regular arrays of device components has been essentially required for the following assembly process of pick-and-place on flexible substrates of interest. Here in, we demonstrate a method of fabricating position-controlled ZnO microrod (MR) arrays on all-graphene surface via remote epitaxy technique. Selective-area remote heteroepitaxy of ZnO MRs was performed on patterned graphene-coated GaN substrate by hydrothermal growth method. The patterned graphene layer consists of two graphene parts of (i) hole-patterned multilayer graphene (MLG) that prevents the remote epitaxy, which act as a growth mask layer, and (ii) single-layer graphene (SLG) as a basal layer for MR growth to allow the confined area remote heteroepitaxy of ZnO MR through the hole opening of mask layer. The spatial geometry as well as morphology of ZnO was controlled by changing diameter and spacing of patterns. Scanning electron microscopy was utilized to observe the surface morphology of ZnO MR arrays and Raman spectroscopy was used to confirm the presence of graphene. The remote heteroepitaxial relation between ZnO MR and GaN substrate across graphene layer was investigated via atomic-resolution transmission electron microscopy. Density functional theory (DFT) calculations demonstrated mechanism of remote epitaxy across graphene and why the remote heteroepitaxy could be achieved on the thin patterned SLG area, rather than thick MLG mask layer. In addition, utilizing a weakly bound feature of graphene on substrate, release of overlayer MR was conducted via a facile sticky tape-assisted exfoliation technique. After the exfoliation, the native GaN substrate was reused for repeating selective-area remote heteroepitaxy.

Keywords:

selective-area remote heteroepitaxy, ZnO, microrod, graphene, hydrothermal growth

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D8.04

비정질 실리콘 및 그래핀을 이용한 유연한 광 센서

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Abstract:

본 구조는 Fermi 준위 조절이 가능한 Graphene의 특성을 이용하여, 기존의 MOS 광 센서와 달리 heterojunction에서의 Schottky barrier 준위를 효과적으로 조절할 수 있으며, 이를 이용하여 높은 광효율을 지닌 소자를 구현하였다. 이를 통하여 광 증폭기 구조가 필요 없는 광 센서를 제작할 수 있고, 광량이 매우 낮은 곳에서도 사용할 수 있다. 일반적인 Graphene 기반 GIS(Graphene-Insulator-Silicon) 광 센서의 경우, 3D 물질인 Silicon을 기반으로 하여, 2D 물질인 Graphene을 전사하는 구조를 사용한다. 이러한 구조의 경우 2D 물질을 3D 기판 상에 직접적으로 성장을 시켜서 발생하는 물리적인 Contact으로 인해 2D 물질의 손상 및 오염을 유발한다. 본 구조에서는 3D 물질을 2D 기판 상에 증착하는 반전 구조를 형성함으로써, Graphene에 발생하는 손상과 오염을 최소화했다. 반전된 구조와 그렇지 않은 기본 구조로 GIS 광 센서를 제작하여 비교하였으며, 파장 별 Dark current와 Photo current 특성을 분석하였다.
또한 비정질 실리콘과 Graphene을 이용했기 때문에 유연, 대면적 소자 개발이 용이하다는 특징을 가지며 왜곡이 적은 곡면 및 가변형 센서의 제작이 가능하다. 또한 차량용 야간 주행 센서나 낮은 방사선 선량을 이용한 측정 등 다양한 부분에서 응용이 가능할 것으로 보인다.

Keywords:

Graphene, 광센서, 유연소자

2020 KPS Spring Meeting
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D8.05

Graphene based nano-electro-mechanical resonator for radio application

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Abstract:

We have fabricated a graphene nano-electro-mechanical resonator and studied its electromechanical properties, especially focused on its RF applications. A drum-like trench substrate was prepared and the suspended graphene on trench substrate~~s~~ was transferred. The resonance frequency of the graphene electromechanical resonator was measured by a laser interferometry technique. The radio frequency near the resonance frequency of the graphene drum was modulated and transmitted to the resonator. The amplitude of the transmitted radio signal was modulated by mixing a sound source and the radio frequency signal. The graphene resonator demodulated amplitude and reproduced the sound output through the speaker. The sound from the speaker could be easily recognized through ears. The resonance frequency of graphene radio has shown in the megahertz range, which can be tuned by applying electrostatically induced strain to the resonator. The duffing like nonlinear resonance behavior was utilized to detect a small amount of mechanical resonance frequency change. In this presentation, our graphene nano-electro-mechanical drum radio represents the possibility of approaching highly sensitive mass resolutions of several daltons by measuring the resonance frequency.

Keywords:

NEMS, Nano-Electro-Mechanical Systems, Graphene, Electromechanical resonator, Graphene resonator

D8.06

In-situ TEM Observation of dynamic changes on Graphene

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Abstract:

We investigated dynamic modification changes of graphene using *in-situ* scanning transmission electron microscope (STEM) observation. A suspended graphene was prepared on the SiN membrane substrate with gold electrodes. The STEM observation was performed on mono/bi-layer graphene surface and edge as well as on nano hole area. We observed graphitization by e-beam irradiation at the holes of the mono layer graphene section and at the boundary section between mono and bi-layer graphene. A donut shape graphene growth was observed at the hole area during e-beam irradiation. *In-situ* STEM observation on graphene was also conducted while temperature of graphene was increased by Joule-heating process during the e-beam irradiation. A graphene was torn, and crack was formed along armchair direction when a bias voltage for Joule-heating was applied up to 2.3 V. During the Joule-heating process we observed that small carbon contaminations were rotated. In this presentation, various interesting changes and movements of molecules observed on graphene surface are demonstrated.

Keywords:

Graphene, TEM observation, Joule-heating, E-beam irradiation

2020 KPS Spring Meeting
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D9.01

Network science: Standing on the edges of a giant collaboration network

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Abstract:

Network science is a field of physics about the fundamental structure and dynamics of interacting entities. In this talk, I briefly review basic terminology and notions of network science, in parallel with its recent historical development, followed by my main research interest in extracting mesoscale and hidden structures of networks. In particular, standing on the edges of a collaboration network, we focus on the utilization of information theory to decipher the most essential and potentially asymmetric interactions. When a node in a network with limited interaction capacity spends its capacity to its neighboring nodes, the allocation of the total amount of interactions to them can be vastly diverse. Even if such potentially heterogeneous interactions epitomized by weighted networks are observable, as a result of the aforementioned ego-centric allocation of interactions, the relative importance or dependency between two interacting nodes can only be implicitly accessible. We provide a systematic criterion to select the most essential interactions for individual nodes. The criterion is symbolized by assigning the effective number of neighbors to each node, and the resultant directed subnetwork decodes the originally hidden dependent relations by leaving only the most essential directed interactions. As a final remark, in the midst of the COVID-19 outbreak and development of machine learning, I would like to bring some attention to the limitation of top-down theoretical approaches and the importance of data-driven ones, which frankly might not be physicists' cup of tea traditionally.

Keywords:

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D9.02

국제관계와 자산가격 간의 관계 분석: 엔터테인먼트 기업을 중심으로

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Abstract:

본 연구의 목적은 2016년 한국의 고고도미사일방어체제 배치로 촉발된 중국의 한한령이 국내 엔터테인먼트 주식에 미친 영향을 분석한다. 이를 위해, 국내 엔터테인먼트 주가를 통계적 균형 관점에서 비교 분석을 진행 하였다. Symbolic Time Series Analysis를 적용한 엔트로피로 실증 분석한 결과 중국의 한한령은 국내 엔터테인먼트 주식의 가격 결정 복잡성에 부정적인 영향을 미친 것으로 확인되었다. 이는 엔터테인먼트 산업의 실적 악화를 우려한 투자자들의 거래 감소로 시장의 정보가 효율적으로 반영되지 않아 주식 가격의 패턴을 단조롭게 만든 것으로 이해 할 수 있다.

Keywords:

국제관계, STSA엔트로피, 한한령, 엔터테인먼트 주식

2020 KPS Spring Meeting
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D9.04

Prediction of sea level rise and volatility analysis near the Korean Peninsula

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Abstract:

The sea level rise due to global warming is an issue at a global level and its causes already have been studied clearly in early times. IPCC creates scenarios for greenhouse gas emissions and predicts global average sea level rise accordingly. Ice Sheet System Model is a numerical model of ice sheet dynamics process caused by the loss of ice sheets in polar regions. In particular, the global sea level rise prediction through the Glacial Isostatic Adjustment provides seawater flows from the ice sheet at a macroscopic scale. However, this global scale modeling has limitations in insufficient mesh size due to computation speed and makes it difficult to predict local differences in sea level rise in microscopic scale and complex terrain. In particular, in the Korean Peninsula, high sea level rise rate differences between tidal stations have been reported in microscopic areas (~ 100 km). In this study, we study regression and empirical mode decomposition for sea level rise prediction using tidal data near Korean Peninsula. And we also analyze correlation, causality, and volatility to understand the difference between tidal stations.

Keywords:

sea level rise, tidal level, regression, empirical mode decomposition, causality analysis

2020 KPS Spring Meeting
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D9.05

Quantum Attractors and Complex Spacing statistics

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Abstract:

Level-splitting statistics of quantum Hamiltonian systems has gained a lot of attention to describe systems that are chaotic or regular. We extend this notion to dissipative quantum systems with a driven quantum Duffing oscillator model. We define the chaotic or regular regime by studying the bifurcation diagram in the classical limit of our model. For our model we find that the Wigner distribution obtained via a fully quantum description shows similarities with the classical phase space distribution indicating that overall even our quantum system shows chaotic or regular behavior. We then look at the complex spacing (aka level-splitting for closed systems) statistics for the dissipative generator and find that the spacing statistics show either a Wigner-Dyson-like distribution for the chaotic regime or a Poissonian-like distribution for the regular case. This is the first time we are able to find a connection between complex-spacing statistics for an open quantum system to the phase space (Wigner) distributions that can be compared to the classical limit of the model. Our work provides a direct route to connect the standard notions of chaos to the modern ideas of level-splitting statistics.

Keywords:

Quantum Open Systems, Duffing Oscillator, Level-splitting statistics

2020 KPS Spring Meeting
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D9.06

Effect of Diverse Spiking Patterns of Granule Cells on Optokinetic Response in The Cerebellum

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Abstract:

We investigate the effect of diverse recoding of granule (GR) cells on optokinetic response in a cerebellar ring network by varying the connection probability p_c from Golgi to GR cells. For an optimal value of p_c^* (=0.06), individual GR cells exhibit diverse spiking patterns which are in-phase or out-of-phase with respect to their population-averaged firing activity. Then, these diversely-recoded signals via parallel fibers (PFs) from GR cells are effectively depressed by the error teaching signals via climbing fibers (CFs) from the inferior olive which are also in-phase ones. Synaptic weights at in-phase PF-Purkinje cell (PC) synapses of active GR cells are strongly depressed via strong long-term depression (LTD), while those at out-of-phase PF-PC synapses are weakly depressed through weak LTD. This kind of "effective" depression at PF-PC synapses causes a big modulation in firing of PCs, which then exert effective inhibitory coordination on vestibular nucleus (VN) (which evokes OKR). For the firing of VN neuron, the learning gain degree L_g, corresponding to the modulation gain ratio (i.e., normalized modulation divided by that at the 1st cycle), increases with increasing learning cycle, and it saturates at about the 300th cycle. By varying p_c, we find that a plot of L_g^* versus p_c forms a bell-shaped curve with a peak at p_c^* (where the diversity degree D in firing of GR cells is also maximum). The more diverse in recoding of GR cells, the more effective in motor learning for the eye movement.

Keywords:

Optokinetic response, Cerebellar ring network, Granule cells, Diverse recording, Motor learning

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D9.07

Glassy dynamics of compressed pulmonary surfactant monolayers

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Abstract:

Through extensive atomic resolution molecular dynamics (MD) simulations and theoretical analyses, we study the lateral dynamics in the lipid monolayers upon lateral compression. As previously shown for bilayers, the single-lipid motion in the monolayers manifests Gaussian subdiffusion with algebraically decaying displacement autocorrelation at the usual condition of lipid density. The MD simulation, however, reveals that at high-pressured states beyond a threshold the lateral motion turns to exhibit dynamic anomalous states, where the particle movement is strongly coupled and the propagator becomes non-Gaussian. As the monolayer is cooled and laterally compressed over the threshold, the particle-to-particle heterogeneity of dynamic scales grows, superstatistically leading to non-Gaussian ensemble statistics. Another noteworthy is that this heterogeneity is accompanied by the formation of dynamically distinct clusters of mobile and immobile lipids over the membrane; this structure, both qualitatively and quantitatively, resembles dynamic heterogeneity reported for supercooled colloidal systems. We show that for lipid monolayers the dynamic heterogeneity originates from the undulation coupling of the lateral dynamics. The lipid mobility is found to be statistically correlated with the local membrane curvature, which is long-lived due to the mechanical locking of undulation by pressure. Beyond the threshold pressure, the membrane undulation also exhibits anomalous dynamics. The conventional Canham-Helfrich membrane elasticity model with a homogeneous bending rigidity fails to describe the observed slowly-decaying undulation dynamics.

Keywords:

Lipid monolayer, Anomalous diffusion, Glassy dynamics, Dynamic heterogeneity

Persistence of harmful intragenomic elements in bacterial populations

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Abstract:

In bacterial genomes, there are a large number of short repetitive sequences called REPINs, which persist in bacterial genomes for long periods. However, due to the chance to kill an active bacteria gene during REPIN duplication, REPIN populations suppose to die out eventually. Then how do they persist for a long time in bacterial genomes? Here we model the ecological dynamics of REPIN populations and their interactions with the bacterial host's genome to resolve this contradiction. We found that internal horizontal gene transfer cannot explain the persistence of REPINs while a mutualistic relationship can do. In addition, our results show that the benefit of each REPIN needs to decrease as more REPINs are added to the genome to maintain a stable REPIN population inside the genome.

Keywords:

Eco-evolutionary dynamics, Host-parasite relationship, Mutualism

2020 KPS Spring Meeting
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E1.01

Top quark pair reconstruction using an attention-based neural network

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Abstract:

For many top quark measurements, it is essential to reconstruct the top quark from its decay products. For example, the top quark pair production process in the all-jets final state has six jets initiated from daughter partons and additional jets from initial/final state radiation. Due to the many possible permutations, it is very hard to assign jets to partons. We use a deep neural network with an attention-based architecture together with a new objective function to the jet-parton assignment problem. Our novel deep learning model and the physics-inspired objective function enable jet-parton assignment with high-dimensional data while the attention mechanism bypasses the combinatorial explosion that usually leads to intractable computational requirements. The model can also be applied as a classifier to reject the overwhelming QCD background, showing increased performance over standard classification methods.

Keywords:

jet-parton assignment, top quark pair reconstruction, deep learning

2020 KPS Spring Meeting
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E1.02

R-Parity Violating Supersymmetry event classification using Convolutional Neural Network with Large Scale Deep Learning

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Abstract:

Deep Neural Network (DNN) is the most promising tool to explore rare physics phenomena from huge amounts of background at the LHC experiments. Convolutional Neural Network (CNN) is one of the successful Deep Learning (DL) techniques in pattern recognition. We implement the CNN architecture to discriminate the R-parity Violating Supersymmetry (SUSY) events from the quantum chromodynamics (QCD) background. Low-level information of the CMS detector such as tracking system, electromagnetic and hadronic calorimeters are used as 3-channel input images of our CNN model. The model is trained with Monte Carlo samples based on the Delphes fast simulation software with the CMS detector configuration. The benchmark studies are performed to compare with a traditional cut based physics selection in the realistic condition with multiple proton-proton interactions (pileup). To perform the DNN training with the big data of the CMS detector in a reasonable time, we employ the High-Performance Computing (HPC) infrastructure based on the Nurion supercomputer provided by the KISTI national supercomputing center. Optimization of computing performance at the Nurion's Xeon-Phi architecture is performed to minimize possible bottlenecks on the system. We report speed-up tests of the DL training at large scale on the Nurion supercomputer.

Keywords:

Deep Learning, CMS, Convolutional Neural Network, LHC, CERN

2020 KPS Spring Meeting
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E1.03

Application of Graph Neural Network on RPV SUSY Event Classification

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Abstract:

Application of Deep Learning (DL) to high-energy physics has gotten much attention. Graph Neural Network (GNN) is one of the novel DL architectures, which has gained increasing popularity recently. The strength of the GNN in modeling the relationship of nodes in a graph enables handling data embedded in the non-Euclidean geometries. In this study, we implemented GNN architectures on a cylindrical surface which can reflect CMS detector geometry to discriminate R-parity Violating Supersymmetry (RPV SUSY) events from QCD multijet backgrounds with high accuracy. We present the benchmark studies based on the GNN model for the RPV SUSY search, which shows comparable physics performance of the existing model based on the Convolutional Neural Network.

Keywords:

Deep Learning, CMS, RPV SUSY, Convolutional Neural Network

2020 KPS Spring Meeting
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E1.04

Simulation for Particle Shower in EM Calorimeter with Deep Learning (Generative Adversarial Network)

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Abstract:

Geant4 is used to simulate particle interactions in electromagnetic Calorimeters. Our aim is to generate the EM showers simulated by Geant4 using Generative Adversarial Networks. The GAN model consists of 2 different networks, generator and discriminator, trained in an adversarial relationship. If both networks are trained well enough, the generator will be able to generate similar images to Geant4.

Keywords:

deep learning, calorimeter, simulation, GAN

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E1.05

Overview and status of Dual-Readout Calorimeter R&D for future collider projects

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Abstract:

The dual-readout method is a state of the art calorimetry technique enables high-quality energy measurement for both electromagnetic and hadronic particles. The dual-readout calorimeter has been included in the conceptual design reports of both FCC-ee and CEPC projects. Further performance studies of the design are on-going. Recent progress and plan of the dual-readout calorimeter R&D in Korea will be presented in this talk.

Keywords:

Dual-readout calorimeter, CEPC, FCC-ee, IDEA

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.01

Scratch 블록코딩 기반의시뮬레이션 구성을 통한 역학교육

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Abstract:

본 연구는 최근 광범위하게 사용되고 있는 블록코딩 기반의 프로그래밍도구를 활용한 역학 시뮬레이션이 역학 교육에 기여할 수 있는 방법을 알아보고자 하는 것이다. MIT에서 개발하여 공개하고 있는 Scratch는 전세계적으로 가장 널리 활용되는 웹기반 블록코딩 프로그램도구이고, 우리나라에서도 자체개발한 '엔트리' 등이 학교 교육에서 활용되고 있다. 현재 일선 학교에서는 이러한 블록코딩 도구를 주로 간단한 애니메이션 구성이나 산술 프로그램 제작 등에만 사용하고 있으며, 이 도구가 가진 물리교육적 역량에 대해서는 거의 잘 이해되지 못하고 있는 실정이다. 본 연구에서는 이러한 블록코딩 도구를 활용한 1차원 동역학, 2차원 동역학 등 다양한 시뮬레이션 구성 방법에 대하여 교원 연수를 통한 교수 교육에 적용하고, 이에 대한 장단점과 학교 현장의 적용 가능성에 대한 교사들의 의견을 제시한다.

Keywords:

역학 시뮬레이션, 블록코딩, Scratch

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.02

Comparison of data logging method of block-based physical computing system

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Abstract:

블록기반 피지컬 컴퓨팅 시스템은 코딩을 배우기 위한 문턱이 낮으면서 수준높은 산출물을 비교적 쉽게 개발할 수 있다는 점에서 융합 교육의 도구로 큰 주목을 받고 있다. 이 시스템이 물리교육에 본격적으로 활용되기 위해서는 무엇보다 데이터 수집 및 분석이 용이해야 한다. 따라서 본 연구에서는 데이타 수집 및 분석의 용이성 차원에서 기존에 널리 활용되는 피지컬 컴퓨팅 시스템을 분석하였다.

Keywords:

physical computer, data logging , scratch, microbit, arduino

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.03

컴퓨팅 기반 물리 실험 보고서 작성이 과학고등학교 학생들의 탐구능력 및 태도에 미치는 영향

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Abstract:

학교 실험실 현대화로 인해 데이터를 수집하고 분석하는데 컴퓨터의 활용이 증가하였지만, 실험 보고서의 경우 여전히 전통적인 방식으로 작성되고 있다. 이는 분석 소프트웨어를 통해 도출한 결과를 별도로 출력하거나 불러오도록 하는 등 보고서 작성의 효율을 저해하고, 컴퓨팅을 통한 2차 분석을 제한하여 정량적인 결론 도출을 어렵게 한다. 이 연구는 파이썬과 주피터 노트북 기반의 실험 보고서가 과학고등학교 학생들의 탐구 능력과 태도에 미치는 영향을 조사한다. 이를 위해 주피터 노트북 플랫폼을 기반으로 브라운 운동에 대한 컴퓨팅 기반 실험 매뉴얼을 개발하고, 과학고등학교 3학년 학생 100명을 대상으로 적용하였으며, 설문을 통해 물리 실험에서 컴퓨팅 능력에 대한 자기효능감과 가치에 대한 인식을 분석하였다. 이를 통해 물리교육에서 컴퓨팅 기반 물리 실험 보고서 작성의 교육적 의의와 시사점을 도출하였다.

Keywords:

실험 보고서 작성, 컴퓨팅, 인식, 탐구능력, 과학고등학교

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.04

과학교과서 텍스트의 계량적 분석을 이용한 과학 개념어의 생산적 지식 교육 방안 탐색

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Abstract:

과학 개념에 대한 이해를 언어학적 관점에서 바라보면 학생들이 과학 개념어에 대한 깊고 정교한 이해와 더불어 정확하게 사용할 수 있는 능력을 길러주는 것이 매우 중요하다. 본 연구에서는 지금까지 과학 교육에서 과학 개념어에 대한 생산적 지식 교육의 기틀이 잘 마련되어 있지 않음에 주목하고, 과학 개념을 구성하고 있는 단어들 사이의 관계를 생산적이고 효과적으로 교육할 수 있는 방안을 탐색함으로써 과학 개념어의 생산적 지식 교육의 기틀을 제공하고자 하였다. 이를 위해 첫째, 몇 가지의 계량 언어학적 텍스트 분석 방법을 이용하여 과학 교과서 텍스트로 부터 과학 개념을 구성하고 있는 단어들과 그들 사이의 관계를 추출하고, 둘째, 각 방법의 결과로 추출된 단어 관계의 의미를 정성적으로 살펴본 뒤, 셋째, 이를 이용하여 과학 개념어의 생산적 지식 향상에 도움을 줄 수 있는 쓰기 활동 방법을 제안해 보았다. 중학교 1학년 과학교과서 '힘과 운동' 단원 텍스트를 클러스터 분석, 공기 빈도 분석, 텍스트 네트워크 분석, 그리고 워드 임베딩의 네 가지 계량 언어학적 분석 방법을 사용하여 분석해 보았다. 연구 결과 첫째, 클러스터 분석 결과를 활용하여 문장 완성하기 활동을 제안하였다. 둘째, 공기 빈도 분석 결과를 이용한 빈 칸 채우기 활동을 제안하였다. 셋째, 네트워크 분석 결과를 이용하여 소재 중심 글쓰기 활동을 제안하였다. 넷째, 워드임베딩을 이용한 학습 중요 단어 목록 작성을 제안하였다.

Keywords:

과학교과서, 공기 빈도, 텍스트 네트워크 분석, 클러스터 분석, 워드 임베딩

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.05

과학영재학생들의 심화탐구 분석을 통한 옴의 법칙 탐구의 문제점과 효과적인 학습 전략 제안

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Abstract:

옴의 법칙은 일정한 온도의 도체 두 지점 사이에 나타나는 전위차에 의해 일정한 전류가 흐르는 현상을 설명한다. 또한, 옴의 법칙을 나타내는 식은 옴의 법칙의 성립 여부와 상관없이 임의 도체에 대한 저항 R을 정의하기도 한다. 그러나 옴의 법칙은 R이 상수인 경우에 한하여 성립한다. 또한, 금속의 저항은 물질과 온도에 따라 달라지므로 옴의 법칙은 만유인력의 법칙이나 쿨롱의 법칙과 같이 일반적으로 타당한 법칙이 아니다. 그러나 과학과 교육과정에서 옴의 법칙은 전류(I), 전압(V), 저항(R)사이의 관계를 나타내는 수학적인 관계로만 서술하고, 탐구실험에서도 수 옴의 작은 저항을 이용하여 검증하기 힘든 상황에서 옴의 법칙 탐구를 제시함으로써 학생들이 옴의 법칙을 이해하는데 어려움을 느끼고 있다.

이에 본 연구에서는 옴의 법칙에 대한 학습과 탐구 상황에서 학생들이 겪는 어려움과 문제점을 알아보기 위해 일반물리학실험을 수강하는 과학영재학교 2학년 학생 102명을 대상으로 일반적인 옴의 법칙에 관한 실험을 실시하여 학생들이 겪는 어려움과 오류를 분석하게 하고, 이와 관련된 심화탐구 주제를 조별로 선정하고 이를 탐구하여 발표하게 하였다. 27개조의 탐구를 분석한 결과 학생들은 휘트스톤 브릿지나 접촉저항의 영향을 분석하여 오차를 줄이려는 탐구, 멀티미터 내부의 저항을 고려하여 오차를 줄이려는 탐구, 4 point probe method를 통한 저항이 작은 금속판을 이용한 옴의 법칙 증명 탐구, RLC 회로의 시상수 값을 이용한 옴의 법칙을 알아보는 탐구 등의 주제로 탐구를 진행하였다. 대부분의 탐구는 어떤 물체의 저항 값을 구하고 이를 이전의 저항 값과 비교하여 실험의 정밀도를 높이는 실험이었다. 학생들은 다양한 방식으로 옴의 법칙과 이에 대한 탐구가 갖는 문제점과 어려움을 인식하고 이를 해결하고자 하는 탐구를 진행하였다. 그럼에도 불구하고 학생들은 회로 전체에 대한 옴의 법칙 적용보다는 회로의 일부에 대하여 법칙을 적용하고 있었고, 옴의 법칙이 항상 사실이고 저항이 상수라는 것을 가정함으로써 어떤 도체의 저항이 상수라는 것을 검증하기 위해 옴의 법칙을 사용하여 옴의 법칙을 저항의 정의와 혼동하는 순환 논리적 이해의 경향을 보여주었으며, 수 옴의 작은 저항에 대하여 옴의 법칙을 적용함으로써 큰 오차를 얻는 등 옴의 법칙과 이에 대한 탐구가 가지고 있는 다양한 맥락과 한계에 대한 이해 부족을 보여주었다.

본 연구를 통해 옴의 법칙이 각 개념의 수학적인 관계 서술을 뛰어넘어 옴의 법칙이 갖는 배경과 한계, 옴의 법칙을 따르지 않는 경우, 전선이나 저항의 발열이 옴의 법칙에 미치는 영향, 옴의 법칙을 따르는 니크롬선과 같은 옴 소자와 그렇지 않는 소자, 물질의 비저항은 같지만 물체의 저항은 같지 않을 수 있다는 사실 등에 대한 학습을 통해 법칙과 실제 실험 결과와의 오차를 관찰하게 함으로써 과학의 본성을 이해할 수 있는 옴의 법칙에 대한 효과적인 학습 전략을 제안하고자 한다.

Keywords:

옴의 법칙, 탐구, 과학의 본성

E10.06

뉴턴의 제2법칙 실험을 향한 과학영재들의 도전과 배움

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Abstract:

과학에서 탐구 및 실험 활동은 핵심적인 활동의 하나로 이해되고 있으나, 과학교육의 맥락에서 실험이 학생들의 교육에 효과적인 방법인지에 대해서는 많은 논란이 있다. 이에 따라 실험 수업의 실태에 대한 많은 연구가 수행되었으며, 교과서에는 주로 예시적 확인 실험, 탐구의 설계를 일방적으로 제시하고 있는 방식 등이 제시되어 있고, 실험 수업도 요리책 스타일의 확인 실험이 주로 이루어지고 있는 것으로 나타났다. 많은 연구들에서 학생들에게 방법 및 결론이 정해진 닫힌 안내 실험을 하게 하기보다 열린 개방형 실험을 하게 하는 경우 학생들의 성취도뿐만 아니라 동기부여에도 도움이 된다고 주장하고 있지만 실제 학교 현장에서는 여러 환경적 어려움으로 완전히 열린 형태의 개방형 실험 수업을 진행하기는 힘들다. 이에 본 연구에서는 많은 학생들이 이해에 어려움을 겪고 있는 뉴턴의 제2법칙을 주제로 개방형 실험을 수행하게 하고 학생들의 실천 및 이러한 방식의 실험에 대한 학생들의 생각을 조사하였다. 구체적으로는 학생들이 교사가 안내하는 방식대로 뉴턴의 2법칙을 수행하게 한 후, 자유로운 실험 설계를 통해 본인만의 뉴턴 2법칙을 설계 및 수행하고, 본인이 어떤 수행을 했는지 발표하는 과정을 거쳤다. 연구 결과 학생들은 기존의 실험이 통제되지 않는 수레 및 도르래의 마찰의 문제, 수레를 끄는 추의 진동 문제 등이 있다고 보고 다양한 창의적인 방법을 통해 기존 실험의 문제점을 해결하려 하였으며, 특히 뉴턴의 제2법칙의 의미에 대한 깊은 고찰을 통해 원래의 의미를 잘 살릴 수 있는 완전히 새로운 실험 방법을 시도한 경우도 찾아볼 수 있었다. 본 연구에서 진행한 실험 수업을 통해 학생들은 이론과 실제, 이상과 현실은 차이가 있으며, 아무리 간단한 실험이라 할지라도 생각보다 많은 오차가 있고, 상당히 많은 복잡한 요소를 내포하고 있다는 사실을 깨달은 것으로 보였다. 또한 실험 설계의 중요성, 실험 과정의 의미, 좋은 실험의 의미에 대한 고민을 하는 등 향후 실험에 임할 태도에 대해서도 깊이 반성하는 모습을 보였다.

Keywords:

뉴턴의 제2법칙실험, 과학영재, 학생들의 실천

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.07

상대성 이론 수업에서 과학의 본성 및 시공간에 대한 초등학교 6학년 학생의 이해 변화

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Abstract:

본 연구에서는 초등학교 6학년을 대상으로 한 상대성 이론에 관한 수업에서 학습의 효과로서 학생들의 과학의 본성 및 시공간에 대한 이해의 변화를 탐색하였다. 초등교육과정과 연계 가능한 상대성 이론 관련 기초 개념 및 요소를 선정하여 이를 반영한 총 6차시의 수업을 설계하여 6학년 3개 학급 총 56명을 대상으로 실시하였다. 수업의 효과를 측정하기 위해 문헌에 기초하여 개발한 평가지로 '과학의 본성' 및 '시간과 공간'에 대한 사전, 사후 검사를 실시하여 변화를 분석하였다. 또한 일부 학생들을 대상으로 면담을 실시하여 수업의 어떤 특성이 학생들의 이해에 영향을 미쳤는지, 어려움을 주었는지를 조사하여 분석했다. 수업 전후 과학의 본성에 대한 인식 변화를 분석한 결과 수업 후 과학 지식의 발전성. 창의성, 검증 가능성에 대해 학생들의 이해가 향상한 것이 확인되었다. 그리고 수업 전후 시간과 공간에 대한 이해를 비교, 분석한 결과 상당한 비율의 학생의 인식이 절대성에서 상대성으로 전환되었음이 확인되었다. 또한, 학생들이 수업에서 다룬 상대성 이론 관련 기초 개념 및 요소 대부분을 이해한 것으로 드러났다. 학생들은 면담에서 과학학습의 자신감이 증가했음을 드러냈고, 학생들의 과학의 본성에 대한 이해를 향상하는데 특별히 기여한 일부 활동을 지정하였다. 한편, 추상적인 사고실험, 기하학적 표상, 강도 높은 학습지 활동에 대해 어려움을 호소했다. 이러한 연구결과는 초등학생 수준에 맞는 상대성 이론의 기초 개념 요소를 선별해서 적절한 모델과 비유를 활용하여 개발한 프로그램을 적용할 때 초등학생도 기초 개념과 과학의 본성을 충분히 학습할 수 있음을 시사한다. 연구 결과를 바탕으로 추후 필요한 연구 주제와 상대성 이론에 관한 초등학생 대상 수업 설계에 대한 시사점을 제시하였다.

Keywords:

상대성 이론, 과학의 본성, 시간, 공간, 교육과정

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.08

공학계열 전공 전자기학에서의 벡터 연산 이해에 대한 연구

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Abstract:

교양으로서 일반물리학을 수강한 전문대학 전기전공 학생을 대상으로 전공 전자기학의 벡터 연산 부분의 학업 성취도를 고찰 하였다. 본 대학 전기전공 학생들의 경우, 산업현장 적응력을 갖춘 전문 인력으로서의 능력 발휘를 위해 기본적으로 국가기술 자격증 취득을 목표로 한다. 전자기학은 자격증 취득 과목 중 하나이면서 고급 전공과목의 이해에 필수적인 전공기초 과목이다. 따라서 전자기학 이해의 기본이 되는 가우스 법칙을 포함한 벡터 미적분 방정식의 풀이와 물리적 이해의 중요성이 강조되고 있다. 일반물리학에서 다루어지는 기본 벡터 연산인 합과 차 그리고 내적과 외적의 의미를 이해한 학생들이 전공 전자기학 수업에서의 벡터연산 이해와 학업성취도의 향상에 영향을 끼쳤는지 알아보았다. 3차원 직각 좌표계에서의 델 연산자의 의미를 포함하여 가우스 법칙과 관련된 다이버젼스의 계산은 가능하지만 발산정리의 물리적 의미와 폐곡면 적분 계산에 대한 이해는 부족한 것으로 나타났다.

Keywords:

전자기학, 벡터연산, 발산정리, 가우스 법칙

E10.09

과학-예술 교육과정 콘텐츠 ‘다온’의 개발과 적용
- 대구 코로나 바이러스 상황을 중심으로 -
Application and development of ScienArt curriculum ‘DAON’
- Focusing on the context of the Coronavirus in Daegu -

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Abstract:

최근 세계 각국은 신종 코로나 바이러스가 확산되면서 혼란과 두려움이 엄습하고 있다. 우리나라의 경우, 온 국민이 협력하여 이 상황을 극복하고자 노력하고 있다. 본 연구는 사회적 거리두기의 일환으로 온라인 과학교육과정 콘센츠 ‘다온’을 개발하여 휴교 중인 고등학생들에게 적용함으로써 안전하고 활기찬 교육문화를 조성하고자 노력하였다. 여기서 다온은 ‘좋은 일들이 다 온다’는 순우리말이다. 먼저, 본 연구는 대구과학관을 기반으로 제작한 경북지역 고등학생들의 작품제작과정을 살펴보았다. 4차 산업혁명 시대를 맞이하여 세계 각국은 정보와 지식을 활용할 수 있는 능력을 함양하기 위하여 핵심역량을 중심으로 교육과정 체계를 개편하였다(OECD, 2003; 2006). 작품제작과정에서 학생들의 핵심역량이 두드러지게 나타났다. 다시 말하면, 학생들은 진로에 맞추어 작품 주제를 정하였으며(자기관리 · 의사소통역량) 과학뿐만 아니라 환경 · 기술/공학 · 예술 · 인문학 등 다양한 영역과 개념들을 도입하였다(지식정보처리 · 창의적사고 · 심미적감성역량). 사용한 과학개념들은 수능 출제 문항에도 제시되었음을 알 수 있었다. 공동체역량은 환경과 관련된 주제의 작품에서 나타났다(Lee & Park, 2018). 즉, 예술과 인문학을 접목한 과학교육은 과학에 대한 흥미와 상상력을 일깨운다고 볼 수 있다(Medina-Jerez, 2012; Igal Galili, 2013; Lee et al., 2019). 이는 교육과정의 개발 이 과학을 다양한 시각으로 바라보며 핵심역량을 강화하는 방향으로 나아가야 함을 의미한다고 할 수 있었다.

또한, 본 연구는 개발한 교육과정을 코로나 상황이 극심한 대구지역 고등학교 1학년 학생들에게 적용하였다. 이 교육과정은 동영상 강의를 통해 과학 지식을 체계적으로 교육하고 예술과 인문학, 첨단기술 등을 교과 내용과 접목하였다. 특히, 학생들은 화상토론에 적극적으로 참여하였는데, 주제 ‘코로나 바이러스’에 대하여 “...감염을 막고 면역력을 강화하는 화학·생물적 방어가 필요하지만 항바이러스제가 개발되지 않아서 사망자가 속출하고 있다. 마스크 · 손씻기 등의 물리적인 방어만으로는 한계가 있다(지식정보처리 · 자기관리역량)” 고 답변하였다. 학생(A)는 "음압병동이라는 첨단기술적 방어가 원활해야 하므로 ‘콘테이너 병동’을 개발해야 한다"고 하였으며(창의적사고역량) 학생(B)는 "의료진들의 희생과 같은 인문학적 방어가 위안을 주었고(심미적감성역량) 정치·경제·외교 등과도 조화를 이루어야 한다"고 주장하였다(의사소통 · 공동체역량). SNS 면담 결과, 학생들은 시간이 갈수록 점점 불안함을 느꼈으나 우리 선조들의 강인한 정신과 역사 이야기를 들은 후, 코로나 상황에 대한 두려움을 극복할 수 있었다고 답변하였다. 따라서 미래 교육과정은 학교뿐만 아니라 가정과 사회가 조화를 이루어야 하며 핵심역량과 함께 민족문화역량을 도입할 필요가 있음을 알 수 있었다.

Keywords:

과학과 예술, 교육과정, 핵심역량, 민족문화역량

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E10.10

150년간의 미국 물리교육의 변동사 (The History of U.S. Science Education Focusing on Physics Education Since the 1860s)

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Abstract:

이 연구는 1860년대 부터 최근까지의 미국 과학교육의 변동을 물리교육을 중심으로 고찰한다. 이 연구를 위하여 미국 과학교육사에 대한 선행연구, 미국 교육관련 법안을 검토하고, 이를 통해 물리교육과정의 변동을 시대적 맥락에 기반하여 논의한다. 미국의 물리교육의 변동사에 대한 고찰은 한국의 물리교육이 앞으로 나아가야할 지향점을 논의하는데 기초자료로 활용할 수 있으며, 이 연구는 한국의 과학교육정책에 대한 함의점을 함께 논의한다.

Keywords:

물리교육, 물리교육사, 과학교육정책, 물리교육과정

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E13.01

루비듐 원자 증기셀에서 에너지-시간 얽힘 광자쌍 생성과 유도방출 비트 간섭계를 이용한 얽힘 특성 연구

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Abstract:

광자를 이용한 장거리 양자통신, 양자 컴퓨팅, 양자 계측, 양자 센서 등 양자 기술 활용과 구현을 위한 양자 광원 개발과 특성 연구는 매우 중요하다. 본 연구에서는 시스템적으로 단순성의 장점을 가지는 따뜻한 루비듐 원자 증기셀을 이용하여 자발 사-광파 조화 현상으로 에너지-시간 얽힘 광자쌍을 생성하고 유도방출 비트 간섭계 방법을 이용하여 에너지-시간 얽힘의 특성을 조사, 분석하였다.

Keywords:

자발 사-광파 조화, 에너지-시간 얽힘, 유도방출 비트 간섭계

2020 KPS Spring Meeting
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E13.02

Phase Matching Condition of Coherent Extreme Ultraviolet Emission Generated through Frustrated Tunneling Ionization

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Abstract:

An atom exposed to an intense laser field can be ionized through tunneling. An electron liberated from the atom through tunneling follows different paths depending on its birth time. An electron wavepacket freed at the local extrema of the laser field can return to the parent ion with a zero kinetic energy. They can recombine to the excited state of the parent atom at the end of the laser field. This strong field excitation is called frustrated tunneling ionization (FTI) [1]. A coherent photon can be emitted through the transition from an excited state to the ground state. In this case, the photon energy can reach up to extreme ultraviolet (EUV). Since the FTI processes are repeated every half cycle of the laser pulse, the FTI emission exhibits an interference effect. Unlike high-harmonic generation (HHG) where photons interfere, however, electron wave packets interfere in the case of FTI radiation. We solve the time-dependent Schrodinger equation (TDSE) in one dimension and compare the theoretical results with the experimental results. It is shown that the theoretical results and the experimental results agrees well. Finally, the phase matching condition of the FTI radiation is discussed.

References
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[2] S. Bengtsson *et al.*, "Space-time control of free induction decay in the extreme ultraviolet", Nature Photonics **11**, 252-258 (2017)
[3] H. Yun *et al.*, "Coherent extreme-ultraviolet emission generated through frustrated tunneling ionization", Nature Photonics **12**, 620 (2018)

Keywords:

EUV source, Tunneling ionization, Coherent line emission

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E13.03

Microwave to optical wave conversion via ferromagnetic material

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Abstract:

We present directional coherent conversion from microwave to optical wave via collective spin excitation in a single crystal yttrium iron garnet (YIG) which is coupled to the microwave mode in a three dimensional rectangular cavity. The microwave field is coupled to the hybrid system through the cavity mode, and this itinerant microwave field inside the cavity can be coupled to a traveling optical wave field through this hybrid system. Here, we experimentally demonstrate coherent conversion from the microwave field to optical wave field in free space. In addition, we also theoretically analyzed and experimentally evaluated the characteristics of normal-mode splits and coupling strengths of the ferromagnetic resonance and magnetostatic modes coupled to the microwave cavity mode TE_{101} in YIG spheres with different sizes. Our work will provide a cavity magnon-microwave photon system that can be used for coherent conversion between microwave and optical photons.

Keywords:

ferromagnetic material, magnon, coherent conversion, hybrid system

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E13.04

고전 전자기학을 이용한 Planck's 상수 값의 수학적 유도

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Abstract:

일반적으로 원자 내의 전자 전이에서 방출된 광자는 전자기파이지만, 이것이 왜 전자기파인지를 증명할 수 없는 이유는 어느 누구도 플랑크 상수 값을 수학적으로 증명한 한 적이 없기 때문이다. 전자기학 이론에 따르면, 반경 r_0의 궤도에서 회전하는 전하가 교류로 흐를 때, 자기 쌍극자 복사인 전자기파를 방출한다. 본 발표는 외부에너지로 인해 전자가 반경 r_{nor}에서 수소 원자의 양성자 주위를 진동과 회전에 의해 교류가 생성할 때, 수소 방출 스펙트럼 영역인 적외선부터 자외선까지의 전자기파가 방출됨을 수학적으로 증명할 것이고, 그 수학적 결과는 광자가 빛의 이중성이 아니라 전자가 보유하고 있는 에너지를 방출하기 위한 하나의 수단으로 전자기파를 방출하는 것임을 증명하였다. 이에 대한 물리적 증명은 실험적 플랑크 상수 h가 정확히 수학적으로 유도될 뿐만 아니라 보어의 수소 모델과 적외선에서 자외선 영역의 전자기 스펙트럼도 설명할 수 있기 때문이다.

Keywords:

전기쌍극자 복사, 자기쌍극자 복사, 이론적 플랑크 상수, 전자기스펙트럼

2020 KPS Spring Meeting
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E13.05

Detection of radio-frequency magnetic fields by optically pumped Rb atomic magnetometers

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Abstract:

We demonstrate the radio-frequency atomic magnetometer based on optically pumped Rb atoms. The optically pumped Rb atoms precess due to the aligned ground state by a small oscillating magnetic field in the presence of an external static magnetic field and make nonlinear magneto-optical rotation of detuned resonant probe light. The operating radio-frequency can be adjusted to any desired value by changing the static magnetic field.

Keywords:

rf atomic magnetometer, optically pumped magnetometer(OPM), nonlinear magneto-optical rotation(NMOR)

2020 KPS Spring Meeting
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E13.06

미세 중력 환경에서 동작하는 마이크로파 공진기 레이저냉각 원자시계의 성능 분석

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Abstract:

초의 정의를 실현하는 세슘원자분수시계의 경우 원자를 포획하고 냉각하는 3D MOT 부분이 아래에 위치하고 마이크로파-원자 상호작용이 일어나는 마이크로파 공진기가 위에 위치하는 선형구조로 되어 있다. 3D MOT 챔버에서 냉각된 원자를 연직상방으로 쏘아올리면 원자가 마이크로파 공진기를 통과해 올라가고 내려오면서 Ramsey 상호작용을 한다. 이러한 분수형 구조는 상호작용시간이 길기 때문에 선폭이 약 1 Hz의 매우 좁은 Ramsey 신호를 얻을 수 있는 반면, 신호를 얻는 반복률이 1초 이상이고 진공조 (물리부)가 매우 크다는 단점이 있다. 만일 공진기 내부에서 원자를 포획, 냉각 후 마이크로파 상호작용을 하게 되면 비록 공진신호의 선폭은 수십 Hz로 넓어 지지만 반복률을 높일 수 있고 원자시계를 소형으로 만들 수 있다. 본 연구에서는 소형 loop-gap 마이크로파 공진기 내에서 3D MOT을 이용해 냉각된 원자들이 마이크로파 상호작용하는 과정을 몬테카를로 방법으로 시뮬레이션 하였다. 이를 위해서 공진기 내부 3차원 공간의 마이크로파 진폭과 위상을 COMSOL Multiphysics RF 모듈을 이용하여 계산하였다. 냉각된 온도에 의해 결정되는 가우시안 속도분포를 가지는 수만 개의 원자들을 생성하여 마이크로파와 각각 상호작용 후 전이확률을 계산하였다. 원자의 초기온도, 상호작용 시간에 따른 Rabi 및 Ramsey 마이크로파 공진신호를 얻었고 계산결과는 실험결과와 잘 일치하는 것을 알 수 있었다. 공진기 내에서 냉각 및 마이크로파 상호작용이 동시에 수행되는 원자시계는 중력을 무시할 수 있는 항법위성에 탑재하게 되면 지상에서 동작할 때 원자가 중력에 의해 떨어지면서 공진기에서 벗어나는 현상을 없앨 수 있다. 따라서 원자-마이크로파 상호작용 시간이 늘어나 공진신호의 선폭을 줄 일 수 있어서 안정도가 획기적으로 향상될 것으로 예상한다. 특히 실험으로 구현이 불가능한 미세중력 상황에서 원자시계의 특성 및 성능을 시뮬레이션을 통해 확인 할 수 있었다.

Keywords:

Rubidium, Loop-gap cavity, Monte Carlo, Atomic clock, Ramsey

E14.01

Colloidal 2D van der Waals Template for Synthesis of Uniform Bimetallic Oxide Nanoparticles

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Abstract:

The bimetallic oxide nanoparticles (BMONPs) are significant materials in various applications owing to excellent physical, chemical, magnetic, and optoelectronic properties. However, their tricky handling in size distribution control make them to stay out of limelight in various application fields. In addition, synthesis approaches have become complex due to many combinations of metals for BMONPs. In this study, the cobalt-molybdenum (CoMo) BMONPs with extremely narrow size distribution are synthesized by forming uniform Co NPs through the van der Walls (vdW) gap of colloidal MoS_2 as a natural template. To demonstrate expandability of metals, guest metals (Ni, Fe) and host transition metal dichalcogenides (WS_2) were also employed and successfully synthesized various compositional BMONPs with unified method. Furthermore, prepared CoMo BMONPs were used as transformation catalyst for carbon nanotubes (CNTs) growth. Consequently, the uniform size distribution of CoMo BMONPs was clearly proved by observing exceedingly narrow dimeter distribution of synthesized CNTs.

Keywords:

bimetallic oxide nanoparticles, van der Walls gap, uniform size distribution, transition metal dichalcogenides, thin multi-walled carbon nanotubes

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E14.02

Intercalation of Dipolar Molecules in MoS_2/WS_2 Heterobilayer

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Abstract:

Since the discovery of graphene, the two-dimensional transition metal dichalcogenides are of interest for their properties and tunability, such as external electric field and strain engineering. Such methods were well known as tuning the band gap of TMDCs. We found that, by using density functional theory, the change of band alignment of MoS_2/WS_2 heterobilayer was tuned by intercalating with a chemical molecule via the field effect of its dipole moment. This is analogous to the band structure modulation and band gap tuning in TMDC bilayers under external electric field via the giant Stark effect. The molecular dipole larger than about 10 Debye could sufficiently decrease the systemic band gap by ignoring offset dipole. The intercalating of dipolar molecules suggests a viable approach in a wide range of applications in the absence of the external sources.

Keywords:

dipole moment, hetero-bilayer TMDCs

E14.03

Enhancement of Stability in Two-Dimensional Organometal Halide Perovskites

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Abstract:

Recently, Ruddlesden–Popper two-dimensional organometal halide perovskites (2D OMHPs) are attracting attention because of the significant improvement in moisture stability and its compositional diversity compared to their 3D bulk counterparts. The large organic spacers in 2D OMHPs suppressed the penetration of water molecules from the surface into the octahedron layer of 2D OMHPs, suppressing their degradation mechanism and improving the long-term stability. However, despite this significant improvement in humidity stability, the lifetime improvement required for the commercialization of solar cells has not been achieved yet. In this work, therefore, we studied the effects of the external electric field on 2D OMHPs to further improve their humidity stability. The external electric field perpendicular to the octahedral layer changed not only the relative energy with the position of water molecules, but also the diffusion energy barrier, improving the humidity stability of the 2D OMHPs both thermodynamically and kinetically.

Keywords:

2D organometal halide perovskites, humidity stability, external electric field

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E14.04

Layer-number dependent optical properties of two-dimensional MoS_2

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Abstract:

화학증기증착법으로 성장된 2차원 MoS_2 층상 구조의 층수에 따른 라만 산란 및 광 발광 실험 결과를 보고한다. 원자힘현미경과 공간 분해된 라만 산란 실험을 통해 층수를 확인하였다. 동일한 영역에 대해 공간 분해된 광 발광 실험을 진행한 결과 이중 층 경계면 주위의 단일 층 영역에서 엑시톤 세기가 비균질적으로 증가함을 알 수 있었는데 이는 주로 경계면을 통한 전하이동에 의한 현상으로 분석된다. 층수 변화에 따른 편광 라만 산란 실험을 진행한 결과, 단일 층에서의 E′ 포논은 입사된 빛과 산란된 빛의 편광 방향 사이의 각도 변화와 무관하게 일정한 세기를 나타냈다. 반면, 다중 층에서 E′ 포논 세기는 입사된 빛과 산란된 빛의 편광 방향이 서로 수직할 때보다 평행할 때 더 큰 값을 보였고, 그 차이는 층수가 증가함에 따라 점차 커졌다. 포논 세기의 이러한 편광각 의존도 및 엑시톤 세기의 비균질적인 분포는 MoS_2 층상 구조 성장의 불완전성에 의한 것으로 분석된다. [이 성과는 2019년도 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임 (No. 2019R1A2C1003366)]

Keywords:

MoS2, exciton, optical phonon

2020 KPS Spring Meeting
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E15.01

Ranking Candidate Signals with Machine Learning in Low-Latency Searches for Gravitational Waves from Compact Binary Mergers

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Abstract:

In the multi-messenger astronomy era, accurate sky localization and low latency time of gravitational-wave (GW) searches are keys in triggering successful follow-up observations on the electromagnetic counterpart of GW signals. We, in this work, study the feasibility of adopting supervised machine learning (ML) method for scoring rank on candidate GW events. We consider two popular ML methods, random forest and neural networks. We observe that the evaluation time of both methods takes tens of milliseconds for ~ 45,000 evaluation samples. We compare the classification efficiency between the two ML methods and a conventional low-latency search method with respect to the true positive rate at given false positive rate. The comparison shows that about 10% improved efficiency can be achieved at lower false positive rate $\sim 2\times10^{-5}$ with both ML methods. We also present that the search sensitivity can be enhanced by about 18% at $\sim 10^{-11}$Hz false alarm rate. We conclude that adopting ML methods for ranking candidate GW events is a prospective approach to yield low latency and high efficiency in searches for GW signals from compact binary mergers.

Keywords:

gravitational wave, compact binary merger, machine learning

2020 KPS Spring Meeting
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E15.02

The TeV Gamma-ray Sky as seen by 300 Water Tanks – HAWC Overview and Results

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Abstract:

The High Altitude Water Cherenkov (HAWC) Observatory has continuously been observing the two-thirds of the TeV gamma-ray sky since 2015. The 2 sr field-of-view, >95% duty cycle, and sensitivity reaching over 100 TeV make HAWC a unique experiment in the field of High Energy Astrophysics. In this presentation, I will show some of the exciting highlights of the HAWC results such as the detection of extended gamma-ray "halos" from the Geminga and Monogem pulsars and the discovery of TeV gamma rays from the jet lobes of microquasar SS 433. I will also discuss some of the more recent results from HAWC on various sources both Galactic and extragalactic.

Keywords:

Gamma-ray Astrophysics, TeV Photons, Water Cherenkov, Galactic, Extragalactic

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E15.03

Cosmic-ray proton and helium spectra from the ISS-CREAM experiment

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Abstract:

The Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM) experiment is designed for measurements of energy spectra and elemental composition of cosmic rays. The ISS-CREAM experiment successfully took the data until Feb. 12, 2019 from the launch of the International Space Station (ISS) in August 2017. The ISS-CREAM instrument can measure protons to iron nuclei in the energy range of TeV – PeV. For the elemental identification of cosmic rays, we use the silicon charge detector (SCD) placed at the top of the ISS-CREAM payload. The four-layer SCD consists of 10,752 silicon pixels, and the active area in each layer is 78.2 x 73.6 cm^2. Each pixel is 1.57 cm x 1.37 cm x 0.05 cm in dimensions. A preliminary analysis shows good performance of the SCD throughout the flight with charge resolutions of 0.1 – 0.3e for protons to iron nuclei. Energy measurements are made with a sampling calorimeter which is below a carbon target and consists of twenty layers of tungsten plates and scintillating fibers. The calorimeter also provides the tracks of incident cosmic rays. We will report preliminary spectra of the protons and heliums of the high energy cosmic rays using the data accumulated on the ISS.

Keywords:

ISS-CREAM, cosmic ray, spectrum

2020 KPS Spring Meeting
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E15.04

Preliminary analysis of TAx4 hybrid trigger and events

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Abstract:

Since 2009 the Telescope Array (TA) experiment has observed air showers created by ultra-high energy cosmic rays (UHECRs) using a combination of ground array particle detectors and air-fluorescence induced UV detection telescopes. Making detection area 4 times larger and thus improving UHECR event statistics significantly, we have constructed TAx4 observatory since 2018, which contains a new 500 particle detectors and 3 telescope stations. We have deployed 270 detectors late 2018, and tuned and calibrated them up until now to have all in operation. While the TAx4 surface detector has superior statistics in measurements of the event arrival directions and the energy spectrum, it should be noted that the TAx4 fluorescence detector sees the full longitudinal profiles of the air showers in the atmosphere and therefore determines their energies more accurately than the TAx4 SD. Events seen in common by the TAx4 FD and SD are used for establishing the energy scale of the TAx4 SD. Also, the FD longitudinal profile is used for determining the mass composition of the primary comic ray particles, when the event geometries are well constrained by simultaneous FD and SD measurements. Such events are called “hybrid events”, and for this reason, the TA is often referred to as a “hybrid cosmic ray detector” in literature. Despite large differences in their stand-alone performances, both detector types complement each other in measuring important physical quantities. Since end of August 2019, hybrid triggers have been implemented in TAx4 SD. In this presentation I want to talk about Preliminary analysis of TAx4 hybrid trigger and TAx4 hybrid events.

Keywords:

Astroparticle physics, Telescope Array, TA, TAx4, cosmic ray, UHECR, astrophysics

2020 KPS Spring Meeting
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E15.05

Preliminary analysis on energies and arrival directions of UHECRs detected by TAx4 Surface Detectors

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Abstract:

Telescope Array(TA) is the project to study Ultra High Energy Cosmic Rays(UHECRs) from the hybrid detection of Fluorescence Detectors(FDs) and Surface Detectors(SDs). TAx4 was proposed to broaden detection area, and we constructed and deployed 260 SDs at Utah, USA. Since 2019, we have accumulated signals from SDs and reconstructed arrival direction and energies of UHECRs. We will present the preliminary result of energies and arrival directions of UHECRs detected by TAx4 SDs.

Keywords:

Cosmic Ray, Ultra High Energy Cosmic Ray, UHECR, Telescope Array, TAx4

E16.01

Direct communications of distant cells

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Abstract:

In recent decades, thin tubes connecting cells as far as up to a hundred micrometer *in vitro* have been recognized as a new pathway for long-distance communication between cells. However, it is not yet known how such a fine structure can be formed and remains robust for several hours. In this study, we revealed spatiotemporal processes of the intercellular tube formation, which is evolved from fine nanostructures of filopodial bridges (two-filopodia complex: DFB) to a single filopodial bridge (SFB). Two filopodia randomly interact via cell adhesion cadherin molecules on the filopodia. Surprisingly, the transition of DFB into SFB is triggered by a helical structure of DFB. Mechanical studies and computer-aided simulations strongly suggest that the development is likely that accumulated torsional energy in DFBs with the helical deformation breaks cadherin-cadherin interactions between two filopodia. And then, the retrograde actin flow of the released filopodium leaves a single bridge attached to a paired cell. Cadherin-cadherin clusters strongly support the single bride at the junction between the end of the bridge and the partner cell. Our research pinpointed the mechanistic questions in the battle lines.

Keywords:

Intercellular nanotube, Cellular communications, Cell biophysics

2020 KPS Spring Meeting
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E16.02

Imaging activity-dependent dynamics of endogenous Arc mRNA in neurons in vivo

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Abstract:

Local translation plays a crucial role in synaptic plasticity and memory consolidation. However, it has not been possible to follow the dynamics of memory-associated mRNAs in living neurons in response to neuronal activity in real time. Here we have developed a new mouse model to fluorescently label endogenous *Arc* mRNA (Das, et al., Science Advances, 2018). The immediate early gene *Arc* (also known as *Arg3.1*) is highly involved in the formation of long-term memory. Expression of *Arc* is tightly coupled to the activity of the neuron; *Arc* mRNA is rapidly produced in response to neural activity and transported to distal dendrites for local translation. We generated *Arc-PBS* mouse by knocking in 24 tandem arrays of PP7 binding site (PBS) in the 3′ untranslated region (3′ UTR) of the *Arc* gene. Using this mouse model, we simultaneously monitored calcium spikes and *Arc* transcription in live neurons and found that calcium activity was necessary but not sufficient for triggering *Arc* expression. We also found that blocking neuronal activity did not affect the mobility of *Arc* mRNAs. Two-photon imaging of the live mouse brain revealed immediate-early induction of *Arc* transcription in a subpopulation of neurons in the CA1 region of the hippocampus after contextual fear conditioning and fear memory retrieval. The technology as demonstrated in our work, including the transgenic strategy and high-resolution microscopy of living tissue, will shed light on the dynamic regulation of gene expression during learning and memory processes *in vivo*.

Keywords:

memory, Arc, two-photon microscopy

2020 KPS Spring Meeting
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E16.03

Bleaching-resistant Single-molecule Localization Microscopy

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Abstract:

Single-molecule localization microscopy (SMLM) reconstructs super-resolution images by accumulating precisly localized centroid positions of many fluorescent molecules. The spatial resolution, the highest among various super-resolution methods, is determined by both the precision and density of localization points (i.e. centroid positions of single molecules). While the localization precision has been improved up to sub-10-nm by developing high-photon probes (as in DNA-PAINT) as well as high-precision localization techniques (as in MINFLUX), the localization density is limited by photobleaching involved with permanent, chemical damage of fluorophore molecules. We overcome the photobleaching limit by uncovering new chemistry and classes of exchangable probes whose association and dissociation cycles replace bleached fluorophores with fresh probes in solution [1-2]. DNA-PAINT suffers from high fluorescent background from unbound fluorescent probes in solution that substantially slow down the imaging speed. We chemically reduce DNA-PAINT probes into a nonfluorescent state and improve the imaging speed up to two orders of magnitude, making DNA-PAINT capable of high-throughput super-resolution imaging [1]. For live-cell imaging that requires genetically encodable exchangeable probe, we introduce UnaG, a ligand-activatable fluorescent protein capable of reversible fluorescence recovery that allow for high localization density lasting for a long imaging period [2]. By combining UnaG with CRISPR imaging, we capture live-cell movie of chromatin structures composed of hundreds of super-resolution frames. We anticipate that super-resolution movies of genomic loci will unveil the chromatin structures and dynamics in individual cells that may reflect different states of the cell or the local nuclear environment.

Keywords:

super-resolution microscopy, chromatin structure, DNA-PAINT, Fluorescent Protein

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E16.04

Label-free iSCAT microscopy to study cellular structure and dynamics

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Abstract:

It is of great interest to visualize nano-scale objects in bioscience. Fluorescence microscopy, most powerful bioimaging tool to date, bears limitations in measurement time, time resolution, and sample preparation. To circumvent such problems, a new scattering-based method named iSCAT (interferometric scattering microscopy) has been recently developed. Since this technique relies on scattering signal from a nano-object and detects the interference of the signal with a constant reference, it is less prone to the aforementioned limitations. Here, we show our iSCAT imaging of biological cells and multi-protein focal adhesion complexes. The iSCAT technique enables us to visualize subcellular structures with remarkable spatial, temporal details and sharp contrast even without labeling [1]. In summary, the iSCAT technique would be an indispensable tool in visualizing the nanoscopic biological world.

This work was supported by IBS-R023-D1 and NRF-2019R1H1A2077487.

[1] J.-S. Park, I.-B. Lee, H.-M. Moon, J.-H. Joo, K.-H. Kim, S.-C. Hong*, and M. Cho*, *Chem. Sci.*, **9**, 2690 (2018). J.-S. Park, I.-B. Lee, H.-M. Moon, J.-S. Ryu, S.-Y. Kong, S.-C. Hong*, and M. Cho*, *submitted*.

Keywords:

interferometric scattering microscopy, label-free imaging, cellular dynamics, focal adhesions

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E2.01

Status of AMoRE

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Abstract:

The AMoRE is an experiment to search for neutrinoless double beta decay of ^{100}Mo using molybdate scintillation crystals and a cryogenic detection technique. Detection of both thermal and scintillation signals using metallic magnetic calorimeter (MMC) sensors provides high energy resolution and efficient particle discrimination. From the pilot phase, we have understood the sources of backgrounds and have learned how to reduce them. In Spring 2020, AMoRE-I starts with ~6 kg of crystals in the Yangyang underground laboratory. AMoRE-II will be launched at the Yemilab, a new IBS underground laboratory at Jeongseon, with ~200 kg of molybdate crystals.

Keywords:

$0\nu\beta\beta$, Molybdate crystal, MMC, low temperature, underground

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E2.02

Status of AMoRE-I

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Abstract:

Advanced Mo-based Rare process Experiment (AMoRE) is an international collaboration project searching for neutrinoless double beta decay (0νββ) of 100Mo using molybdenum-based enriched crystals in a cryogenic condition. The project aims at operating the detector in zero-background condition to detect this extremely rare decay event. Thus, we carried out 3 years of pilot phase during which we identified and reduced various background source; the experiments have been performed at milli-Kelvin temperatures in order to minimize the thermal fluctuation. In the next phase of the project with larger size detectors, AMoRE-I, we are going to use 18 molybdate crystals with a total mass of 6 kg for simultaneous detection of heat and light signals based on Metallic Magnetic Calorimeter (MMC) readouts. It is going to be carried out in the dilution refrigerator installed at Yangyang laboratory which is the same one used in the pilot phase soon.

Keywords:

Neutrinoless Double Beta Decay, Cryogenics, Underground Experiment, Metallic Magnetic Calorimeter, AMoRE

2020 KPS Spring Meeting
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E2.03

A study on AMoRE light detector

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Abstract:

The AMoRE is an experiment searching for neutrinoless double beta decay of 100Mo using molybdenum-based crystals with cryogenic sensors.
This experiment uses both photon (light) and phonon detectors. In particular, the ratio between light signal observed by photon detector and heat signal measured by phonon detector provides a parameter that distinguishes alphas from beta/gamma signals. We can study characteristics of light detector by analyzing its signal. In addition, it is possible to study alpha decays on crystal surface through events occurring directly in the light detector.

Keywords:

AMoRE, neutrinoless double beta decay, light detector, Ge-wafer, CaMoO4

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E2.04

Alpha Background Simulation for AMoRE-Pilot Experiment

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Abstract:

The Advanced Mo-based Rare process Experiment (AMoRE) is an experiment for neutrinoless double-beta decay search of ^{100}Mo using molybdate crystals. AMoRE-Pilot is the first stage of AMoRE experiment which was operated in Yangyang underground laboratory, South Korea. AMoRE experiment requires extremely low radioactive background contributions from crystals and detector materials. Alpha contamination of radioactive isotopes in crystals might be produced from chemical powder that used in crystal growing or during polishing process. Alpha contamination also can be originated from detector component which is directly facing to the crystal such as reflector and photon copper frame. To suppress the radioactive background and optimize the crystals in the future, understanding of the background sources and their contributions are important. To investigate those background, a Monte Carlo simulation was performed. Effects of radioactive isotopes such as ^{238}U, ^{232}Th, and ^{235}U including their daughter isotopes inside crystal and ^{210}Pb inside reflector were simulated. But those background sources are not enough to explain alpha background spectrum from measurement. Additionally, surface alpha simulation was performed. We found that energy distribution changes sensitively with variation of surface depths. Surface simulation can explain the measurement data well. Details about alpha background study with Monte Carlo simulation will be presented.

Keywords:

alpha, AMoRE, background, GEANT4, surface alpha

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E2.05

Status of AMoRE-Pilot data analysis and background modeling

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Abstract:

AMoRE (Advanced Mo-based Rare process Experiment) is searching for neutrinoless double beta decay of Mo-100 with the help of molybdate-based scintillation bolometric detectors operated at milli-Kelvin temperature.
Simultaneous registration of scintillation light and heat (phonon) signals makes it possible discrimination between beta- and alpha-particles to reduce background caused by trace U/Th contamination of the detectors. A pilot experiment, AMoRE-Pilot, was completed in 2019 with six 48deplCa100MoO4 (CMO) crystals of total mass ~1.9 kg in a low-background cryostat at the Yangyang underground laboratory with the minimum overburden of 700 m. In data analysis, Risetime in phonon waveform and Light/Heat ratio were used for particle identification. The identified alpha events were used to infer the internal background activity of the crystal. And beta/gamma events were used to background modeling of the detector based on the internal background and MC simulation results. We will present current status of data analysis and background modeling.

Keywords:

neutrinoless double beta decay

2020 KPS Spring Meeting
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E2.06

Alpha counting measurements for rare event search experiment at CUP

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Abstract:

The Center for Underground Physics (CUP) is conducting two main rare event search experiments, the AMoRE searching for neutrinoless double beta decay and the COSINE searching for WIMP dark matter running at the Yangyang underground laboratory(Y2L). It is important to reduce levels of radioactivities (U/Th/Pb) in respective detector materials of the two rare event experiments. There are three techniques generally used for radioactive assay in the CUP, inductively coupled plasma mass spectrometry(ICP-MS), high purity germanium detector(HPGe) and alpha counter. Especially alpha counter with ionization chamber type has an advantage of distinguishing the surface alpha contamination which affects the detectors' sensitivities among other techniques. For reducing the cosmic ray induced background, the alpha counter placed deep underground at the Y2L. In this talk, alpha counting measurements of detector materials to be used in the rare event search experiments will be presented.

Keywords:

Alpha counter, Ionization chamber, Rare event experiment, Radioactive assay, Y2L

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E2.07

Detection possibility of a new gauge boson with the SHiP experiment

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Abstract:

The SHiP (Search for Hidden Particles) experiment is a new general-purpose experiment to be installed in a beam dump facility at the CERN SPS to search for hidden particles. In this talk, we discuss detection possibility of a new light gauge boson (so called dark Z) with the SHiP experiment.

Keywords:

SHiP experiment, Dark Z

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E2.08

Development of a Novel Detector for KNU Advanced Positronium Annihilation Experiment (KAPAE)

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Abstract:

The KNU Advanced Positronium Annihilation Experiment (KAPAE) aims to study new physical phenomena by accurately measuring the annihilation of positronium. Positronium refers to the bound state of an electron positron pair. This pair usually results in two gamma decay due to the well-known pair annihilation. This two gamma annihilation occurs due to para-positronium (p-Ps) having a singlet spin state. The positronium can annihilate into an ortho-positronium (o-Ps), which is a triplet spin state. The o-Ps generally has decay of 3γ or rare 5γ and 7γ decay as well. Therefore, accurate measurement of positronium decay provides an opportunity to study a variety of new physical phenomena. We planned KAPAE for the study of positronium annihilation and developed a novel detector for this purpose. The developed detector for KAPAE is made of 393 channels of silicon photomultipliers (SiPMs) and 200 bismuth germinate (BGO) scintillators. In particular, the trigger part uses a direct measurement method to increase efficiency. It is expected to study precisely C-parity violation, invisible and rare decay using the novel detector developed for KAPAE.

Keywords:

Positronium, KAPAE, SiPM

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E2.09

Geant4 profiling on an evolving computing architecture

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Abstract:

Many efforts have been made to develop physics software that saves central processing unit (CPU) time and optimizes memory size. The High Luminosity Large Hardon Collider (HL-LHC) project that is currently being planned by CERN requires greater storage and a larger CPU for simulation data. Therefore, the CPU and the memory size of the Geant4 simulation tool kit must be optimized. To study the evolving computing architecture, we have performed Geant4 simulations and brachytherapy profiling of low-energy physics using the KISTI-4 and KISTI-5 supercomputers. The results enable the optimization of high performance computing with Geant4 in the evolving computing architecture.

Keywords:

Geant4 , Profiling, Supercomputer, Simulation

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E2.10

Overview of Neutrino Elastic-scattering Observation with NaI(Tl) : The NEON experiment

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Abstract:

Neutrino coherent scattering in an NaI(Tl) crystal using reactor anti-neutrinos has not been measured so far and the measurement can provide interesting physics such as dependence on the target nucleon numbers and non-standard interactions. The ready-made NEON prototype detector consists of a total of 10 kg NaI(Tl) target mass with a sub-keVee threshold which is expected to be installed 24 meters from the Hanbit reactor core. Shields include 40 cm liquid scintillator, 10 cm leads, 30 cm HDPE for vetoing various background radiations. Sensitivity studies show that 1 year of reactor-on data and 4 months of reactor-off data of this prototype can provide roughly 3-sigma evidence of the neutrino coherent scattering. Overview and current status of the NEON experiment will be described in this talk.

Keywords:

Neutrino, Coherent scattering. NaI(Tl)

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E3.01

f0(980) resonance production with ALICE

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Abstract:

Short-lived resonances are powerful probes to understand the hadronic phase in ultra-relativistic heavy-ion collisions, due to their lifetimes of ~10 fm/c, comparable to the time span between the chemical and kinetic freeze-out. We present the production of f0(980) at mid-rapidity (|y|<0:5). The measurement is performed with ALICE at the LHC and the particles are reconstructed in the f0(980)→ $\pi^+\pi^-$ decay channel. The presentation includes details of the signal extraction, transverse momentum spectra, particle yield and mean transverse momenta of f0(980) in various collision systems. Furthermore, we discuss a possible internal structure of the f0(980) resonance with the nuclear modification factor and the particle yield ratios.

Keywords:

ALICE, f0(980), scalar meson, light flavour, mesonic molecule

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E3.02

Study of the string shoving model in Pythia8 for long-range correlation in pp collisions

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Abstract:

The main purpose of relativistic heavy-ion collision experiments is to understand the Quark-Gluon Plasma (QGP) which is a very hot and dense QCD matter produced in heavy-ion collisions. Early results from the RHIC such as suppression of high p_T particles and elliptic flow have been supported by a scenario of strongly interacting QGP. Strikingly, various studies of particle correlations in small collision systems like pp and p-Pb collisions have shown a clear long-range correlation called ridge; this is very similar with those seen in the results of heavy-ion collisions. Several theoretical models have been proposed, but these results in small collision systems are clearly understood yet. A model considering an environment of dense strings in pp collisions called the string shoving model is able to describe the long-range particle correlation in high-multiplicity pp collisions. Since this model is implemented in the Pythia8 Monte Carlo event generator, it is allowed to perform a study to compare with various experimental measurements. We will present the study of this model to understand the origin of collectivity in small collision systems.

Keywords:

small system, heavy-ion physics, correlations, Pythia, string shoving

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E3.03

Elliptic flow studies of Upsilon states in PbPb collisions with the CMS experiment

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Abstract:

At very high temperature and energy densities created by heavy ion collisions at the Large Hadron Collider(LHC), quarks and gluons are expected to be deconfined, forming the Quark-Gluon Plasma (QGP) predicted by Quantum chromodynamics(QCD). The studies of the azimuthal anisotropy of the hadrons emitted in heavy ion collisions have provided meaningful information on the collective behavior of the Quark-Gluon Plasma. In this presentation, the second-order Fourier coefficients v_2 of Υ(1S) and Υ(2S) mesons obtained for PbPb collisions at 5.02 TeV is summarized. The data were collected by the CMS experiment during the 2018 LHC run.

Keywords:

CMS, upsion, heavy ion, flow, v2

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E3.04

Measurement of Ξ0c baryon in pp collisions with ALICE at the LHC

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Abstract:

양자색역학(Quantum ChromoDynamics, QCD)는 표준 모형을 기술하는 이론 중 하나로 우주를 이루는 기본 입자를 이해하기 위해서는 QCD의 이해가 필요하 다. 표준 모형을 이루는 기본 입자 중 하나인 Charm Quark (c)는 약 1.3GeV/c의 질량을 가지고 있다. 이 쿼크는 현재까지 발견된 쿼크 중 비교적 큰 질량을가지고있 다. 기본입자충돌에서 c를 포함한 중입자의 생성은 잘알려져있지 않다. c는 QCD 척도 변수보다 큰 값의 질량을 가지고 있어 c로 이루어진 강입자는 횡단 운동량 (transverse momentum)이 낮은 영역에서도 섭동 이론으로 계산 가능하다. 따라서 c를 포함한 중입자는 중이온 충돌(heavy ion collision)에서 입자 생성 메커니즘을 이해하는데 아주 중요한 역할을 한다. 또한, c를 포함한 중입자는 쿼크-글루온-플 라즈마(Quark-Gluon Plasma,QGP)내에서 자유도에 대한 이해를 제공한다. 그러므로 중이온 충돌에서 c를 포함한 중입자의 측정은 QGP의 특성을 이해하는데 아주 중요한 역할을 한다.
본 연구에서는 Ξ0c가 전자를 포함해 붕괴하는 채널을 이용해 Ξ0c의 생성량을 측 정하고자 한다. 전자를 포함 하는 붕괴 채널을 이용한 분석은 붕괴 확률(branching ratio)가 크고, background가 적다는 장점이 있지만 중성미자를 포함하여 Ξ−의 질량분포의 꼭지점이 나타나지 않고, 불확정성이 크다는 단점이 있다. 연구 방법은 다음과 같다.
Cut을 가해 전자와 Ξ를 구별해 낸 뒤, 전자와 Xi을 결합하여 right sign pair과 wrong sign pair을 만든 다. rignt sign pair은 Ξ0c 붕괴에서 생성되는 입자들의 쌍을 말하고 wrong sign은 다른 쌍을 말한다. 이 후 right sign에서 wrong sign을 빼고 효율을 보정한다. 이를 통하여 실제 Ξ0c의 붕괴에서 생성된 실제 쌍의 개수를 알 수 있다. 중성미자는 검출기에 검출되지 않으므로 횡단 운동량 분포에서 Ξ0c 질량의 피크 가 발견되지 않는다. 따라서 Unfolding을 통해 Ξ0c의 횡단 운동량과 충돌 단 면적을 구한다. 마지막으로 systematic error를 계산한다. systematic error는 cut을 조금씩 변화시켜가며 결과가 어느정도 바뀌느냐에 따라 결정한다.

Keywords:

QGP, Charmed baryon

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E3.05

Recent progress of nPDFs studies with electroweak probes with the CMS detector

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Abstract:

Nuclear parton distribution functions (nPDFs) of quarks and antiquarks, which are the probability density functions for finding a parton within the bounded proton, is the steady items in heavy ion physics.
Electroweak probes such as Drell-Yan process or W bosons which are produced in the early stages of the heavy ion collisions have been used to investigate the nPDFs.
In this presentation, the recent progress of the electroweak probes production in proton-lead and lead-lead collisions with the CMS detector and comparisons to theoretical calculations will be shown.

Keywords:

Drell-Yan, nPDFs, CMS, heavy ion, Electroweak probes, W bosons

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E3.06

ALICE에서 수행한 질량 중심 에너지 5.02TeV 납-납 충돌에서 바닥쿼크를 포함한 강입자로 부터 붕괴한 전자의 측정

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Abstract:

양자색역학에 따르면 높은 온도, 높은 밀도 상태에서 물질을 이루는 쿼크와 글루온이 자유상태가 되고, 이러한 상태는 고에너지 중이온 충돌실험을 통해 생성되고 탐구할 수 있다. 표준 모형에 해당하는 입자들 중 b쿼크(mb~4.18GeV/c)와 c쿼크(mc~1.28GeV/c)는 질량이 무거워 주로 충돌 초기에 생성되고, 충돌을 통해 생성된 고온/고밀도의 물질의 진화과정을 지나 측정되기 때문에 물질을 연구하는데 중요한 역할로 작용한다. 특히 입자가 물질을 통과할 때 충돌과 복사에 의해 에너지를 잃고, 이러한 에너지 손실은 입자의 색전하와 질량에 의존한다고 알려져있다. b쿼크가 c쿼크에 비해 약 3배가량 무겁기 때문에 각각의 핵 보정 인자(RAA)를 계산해 비교 함으로써 물질 안에서의 에너지 손실에 대한 중요한 정보를 얻을 수 있다.
본 연구에서는 ALICE에서 수행한 질량 중심 에너지 5.02TeV 납-납 충돌 실험에서 b쿼크를 포함한 강입자로부터 붕괴한 전자를 측정 함으로써 b쿼크 생성을 연구하였다. 충격 변수를 이용한 방법을 통해 연구하였고, 두 충돌 중심도에서의 비교, 무거운 쿼크를 포함한 강입자에서 붕괴한 전자의 핵 보정 인자와 비교함으로써 b쿼크의 에너지 손실의 밀도 의존성, 질량 의존성을 확인하였다.

Keywords:

QGP

E3.07

Signatures of collectivity in small collision systems observed by PHENIX experiment at RHIC

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Abstract:

A wide variety of recent measurements from small systems indicate that there are collective flow phenomena in these systems, which are well described by hydrodynamics. However, it is widely understood that all flow measurements are affected by nonflow correlations. In order to disentangle the genuine hydrodynamical flow from other contributions, we have systematically studied the v_2 as a function of p_T and eta in p+Au and d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with a mixture of different detector combinations and by comparing several nonflow subtraction methods. We have also measured 4-particle cumulants in p+Au and d+Au at $\sqrt{s_{NN}}$ = 200 GeV with subevents, which kinematically suppress nonflow via removal of short-range correlations. As found in heavy ion collisions, the quark mass dependence of the flow will further provide an evidence of collective effects. PHENIX has measured v_2 vs p_T of muons at forward rapidity originating from heavy quark decays in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV will show these results and discuss implications for the underlying mechanism that drives both light and heavy quark collectivity.

Keywords:

small systems, flow

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E3.08

K* and K_1 production from heavy-ion collision

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Abstract:

We study the production of K* and K_1 mesons in heavy-ion collision.
For that purpose, we first construct an effective model that reproduces well the experimentally measured decay width of these particles.
We then calculate the dissociation of the K_1 meson by light mesons in the hadronic stage of heavy-ion collision.

Keywords:

K*, K1, heavy-ion collision

2020 KPS Spring Meeting
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E3.09

Azimuthal anisotropy and nuclear modification of Upsilon states in heavy-ion collisions with the CMS detector

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Abstract:

Bottomonia are produced by hard scattering in the early times of a relativistic heavy-ion collision, therefore, they serve as excellent probes of the quark gluon plasma (QGP). Early CMS data showed that the yields of the Υ(1S), Υ(2S), and Υ(3S) mesons are suppressed in PbPb relative to those in pp. In order to interpret the results in PbPb collision unambiguously, the cold nuclear matter effects need to be quantitatively estimated using pPb collisions data. Additionally, the measure- ment of the elliptic azimuthal anisotropy of bottomonium states have been suggested as a powerful tool to study the different in-medium effects such as dissociation and regeneration. In these proceedings, the new bottomonium results are reported for pPb and PbPb collisions data at 5.02 TeV with the CMS detector. First, the nuclear modification factors of the Υ(1S), Υ(2S), and Υ(3S) mesons are presented in pPb collisions as functions of the transverse momentum and rapidity. Then, the new measurements of the azimuthal anisotropy (v2) of the Υ(1S) and Υ(2S) mesons are reported using PbPb collisions data at 5.02 TeV taken in 2018.

Keywords:

Quark Gluon Plasma , QGP, Quarkonia, Flow, Upsilon

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E3.10

Two-particle correlation via Bremsstrahlung

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Abstract:

In high-energy heavy-ion collision experiments, a rapidity-independent shape called “Ridge” structure appears in two-particle angular correlation. This structure in nucleus-nucleus collisions has been explained by hydrodynamics, especially with elliptic and higher-order flows. However, recently, in small collision systems like in proton-proton collisions with high-multiplicity, the Ridge structure is also discovered. This situation is difficult to understand since it is regarded that the thermalized and dense medium such as quark-gluon plasma (QGP) is hard to produce in small systems. Thus, we propose the pure kinematic mechanism to describe this.
We consider the energy and momentum loss mechanism of jet particles when this collides with medium bulk. Jet particles collide with several partons in medium bulk and lose some energies and momenta while passing through the medium bulk. These energies and momenta are delivered from jet particles to medium partons through photon/gluon radiation, and the collective motion might occur along the jet direction. In this study, we concentrate on the Bremsstrahlung process to consider this situation simply.

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E4.01

Atomic-scale Metal-Insulator Transition in $SrRuO_3$ Ultrathin Films Triggered by Surface Termination Conversion

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Abstract:

The metal-insulator transition (MIT) in transition-metal-oxide is fertile ground for exploring intriguing physics and potential device applications. Here, we report an atomic-scale MIT triggered by surface termination conversion in $SrRuO_3$ ultrathin films. Uniform and effective termination engineering at the $SrRuO_3$(001) surface can be realized via a self-limiting water-leaching process. As the surface termination converts from SrO to RuO_2, a highly insulating and non-ferromagnetic phase emerges within the topmost $SrRuO_3$ monolayer. Such a spatially-confined MIT is corroborated by systematic characterizations on electrical transport, magnetism, and scanning tunneling spectroscopy. Density functional theory calculations and X-ray linear dichroism further suggest that the surface termination conversion breaks the local octahedral symmetry of the crystal field. The resultant modulation in 4*d* orbital occupancy stabilizes a non-ferromagnetic insulating surface state. This work introduces a new paradigm to stimulate and tune exotic functionalities of oxide heterostructures with atomic precision.

Keywords:

SrRuO3, Metal-insulator transition, Crystal field, Surface termination

2020 KPS Spring Meeting
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E4.02

Observation of Kondo hybridization with orbital-selective Mott phase in 4d $Ca_{2-x}Sr_xRuO_4$

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Abstract:

The physics of heavy fermion (HF) state, usually manifested in *f*-electron systems [1], was recently observed in several 3*d*-orbital systems such as van der Waals ferromagnet Fe_3GeTe_2, transition metal oxide (TMO) LiV_2O_4 and Fe-based superconductors [2-4]. However, even the very existence of HF behavior in more extended 4*d* orbital systems has not been confirmed, not to mention its underlying mechanism. Here, we report our concentration and temperature dependent angle-resolved photoemission spectroscopy study results of $4d$-t_{2g} multi orbital TMO, $Ca_{2-x}Sr_xRuO_4$ which show an unexpected Kondo hybridization. Lowering the Sr concentration x below 0.5, we observe a massive spectral weight transfer and opening of soft 100 meV-orbital selective Mott (OSM) gap in $4d_{xy}$ γ band. The localized γ band is found to Kondo hybridize with itinerant $d_{xz/yz}$ β band, resulting in a massive spectral weight suppression near Fermi level. We propose that the OSM phase with Kondo hybridization can be explained by the critical role of the octahedral tilting. Our result demonstrates the first Kondo hybridization behavior in 4*d* TMO and expands the material boundary for HF behavior to 4*d* multi-orbital systems.

[1] G. R. Stewart, Heavy-fermion systems. Rev. Mod. Phys. **56**, 755-787 (1984).
[2] Shimizu, Yasuhiro, et al. "An orbital-selective spin liquid in a frustrated heavy fermion spinel LiV_2O_4." *Nature communications* **3** (2012): 981.
[3] Wu, Y. P., et al. "Emergent Kondo Lattice Behavior in Iron-Based Superconductors AFe_2As_2 (A= K, Rb, Cs)." *Physical review letters* **116.14** (2016): 147001.
[4] Zhang, Yun, et al. "Emergence of Kondo lattice behavior in a van der Waals itinerant ferromagnet, Fe_3GeTe_2." *Science advances* **4.1** (2018): eaao6791.

Keywords:

orbital-selective Mott transition, 4d/5d multi orbital transition metal oxide, Kondo hybridization, Heavy fermion, Ca2-xSrxRuO4

E4.03

Electronic origin of the octahedral rotation in perovskite oxides

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Abstract:

One of the key goals in the research of perovskite transition metal oxides (TMOs) is to design and control their physical properties, for which MO_6 (M=transition metal) octahedron rotation (OR) is considered to be one of the key control parameters. Thus, changing OR at will might be one of the ways to obtain desired physical properties in perovskite materials. However, in spite of importance, there are only limited number of reports on controlling OR. The main reason is that the OR angle is believed to be an inherent characteristic of a material determined by the steric effect stemming from the sizes of constituent atoms. In my talk, our pump-probe X-ray scattering result reveals that OR in $SrRuO_3$ can be suppressed with pump-light. With the help of first-principle calculation, we revealed that the OR in $SrRuO_3$ does not come from conventional steric effect, but from excitonic mechanism, which suggests possible control of OR via charge carrier doping.

Keywords:

Octahedral rotation, Perovskite, pump-probe X-ray scattering

2020 KPS Spring Meeting
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E4.04

Spin-orbit coupled Hund's metal Sr_2RuO_4 in the vicinity of van Hove singularity

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Abstract:

We investigate a correlated material Sr_2RuO_4 in which Hund's coupling is known to give rise to exotic correlation effects such as orbital selectivity, incoherent regime at low temperature, and large renormalization masses. We analyze its magnetic and electronic properties at zero and very low temperature by using density functional theory + dynamical mean-field theory. Its orbital-dependent deviation from Fermi liquid along with temperature manifests the Hund's metallicity. Doping toward van Hove singularity further promotes the deviation and orbital dependence at very low temperature, which agrees well with previous experiments. Spin-orbit coupling gives Femi surface and spectral weights very similar to experimental measurements. It also significantly enhances magnetic susceptibility of this system at low temperature. This is mostly attributed to enhancement of van Vleck part of the susceptibility, while the other contribution from long-lived moment or Curie part is little sensitive to spin-orbit coupling and is expected to dominate high temperature region.

Keywords:

Sr2RuO4, DFT+DMFT, Hund's metal, correlated metal, spin-orbit coupling

E4.05

Dispersive magnetic excitations with dominant bond-directional exchange interactions in a honeycomb lattice iridate alpha-Li_2IrO_3

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Abstract:

We report on resonant inelastic x-ray scattering to reveal dispersive magnetic excitations in a honeycomb lattice iridate alpha-Li_2IrO_3. The main dispersive excitation reaches the highest energy 25 meV at (h, k) = (0.32, 0) of the magnetic Bragg peak, while the lowest energy 20 meV at (0, 0) and (−1, 0). This observation is compared with the linear spin-wave theory based on a generic nearest-neighbor spin model. It is found that a dominant bond-directional Kitaev interaction of order 20 meV is required to explain the energy scale observed in our study. The observed excitations are understood as steming from optical magnon modes whose intensity is modulated by a structure factor, resulting in the apparent momentum dependence. In line with the dominant Kitaev interacion, strong diffuse magnetic scattering rising from the short-range magnetic correlation well above T_N is observed. In contrast to a sister compound Na_2IrO_3, this diffuse scattering lacks the C_3 rotational symmetry of the honeycomb lattice, suggesting that the bond anisotropy is non-negligible in alpha-Li_2IrO_3.

Keywords:

resonant inelastic x-ray scattering, magnon, Kitaev quantum spin liquid, iridate, magnetic frustration

E4.06

Doping and Temperature Evolutions of Optical Response of $Sr_3(Ir_{1-x}Ru_x)_2O_7$

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Abstract:

We studied temperature and doping evolution of the optical response of the J_{eff} = 1/2 Mott system $Sr_3(Ir_{1-x}Ru_x)_2O_7$ in a wide doping range of $0 \leq x \leq 0.80$. The ground state of the system evolves from the Mott insulator into a correlated metallic state with increasing x across a critical Ru concentration near $x = 0.34$. The optical spectra in the low-energy region barely change with x in the region below and above $x = 0.34$. This indicates a percolative nature of the insulator-metal transition. The extended Drude model analysis on the metallic compounds reveal a linear frequency dependence of the scattering rate, which is one of hallmarks of strange metallic behavior.

We also discuss phonon dynamics of $Sr_3(Ir_{1-x}Ru_x)_2O_7$ system. We found that the phonon modes of the $x = 0.34$ compound in close proximity to the Ru-doping-driven insulator-metal transition show highly asymmetric fano-type line shapes. From the analyses of the doping and temperature dependences of the phonon modes, we suggest that the asymmetry of the phonon modes can be attributed to the spin-phonon coupling, activated by a minute amount of mobile carriers.

Keywords:

Layered iridate, strongly correlated system, 5d transition metal oxide, spin-phonon coupling

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E4.07

Nonsymmorphic Dirac semimetal and carrier dynamics in doped spin-orbit-coupled Mott insulator Sr_2IrO_4

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Abstract:

A Dirac fermion emerges as a result of interplay between symmetry and topology in condensed matter. Current research moves towards investigating the Dirac fermions in the presence of many-body effects in correlated system. Here, we demonstrate the emergence of correlation-induced symmetry-protected Dirac semimetal state in the lightly-doped spin-orbit-coupled Mott insulator Sr_2IrO_4. We find that the nonsymmorphic crystalline symmetry stabilizes a Dirac line-node semimetal and that the correlation-induced symmetry-breaking electronic order further leads to a phase transition from the Dirac line-node to a Dirac point-node semimetal. The latter state is experimentally confirmed by angle-resolved photoemission spectroscopy and terahertz spectroscopy on $Sr_2(Ir,Tb)O_4$ and $(Sr,La)_2IrO_4$. Remarkably, the electrodynamics of the massless Dirac carriers is governed by the extremely small scattering rate of about 6 cm^{-1} even at room temperature, which is iconic behavior of relativistic quasiparticles. Temperature-dependent changes in electrodynamic parameters are also consistently explained based on the Dirac point-node semimetal state.

Keywords:

Dirac semimetal, Nonsymmorphic symmetry, correlation-induced symmetry-breaking electronic order, doped Mott insulator Sr2IrO4

2020 KPS Spring Meeting
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E5.01

Aharonov-Bohm interference in a triangular network of one-dimensional states in marginally twisted bilayer graphene

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Abstract:

The electronic properties of graphene superlattices have attracted intense interest that was further stimulated by the recent observation of novel many-body states at 'magic' angles in twisted bilayer graphene (BLG). For very small ('marginal') twist angles of ~0.1°, BLG was shown to exhibit a strain-accompanied reconstruction that results in submicron-size triangular domains with the Bernal stacking. If the interlayer bias opens an energy gap inside the domain regions making them insulating, marginally-twisted BLG is predicted to remain conductive due to a triangular network of one-dimensional (1D) states hosted by domain boundaries. Here we study electron transport through this network and report giant Aharonov-Bohm oscillations persisting to temperatures above 100 K. At liquid helium temperatures, the network's resistivity exhibits another kind of oscillations that are a function of carrier density and accompanied by a sign-changing Hall effect. The latter are attributed to consecutive population of the flat minibands formed by the 2D network of 1D chiral states inside the gap. Our work shows that marginally twisted BLG is markedly distinct from other 2D electronic systems, including BLG at larger twist angles, and offers a fascinating venue for further research.

Keywords:

graphene, twisted bilayer graphene, quantum interference, topology

2020 KPS Spring Meeting
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E5.02

Phonon- and layer-number dependent electron-phonon scatterings in WSe_2 vertical tunnel junctions

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Abstract:

Electron–phonon scattering in solid-state systems is a pivotal process in determining many of key physical quantities such as charged carrier mobilities and lattice thermal conductivities. Here, we report electron tunneling measurements with a semiconducting transition metal dichalcogenide, WSe_2, as the tunnel medium. In van der Waals (vdW)-coupled vertical heterostructures, inelastic quantum tunnel events activated by turbostratic electron–phonon scatterings constructively establish an adjunct transport channel, which drastically increases its loads in vertical charge flows with increasing tunnel medium thickness. Phonons interacting with the tunnel electrons are layer-number dependent, varying by mono-and triple-layer *vs*. bi- and fourth-layer WSe_2. In addition, we find out that second-order electron–phonon scatterings become conspicuous in the multilayered films, involving assorted phonons in the tunnel media and the vdW heterojunctions.

Keywords:

electron-phonon scattering, inelastic tunneling spectroscopy, two-dimensional semiconductors

2020 KPS Spring Meeting
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E5.03

Transport signature of spin Kosterlitz-Thouless transition in 2D magnetic materials and superconductors

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Abstract:

The theory of the Berezinskii-Kosterlitz-Thouless (BKT) phase transition was formulated to describe the 2D phase transition of easy-plane spin ordering as well as superfluidity. The BKT transition being topological in nature, i.e. not characterized by a local order parameter, its detection has been challenging. The BKT transitions in the latter cases have been observed in experiments, much of which involves transport signatures, such as the current-voltage relation in a thin superconducting film being non-linear below the BKT transition and linear above the BKT transition. By contrast, the experimental efforts to detect the spin BKT transition in solid state systems emerged only in the last few years, stimulated by fabrication of atomic monolayers of van der Waals magnetic materials such as NiPS3 and CrCl3. Interestingly, the spin BKT transition can also occur in the thin film of a spin-triplet superconductor, and thin film samples have been successfully prepared for one of the candidate material, the Ruddlesden-Popper transition metal oxide Sr2RuO4. This recent development in sample fabrication has been accompanied by a corresponding development of spin-transport measurements, offering a tantalizing opportunity to discover novel transport phenomena of spin, which should be expected as the spin, unlike the particle number, is not conserved. In this talk, we show that this non-conservation of spin leads to a distinct signature in spin transport for the spin BKT transition, with the superfluid spin transport below the BKT transition and the exponentially decaying spin transport above the BKT transition.

Keywords:

Berezinskii-Kosterlitz-Thouless (BKT) phase transition, van der Waals magnetic materials, spin-triplet superconductor, superfluid spin transport

2020 KPS Spring Meeting
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E6.01

Thermal Transport Theory for Non-Solid Matter

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Abstract:

Recently, machine learning (ML) methods are widely used to calculate total energies of materials as the sum of energies of individual atoms. Using ML-based many-body potentials, it thus becomes practical to perform large-scale atomistic simulations with ab initio quality. Here, within the Green-Kubo linear response theory, we discuss the physical meaning and role of the ML-inferred atomic energies in the atomistic description of heat transport in condensed matter. Using solid-liquid hybrid phases of Cu_2S as an example, we demonstrate how the proposed thermal transport theory can be used to accurately calculate thermal conductivity of non-solid materials.

Keywords:

Heat transport; Machine learning; Density functional theory

2020 KPS Spring Meeting
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E6.02

Fast search for high-ZT SnSe-based alloys from machine learning prediction

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Abstract:

The thermoelectric effect is one of the core technologies for recycling energy by converting heat to electricity. It has been the ultimate goal to achieve high-performance TE materials through optimizing materials. Recently, tin selenide (SnSe) has been considered as a promising material with high ZT values, and various modifications have been tried to enhance the TE performance such as incorporation foreign atoms into the lattice, oxygen reduction, and increase of phonon scatters. Among these optimizing processes, we focus on extracting doping/alloying knowledge on TE performance with a data-driven search, because the interaction between an incorporated foreign atom and the host material is too complex to find optimal dopants based on computational studies or theoretical analysis. In this talk, we will present the complete procedure of the data-driven search for SnSe-based high *ZT* materials. We prepared datasets of TE properties of SnSe alloys generated from full-cycle TE experiments and computation based on density functional theory (DFT) calculations. From the datasets, we built ML-based predictive models for the TE properties of SnSe-based materials with diverse doping/alloying compositions. Then, we exploited the predictive models as a fast search engine to figure out the best candidates for SnSe-based high *ZT* compounds. We suggest several SnSe alloy compositions selected by our predictive model, and provide further analysis on their electronic band structure to understand the underlying mechanism of the high *ZT* values. We expect that our study not only provide new SnSe-alloy candidates with high-*ZT* values but also a new research strategy searching for optimal materials with a data-driven research.

Keywords:

Machine Learning, Thermoelectric, SnSe, Alloy

2020 KPS Spring Meeting
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E6.03

Extension of multi-space density functional formalism to region-specific optical excitations

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Abstract:

A proper first-principles treatment of optical excitation processes is one of the key challenges for the development of next-generation nano-optoelectronic devices. Among various first-principles methods, the ΔSCF scheme in which the excited situation is captured by controlling the electron occupations has been proved to be an effective optical electronic excitation calculation approach. In this presentation, we apply the multi-space constrained-search density functional theory (MS-DFT) formalism recently developed in our group and develop a spatially-resolving ΔSCF formalism [1]. Applying the extended MS-DFT scheme to molecular junction models that consist of left electrode, channel, and right electrode parts, we consider the effects of optical electronic excitations only within channel region on the junction charge transport properties. The developed formalism can be a valuable tool in developing advanced nano-photonic devices.

[1] H.S. Kim and Y. -H. Kim, arXiv:1808.03608 [cond-mat.mes-hall]; J. Lee, H. Yeo, and Y.-H. Kim, Proc. Nat. Acad. Sci. (in press; arXiv:2001.10186)

Keywords:

Optical excitation, Delta-SCF, MS-DFT, Molecular junction

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E6.05

Extending magnetic force theory JX code to plane-wave DFT

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Abstract:

We introduce an extension of our **Jx** code [1-2] to plane-wave DFT codes. The **Jx** calculates magnetic exchange interaction matrix J based on magnetic force theory (MFT) [3-6] , which calculates the exchange interaction between two local sites at a linear response level. For this reason, defining the atom-projected local Hamiltonian is essential for MFT. In the case of local basis DFT codes such as OpenMX [6], the MFT can be performed immediately after self-consistent DFT calculations finish. However, in the case of plane-wave basis DFT, an additional process of defining a local Hamiltonian is required. In the previous **Jx** version, we used the Wannier function, which requires a tedious self-consistent process. Here we present our new extension of **Jx** to the plane-wave DFT codes (VASP, Quantum espresso) through the projection approaches such as utilizing LOBSTER [7] and projected localized orbitals from VASP. These reduce the effort to define the local Hamiltonian so that we can perform the MFT immediately after the DFT calculation. We examined the basis set dependency on the J for various insulators to metallic systems. When using an interpretable basis set, we found that the J value can be calculated reasonably.

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Keywords:

DFT, spin, exchange interaction , MFT, Heisenberg J

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E6.06

First-principles study of doping-dependent magnetic properties of a van der Waals ferromagnet Fe_3GeTe_2

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Abstract:

Identifying material parameters affecting properties of ferromagnets is key to optimize materials better suited for spintronics. Magnetic anisotropy is of particular importance in van der Waals magnets, since it not only influences magnetic and spin transport properties, but also is essential to stabilizing magnetic order in the two dimensional limit. In this study, we investigate the doping-dependent magnetic properties of Fe_3GeTe_2 using first-principles density functional theory. In contrast to the Fe magnetic moments being insensitive to chemical potential shifts, we find a significant change in the magnetic anisotropy energy (MAE), consistent with the experimental data showing a drastic suppression of the coercivity with hole doping. The momentum-resolved changes in the band structures with magnetization direction show that the hole bands around Γ-point and electron bands around K-point give negative and positive contribution to MAE, respectively. With hole doping, we find the reduction of the electron pockets around K-point, which in turn results in the drastic decease in the MAE, providing an intrinsic mechanism to the suppressed coercivity with hole doping. Our findings provide an understanding of the intricate connection between electronic structures and magnetic properties in two-dimensional magnets and propose a method to engineer magnetic properties through doping.

This work is supported by Institute for Basic Science in Korea (Grant No. IBS-R009-D1) and the KIST Institutional Program (2E29410).

Keywords:

van der Waals materials, magnetic properties, density functional theory, magnetic anisotropy, electronic structures

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

E6.07

Anomalous Hall effects without net magnetization

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Abstract:

It has long been believed that anomalous Hall effects are supposedly related to net magnetization. However, it has been pointed out recently by Chen et al. that the anomalous Hall effect can be observed with vanishing magnetization in non-collinear antiferromagnet. In this work, we extend investigation to collinear magnetic material, Mn_3Al, which is nearly compensated ferrimagnet with magnetization axis along z direction. We found that only σ_{xy} component of anomalous Hall conductivity survives under the constraint of symmetry and explicit first-principles calculations reveal that σ_{xy} is about $310(\Omega \cdot \mathrm{cm})^{-1}$.

Keywords:

Anomalous Hall effect, Compensated ferrimagnet

Polarization switching dynamics of doped hafnia thin film capacitors

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Abstract:

Recent studies on ferroelectric hafnia have renewed the interests on ferroelectric-based electronic devices. Hafnia thin films showing ferroelectricity at very thin thickness of a few nanometers can be used for ferroelectric-gated field effect transistors for memory devices and logic devices. Understanding the polarization switching properties of hafnia thin films is crucial for the realization of these devices. Hafnia-based ferroelectrics are known to show an interesting phenomenon called wake-up, the increase of polarization during the initial polarization switching cycles. The wake-up observed in hafnia is related to microscopic phase formation as well as the redistribution of defects. All the aspects make it difficult to elucidate what governs the polarization switching dynamics of hafnia thin films. We investigated the polarization switching of Si-doped hafnia thin film capacitors by applying voltage pulses with various duration and height. The switching data were analyzed based on nucleation-limited switching model. We report the effect of the wake-up process on the switching characteristics. The effect of annealing condition is also discussed in terms of crystalline phase and oxygen vacancies.

Keywords:

E7.02

Revisiting classical nucleation theory to understand the ferroelectric phase formation in doped hafnia thin films

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Abstract:

The ferroelectricity in doped HfO_2 thin films have attracted increasing interest since the original report by Boescke et al.[1] in 2011. The ferroelectricity could not be expected before the above-mentioned original work, since the stable crystalline phase of HfO_2 is monoclinic phase at room temperature and 1atm pressure. Even at elevated temperatures and pressures, the ferroelectric phase cannot be stabilized. The origin of the unexpected ferroelectricity is not elucidated as the formation of the orthorhombic phase with a space group of $Pca2_1$. However, it is still unclear why the metastable ferroelectric phase can be formed in doped or undoped HfO_2 and ZrO_2 thin films. In this talk, therefore, the mechanism of the ferroelectric orthorhombic phase formation is intensively studied based on classical nucleation theory with the thermodynamic parameters such as bulk free energy of various crystalline phases and interfacial energies between them. From a comprehensive study, it could be concluded that there exists a specific region of doping concentration which is sufficiently high not to induce monoclinic phase nucleation and sufficiently low to induce secondary phase formation to the ferroelectric orthorhombic phase.[2]

References
[1] T. S. Boescke et al. Appl. Phys. Lett. 99, 102903 (2011).
[2] M. H. Park et al. Nanoscale, 11, 19477 (2019).

Keywords:

Ferroelectric, hafnia, thin film, atomic layer deposition

Domain switching dynamics in ferroelectric Si-doped HfO_2 capacitors investigated by modified-piezoresponse force microscopy

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Abstract:

Recently, a flurry of studies have been conducted on ferroelectricity in doped-hafnium dioxide (HfO_2) thin films. One of the reasons is that the binary HfO_2-based films have many advantages for memory applications, compared to conventional perovskite ferroelectrics (e.g., PZT), such as good Si-compatibility, large bandgap (> 5 eV), and extremely thin physical thickness (< 10 nm). However, there are still many remaining issues for realization of HfO_2-based memories. One important issue is to understand domain switching dynamics, i.e., how ferroelectric domain nucleate and grow under an external field, since it is directly related to the operating speed and voltage of the devices. In this presentation, I will report our group efforts to understand ferroelectric domain switching dynamics in Si-doped HfO_2 film capacitors. We have mainly used modified-piezoresponse force microscopy (m-PFM) [1], which is a very powerful tool to direct visualize ferroelectric domain evolution at the nanoscale in real capacitors. We also used transient switching current measurements to understand the macroscopic polarization switching kinetics. I will discuss the specific domain switching behaviors depending on the various conditions, such as nucleation behaviors, domain wall velocity, and so forth.
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Keywords:

ferroelectric, domain, HfO2, piezoresponse force microscopy

2020 KPS Spring Meeting
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E8.01

Improvement of nonlinear weight update in three-terminal artificial synapse device

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Abstract:

A.I. research has grown exponentially since AlphaGo beat a human professional Go player in March 2016. However, most A.I. studies are based on software using von neumann processors such as CPU, GPU, TPU, and so on. To handle big data by optimizing software using the conventional processers, power consumption becomes one of the major issues for use in the applications. Neuromorphic engineering is a research area to mimic biological neural network by electronics, which is one of the promising ways to improve energy efficiency and overcome the limitation.
In this talk, I will briefly review recent neuromorphic research from device and system perspectives. Then I will discuss about a current research on a three-terminal 2D material-based synapse device.

Keywords:

2D material, synapse, neuromorphic, nonlinear

E8.02

Ultralow switching voltage slope based on two-dimensional materials for integrated memory and neuromorphic applications

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Abstract:

To realize ultrafast and energy-efficient electronic devices, reducing the switching voltage slope for ON and OFF states that scales the supply voltage and device dimensions is critical (1-2). Novel device architectures based on two-dimensional (2D) materials have overcome the fundamental thermionic limit of the switching slope (60 mV/ dec); however, a versatile switching device required for highly integrated memory and neuromorphic applications has not been achieved with such exceptional switching slope characteristics (3). Here, we demonstrate a switching voltage slope down to 0.62 mV/dec in a threshold switching device based on a vertical heterojunction of silver/hexagonal boron nitride (h-BN)/graphene (4). The sub-1 mV/dec switching slope for the first time, maintaining a high ON/OFF ratio (up to 10^{10}), originates from the unique coupling between the migrated silver atoms and the chemically-inert graphene electrode through the 2D insulating h-BN. Moreover, our original switching device enables the evolution from a conventional volatile (threshold switching) to non-volatile memristive state by adequate voltage spikes, which is ideal for selector applications in highly integrated crossbar array architecture and in a novel synaptic device for neuromorphic computing.

[1] L. Sun et al., Nano Letters 18, 3229-3234 (2018).
[2] L. Sun et al., Nature Communications 10, 3161 (2019).
[3] L. Sun et al., 2D Materials 6, 015029 (2019)
[4] L. Sun et al., Nano Energy 69, 104472 (2020)

Keywords:

neuromorphic devices, 2D materials, h-BN, graphene, memristor

2020 KPS Spring Meeting
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E8.03

Memristor synapses for low-power and high-performance neuromorphic computation

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Abstract:

Inspired by the biological neural network and cognitive functions, neuromorphic computing architecture has been envisioned as an alternative computing system. Among several neuromorphic device platforms, memristor (memory + resistor) with an inherent switching effect has been considered as one of the strong candidates capable of implementing the artificial synapses. As a first subject, we present a vertical form of gate-tunable silicon oxide (SiOx) memristor synapse, referred to as a probabilistic synaptic barristor, and discuss its potential as a sparse neural network capable of low power learning for image recognition. As a second subject, we suggest a simple approach toward a reliable synaptic array with a very low device variation (< 2 %) using TiOx-based memristor device. And we demonstrate that the device can show the ultra-stable analog switching and transition cycling between long-term potentiation/depression for 15,000 input spikes maintaining their reliability for over more than 6 months. If time is allowed, lastly, we introduce our recent achievements for organic ferroelectric artificial synapses.

Keywords:

Nueromorphic electronics, Artificial synapse, Brain-inspired computing system

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E9.02

Statistical ensemble inequivalence for flexible polymers under confinement in various geometries

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Abstract:

The problem of statistical ensemble inequivalence for single polymers has been the subject of intense research. In a recent publication, we show that even though the force-extension relation of a free Gaussian chain exhibits ensemble equivalence, confinement to half-space due to tethering to a planar substrate induces significant inequivalence [S. Dutta and P. Benetatos, Soft Matter, 2018, 14, 6857-6866]. In this talk, we extend that work to the conformational response to confining forces distributed over surfaces. We analyze in both the Helmholtz and the Gibbs ensemble the pressure-volume equation of state of a chain with free ends in rectangular, spherical, and cylindrical confinement. We especially consider the case of a directed polymer in a cylinder. We also analyze the case of a tethered chain in various geometries. In general, confinement causes significant ensemble inequivalence. Remarkably, we recover ensemble equivalence at the limit of squashing confinement. Our work may be useful to the interpretation of single molecule experiments and caging phenomena.

Keywords:

polymers, confinement, statistical ensembles, fluctuations

E9.03

A case study of the effects of ionic groups on the self-assembly: lyotropic chromonic liquid crystals Sunset Yellow FCF

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Abstract:

Planar molecules having polyaromatic cores and peripheral ionic groups, often make face-to-face aggregates via non-covalent attraction such as π-π interaction. These elongated aggregates form lyotropic chromonic liquid crystal (LCLC) phases, and Sunset Yellow FCF (SSY) is a representative example of LCLCs. Here, we report our experimental study of how the self-assembly of SSY is influenced by its inevitable impurities, i.e., by-products of SSY synthesis. They have molecular shapes similar to SSY but differ in the number and position of sulfonate groups. We observe that impurities with a peripheral sulfonate group added or removed from the SSY, behave like SSY molecules. Namely, the addition of impurities decreases the inter-aggregate distance and increases both correlation length and the phase transition temperature. However, when the impurities having an additional sulfonate group at the core of SSY, is added, the correlation length remarkably decreases. We believe that the impurities take part in the self-assembly of the aggregate, and the critical factor making differences in phase behavior and microstructure is the location of ionic groups in the impurity molecules. These findings not only help us better understand the self-assembly of the ionic molecules but also alleviate data reproducibility and reliability issues by unveiling the roles of the impurities.

The synchrotron-based X-ray scattering was performed at the PLS-Ⅱ 6D UNIST-PAL Beamline of the Pohang Accelerator Laboratory (PAL), Pohang, Republic of Korea, under the proposal-number 2019-3rd-6D-A012. The authors acknowledge the support from the Korean National Research Foundation through NRF-2018R1C1B6002811.

Keywords:

self-assembly, lyotropic chromonic liquid crystals, impurity

2020 KPS Spring Meeting
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E9.04

How nematic liquid crystal in and around a sessile droplet breaks its mirror symmetry

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Abstract:

Achiral liquid crystals can make chiral structures while minimizing their elastic energy, and highly deformed regions such as defects play critical roles in the energetics. In this work, we observe the chiral symmetry breaking of nematic lyotropic chromonic liquid crystal (LCLC) in and around a sessile droplet, utilizing polarized light microscopy and numerical calculations. In the isotropic-nematic coexistence phase of LCLC, we can make two types of sessile droplets having a spherical-cap shape: nematic droplets immersed in the isotropic background and isotropic droplets surrounded by the nematic environment. The curved interfaces deform nematic directors, and topological defects induce twist deformation to lower the penalty of splay deformation. The twist results in spiral optical textures under crossed polarizers. We classify spiral textures according to their handedness, i.e., right-handed or left-handed, and estimate number ratios. With no chiral dopant, the achiral system exhibits both handednesses with an equal probability, whereas a small amount of the chiral dopant breaks the balance. We investigate the handedness of spiral textures according to the concentration of the chiral dopant and propose the director field models to understand the chiral symmetry breaking. We figure out that differences in energetics between two types of sessile droplets result in different behaviors in terms of how number ratios become off-balanced. The authors gratefully acknowledge the financial support from the Korean National Research Foundation through NRF-2015R1A2A2A01007613 and NRF-2018R1C1B6002811.

Keywords:

Chiral symmetry breaking, liquid crystal

2020 KPS Spring Meeting
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E9.05

Sessile heavy water droplets absorb quickly light water vapor from air: Kinetics study using neutron imaging and FT-IR spectroscopy

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Abstract:

At a liquid-vapor interface, the evaporation and condensation of molecules co-occur. Here, we investigate experimentally a sessile heavy water (D_2O) droplet that absorbs light water (H_2O) vapor from the ambient air. First, we take images of a sessile D_2O droplet using neutron. Beer-Lambert law enables us to measure the attenuation coefficient of the specimen and quantitatively estimate H_2O content within the droplet. The quantitative Fourier-transform infrared spectroscopy gives the same conclusion that D_2O droplets with a large surface-to-volume ratio, i.e., small droplets, can be very hygroscopic. For example, 15 percent of a D_2O droplet of 10 microliters in volume can be replaced with H_2O in 10 minutes. We propose a diffusion-based numerical model considering the exchange of D_2O and H_2O between the droplet and the ambient air. The neutron imaging was performed at the ICON beamline of SINQ at Paul Scherrer Institut, Switzerland, under the proposal-number 20180136.
The authors acknowledge support from the 2018 Research Fund (1.180069.01) of UNIST (Ulsan National Institute of Science and Technology) and IBS-R020-D1 funded by the Korean Government.

Keywords:

soft matter, Neutron Imaging, sessile droplet

2020 KPS Spring Meeting
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E9.06

Micro-Viscometry of Sperm Sorting Fluids by Quartz Tuning Fork Sensor

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Abstract:

Rheometers are the widely used instruments for measuring the rheological properties of soft matter. While the rheometers typically require a sample volume of a few mL or higher, the rheology of minute amounts of liquid has been in high demand as a novel tool for medical diagnosis. In this talk, we introduce an atomic force microscope-based micro rheometer that can measure the viscosity of a micro-scale fluid on mica surface. In essence, we employ a quartz resonator, quartz tuning fork (QTF), as a force sensor, and perform dynamic force spectroscopy of nanoliter scale fluids confined between the QTF tip and substrate. We demonstrate the viscosity of water and apply to sperm mobility research to measure viscosity of sperm sorting fluids (PVP, SAGE). We confirm that the mobility of the sperm becomes more straight as the viscosity of sperm sorting fluids approaches human cervical mucus. Furthermore, we realize an electro-micro rheometer that can measure the viscosity and conductivity of a micro-scale fluid under controlled bias voltage.

Keywords:

Rheometer, Quartz Tuning Fork, Microfluidics, Viscosity, Sperm

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E9.07

Quartz tuning fork-based dynamic measurement of mass and density for a single nano-liter drops

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Abstract:

생체 액체의 물리적 특성 연구에서는 매우 제한적인 소량($\leq 100\mu l$) 액체의 다양한 물성 측정이 요구된다. 따라서 보통의 벌크 스케일 액체를 분석하는 장비를 이용하여 생체 액체를 연구하기는 어렵다. 우리는 수정 튜닝 포크 진동자와 고해상도 카메라를 이용하여 액체의 질량, 밀도, 증발률을 측정하는 장비를 제안한다. 우리 장비는 $10^{-9}L$에서 $10^{-4}L$범위의 액체를 측정할 수 있다. 이러한 연구는 녹내장 치료를 위한 안방수 물성 측정에 응용될 수 있다.

Keywords:

Quartz tuning fork, Mass, density, a single nano-liter drops

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F1.01

Status report of R&Ds on trigger RPCs for CMS and SHiP experiments

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Abstract:

We report the current R&D activity for development of trigger RPCs for future CMS and SHiP experiments. A series of intensive R&Ds to satisfy the desired detector performances for the two experiments has been performed by prototype constructions and tests for cosmic muons and gamma rays. For the CMS iRPCs, we focused on the radiation hardness of the RPC detectors under the experimental condition that will be faced in future Phase-2 LHC runs. On the other hands, we put stress on a higher time resolution and detector operations at lower high voltages for the SHiP RPCs. A new quality control procedure that ensures consolidation of the oiled surfaces of the CMS iRPC electrodes was established via the intensive radiation tests. Finally, we report the test result of a thinner-gap SHiP trigger RPC with a 2D read-out tracking capability and with a time resolution better than 500 ps in the presentation.

Keywords:

Resistive Plate Chambers, HL-LHC, Compact Muon Solenoid, Light Dark Matter

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F1.02

Test beam results from LGAD sensor on endcap timing layer for CMS phase-2 upgrade

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Abstract:

The mitigation of simultaneous interaction per punch crossing (pileup) that increases the rate of false triggers during the high luminosity LHC (HL-LHC) running is one of the main challenges to maintain detector performance. The 4D reconstruction with timing information is expected to reduce the pileup effect by around 10%, finding the correct primary vertex. The minimum ionizing particle (MIP) Timing Detector (MTD) is designed to provide timing information for the MIP with a 30-40 ps resolution. For the operation of timing detector, Low Gain Avalanche Detector (LGAD) silicon sensors are tested for the endcap timing layer setup (ETL). In order to ensure a guaranteed level of timing performance and establish the technical requirements for the next round of CMS sensor order submission in early 2021, the time resolution and radiation hardness of the LGAD sensor are studied using Ru106 source and laser setups with 120 GeV proton beams. We present the result of the ETL sensor testing at the Fermilab Test Beam Facility.

Keywords:

Timing, ETL, MTD, LGAD

2020 KPS Spring Meeting
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F1.03

Testing of ETROC performance at the Fermilab Beam Test Facility

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Abstract:

The number of interactions during each bunch crossing based on the nominal scenario of High Luminosity LHC (HL-HLC) will be reached 140 to 200 on average. The primary goal of the CMS Phase-2 upgrade for the HL-LHC is to maintain the current excellent performance of the CMS detector. The MIP timing detector (MTD) which consists of the Barrel timing layer (BTL) and the Endcap timing layer (ETL) can help meet the challenge of high luminosity with 30-50 ps timing resolution of MIP. The ETL uses the LGAD sensor and ASIC to readout the signal. The ETL readout ASIC chip (ETROC) is designed to handle a 16×16 pixel cell matrix, each pixel cell being 1.3×1.3 mm^2 to match with the LGAD sensor pixel size. The ETROC0 is a prototype of ETROC consisting of a charge circuit, preamplifier and discriminator. In this talk, the preamplifier performance of ETROC0 with 120 GeV proton beam at the Fermilab Beam Test Facility is reported.

Keywords:

HL-LHC, CMS, MTD, ETROC

2020 KPS Spring Meeting
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F1.04

Neutron Detection using a Gadolinium-Cathode GEM Detector

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Abstract:

A Gas Electron Multiplier (GEM) detector with a gadolinium cathode has been developed to explore its potential application as a neutron detector.
It consists of three standard-sized (10*10 cm^2)GEM foils and a thin layer of gadolinium plate as the cathode, which is used as a neutron converter. The neutron detection efficiencies were measured for two different detector configurations and for different gaps of the drift region.
The thermal neutron source at the Korea Research Institute of Standards and Science (KRISS) was used to measure the neutron detection efficiency. Based on the neutron flux measured by KRISS, the neutron detection efficiency of our gadolinium GEM detector was 4.8 %.

Keywords:

GEM, Neutron, Gadolinium, Particle Detector

2020 KPS Spring Meeting
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F1.06

Current Status of the SHiP Experiment

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Abstract:

The SHiP (Search for Hidden Particles) Collaboration has proposed a general purpose experimental facility at the CERN SPS accelerator to search for feebly interacting GeV-scale particles. The SHiP complements the world-wide program of New Physics searches by covering a large region of parameter space of superweak coupling down to 10^{-10} ("cosmological interesting region") which cannot be addressed by other experiments. The SHiP detector is sensitive both to decay and scattering signatures of models with heavy neutral leptons, dark photons, dark scalars, light dark matter and other super-weakly interacting particles. In addition, the SHiP can perform unprecedented measurements with tau neutrinos and neutrino-induced charm production. Recently, further optimization of sub-detectors and extention of physics programs have been done and the progress report was submitted for Input to the ESPPU (European Strategy for Particle Physics Update). In this talk, we will report the current status of the SHiP experiment.

Keywords:

SHiP, Hidden Particles, Tau Neutrino, CERN SPS, Intensity Frontier

Plastic scintillator with embedded WLS fibers and MPPC readout for the KOTO experiment

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Abstract:

The KOTO experiment aims to observe K_L -> pi^0 + nu + nu_bar decays with a large CsI calorimeter surrounded by hermetic veto counters. Its highly suppressed decay probability is an important aspect to access new physics beyond the standard model. A key issue in the KOTO experiment is to remove a huge amount of background processes associated with other KL decay modes.

For the K_L -> pi0 pi+ pi- decay, the detection of two charged pions helps suppress the background. However, it can survive when the two charged pions escaping through the beam hole do not reach any charged veto detectors. To remove such a background, we have installed plastic scintillator strips surrounding the beam hole downstream of the CsI calorimeter.

The downstream charged veto (DCV) counter consists of two sets of four plastic scintillator strips embedding wavelength-shifting (WLS) fibers and read out by MPPCs at both ends. Since the DCV has a complicated configuration of the WLS fibers and readout scheme, it needs a detailed Monte Carlo simulation to understand its performance.

We have modeled light propagation in the DCV from energy loss in a scintillating strip to an MPPC readout using the Geant4 toolkit. To verify the simulation results, we fabricated a quarter-size DCV and measured its performance with a 90Sr radioisotope source and cosmic rays. In this talk, we will present the modeling of the DCV and the simulation validation in comparison with the measurement results.

Keywords:

Scintillator, WaveLength Shifting fiber, Mulit-Pixel Photon Counter

2015 개정교육과정에 따른 통합과학 및 과학탐구실험 운영 현황

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Abstract:

2015 개정 과학과 교육과정에서는 신설과목으로 통합과학과 과학탐구실험이 2018학년도부터 고등학교 1학년을 대상으로 학교 현장에서 가르치고 있다. 한국교육과정평가원에서는 ‘통합사회, 통합과학 교과 역량 함양을 위한 교수학습 및 평가 개선 방안 모색’과 ‘2015 개정 교육과정 시행에 따른 과학탐구실험 운영 실태조사 및 지원방안 탐색’이라는 통합과학과 과학탐구실험에 대한 연구를 2019년에 수행하였다. 상기 연구에서는 과목의 운영 실태를 파악하고자 전국 단위의 대규모 설문조사를 진행했었다. 본 발표에서는 두 연구의 설문조사의 결과를 중심으로 고등학교에서 통합과학 및 과학탐구실험 두 과목에 대한 운영 현황에 대해 논의하고, 이를 바탕으로 물리교육의 시사점을 도출하고자 한다.

Keywords:

통합과학, 과학탐구실험, 물리교육

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

F10.02

교사교육자의 주체적 실행 개선을 위한 '셀프 스터디' - 물리교사교육에 주는 시사점을 중심으로

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Abstract:

전문성 있는 교사는 자신의 실행을 끊임없이 반성하고 개선해나간다. 교사의 반성적 실천에 대한 많은 연구가 있지만, 본 발표에서는 교사교육자(혹은 교수)의 주체적 실행 개선을 위한 반성적 연구 방법으로 셀프 스터디의 개념과 방법론적인 특징을 개관하고, 셀프스터디가 과학교육 연구에서 과학 수업 개선을 위한 연구방법으로 어떻게 적용 가능한지를 실제 연구를 수행한 '셀프'와 '비판적 동료'들이 자신의 사례를 중심으로 논의한다. 셀프스터디란 질적 연구방법의 하나로서 연구자 자신을 대상으로 다양한 자전적 자료를 활용하며, 자기 자신, 자신의 실천, 자신의 생각 등 을 대상으로 수행하는 연구를 통칭한다(Hamiliton & Pinnnergar, 1998). 또한, 셀프스터디는 연구가 자기 로부터 시작되고, 자기 자신에 초점을 맞추며, 실행의 개선을 추구한다(Lee et al., 2012). 그러나 기존 자전적 연구와 다른 점으로는 '비판적 동료'와의 협력적 반추를 들 수 있는데 최근 발표자가 수행한 연구 사례를 중심으로 셀프 스터디의 특징과 물리교사교육에 주는 시사점에 대해 논의할 것이다.

Keywords:

물리교사교육 , 셀프 스터디

F10.03

과학교육종합계획(2020-2024)에 따른 물리교육의 현안과 과제

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Abstract:

제4차 과학교육종합계획(2020-2024)은 "기초를 다지고, 첨단을 누리고, 미래를 이끄는 과학교육"을 목표로 6개의 추진 전략과 16개의 중점 추진과제를 제시하였다. 특히 지능정보사회를 이끌 핵심인재 양성을 비전으로 제시하면서 과학, 수학, 정보, 융합교육 종합계획이 동시에 발표된 것이 이례적이다. 본 발표에서는 과학교육종합계획의 수립 과정과 내용을 전반적으로 살펴보고, 이를 토대로 물리교육의 현안과 과제를 제시함으로써 물리교육의 새로운 방향을 논의하고자 한다.

Keywords:

과학교육종합계획 , 지능정보사회 , 융합 , 물리교육

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F14.01

Correlative Investigation of Degradation of Organic-Inorganic Hybrid Perovskite Films Using Infrared Nanoscopy

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Abstract:

The degradation of organic–inorganic hybrid perovskite (OHP) films is a crucial issue in OHP optoelectronics. Herein, we investigate the degradation process of OHP films by simultaneous measurement of topography and infrared absorption mapping images using photothermal induced resonance spectroscopy. By tracking the intensity of molecular vibration, we found that oxygen and moisture are easily attached at the grain boundary (GB) rather than grain interior (GI) of OHP film. These data are well matched with photoluminescence (PL) mapping images, which show that the PL intensity of PbI_2 as an indicator of degradation is relatively intense at the GB. Thus, by using correlated structural, chemical, and optical analyses, we confirm that the degradation of OHP film is initiated at the GB through the attached oxygen molecules and moisture. We expect that this study will contribute to solving the degradation issue and enhancing the stability of OHP optoelectronics.

Keywords:

OHP, Degradation, Infrared Nanoscopy, Moisture, Oxygen

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F14.02

Inorganic 2-D Transition Metal Dichalcogenides for Charge Transport Layers of Perovskite Solar Cells

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Abstract:

As the solar cell application, organic-inorganic hybrid perovskites (OHP) have attracted huge attention due to the advantages of high charge mobility, long carrier diffusion lengths, and low trap density. Despite their attractive properties, perovskite solar cells (PSCs) suffer from the instability of device performance. OHP undergo rapid degradation in ambient conditions. This degradation of perovskite is also accompanied by decreasing the device performance of PSCs. Although many studies have been carried out to prevent its degradation, this is still remained as main problem for the commercialization of PSCs.
Generally, PSCs are composed of transparent conductive oxides (TCO), electron and hole transport layer, perovskite layer, and electrodes. The materials used in PSCs and their interfaces are important for efficiency and stability of PSCs. Particularly, the electron and hole transport layers can play an important role because they directly contact with perovskite layer. Some materials such as PEDOT:PSS, Spiro-OMeTAD, and PCBM are generally used as charge transport layers. But due to their hygroscopic properties, they can internally accelerate the degradation process in PSCs structure. To prevent this internal degradation and improve the stability of PSCs, the other materials which are stable and non-hygroscopic are required. Here, we suggest transition metal dichalcogenides (TMDs) as efficient charge transport materials of PSCs and will discuss mechanism of the charge transport in TMDs-based PSCs.

Keywords:

Perovskite, Transition metal dichalcogenides(TMDs), Perovskite solar cells(PSCs)

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F14.03

Optical absorption and anomalous photoconductivity in Methylammonium lead halide single crystals

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Abstract:

Organic-inorganic mixed halide perovskite ($MAPbX_3$; MA = $CH_3NH_3^+$, X = Cl^-, Br^-, or I^-) single crystals have been highlighted as candidate materials for high efficiency photovoltaics and optoelectronics. However, the outstanding success in increase perovskite device performance like a solar cell, the underlying photophysical mechanism remain unclear.
The persistent photoconductivity (PPC) effect, which is persisted light-induced conductivity for a long period of time after illumination, has been a critical problem in optoelectronic devices. Despite negative feature of it, the PPC is a useful tool for understanding the metastable properties of defects. Nonetheless, the PPC effect of perovskite single crystals has not been studied yet. In this study, optical absorption (OA), photoconductivity (PC), and PPC measurements were employed to analyze deep levels in mixed halide perovskite ($CH_3NH_3PbBr_{3-x}I_x$) single crystals with the planar contact configuration. Mixed halide perovskite single crystals showed abnormal PPC behavior which were related to the existence of metastable gap state from defect sites.

Keywords:

perovskite single crystal, photoconductivity, persistent photoconductivity effect

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F14.04

Origin of dual peak nature and Rashba splitting in halide perovskite single crystals

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Abstract:

Halide perovskite semiconductors have attracted significant attention for superior optical properties and relevant applications. Halide perovskites ($APbBr_3$: A = MA, Cs) are promising materials for light emitting diodes (LEDs) and solar cells because of their high photoluminescence (PL) quantum yield and long carrier/exciton diffusion length. Recently, there has been great interest in Rashba effect in perovskites, which could be applicable for spintronics. But photophysical properties and origin of the Rashba effect are not completely understood yet. In order to address the issue, we investigated optical properties of a bulk (3D) single crystals of $CsPbBr_3$ and $MAPbBr_3$ grown by Bridgman technique and inverse temperature crystallization methods, respectively. Based on ellipsometry and PL excitation spectroscopy, we found that there is an Urbach tail state (E_1, $CsPbBr_3$ ~2.25 *eV*, $MAPbBr_3$ ~2.19 *eV*) as well as the direct band-edge state (E_2, $CsPbBr_3$ ~2.35 *eV*, $MAPbBr_3$ ~2.30 *eV*) at room temperature. Interestingly, we observe that the energy difference (E_2-E_1) of each perovskite reduces as the crystal temperature decreases and even becomes zero below 50 K for $CsPbBr_3$. Furthermore, we thoroughly investigated these perovskite single crystals utilizing a battery of optical characterization tools such as one-photon and two-photon circular-polarization-dependent PL spectroscopy and harmonic generation spectroscopy as a function of temperature and wavelength. In this talk, we first show that the origin of the E_1 state is neither crystal defects nor indirect gaps caused by Rashba splitting, but a photon-recycling effect that depends critically on the crystal size and the collection geometry. Then we show that a small but measurable Rashba effect occurs only in $MAPbBr_3$ at low temperatures due to local reconstruction of MA-cation ordering, which is most significant across a few layers from the crystal surface to the interior. Our important results clearly preclude any chance of previously suggested models of dynamic or static Rashba effect in the bulk or at the surface of the crystals.

Keywords:

Halide perovskite, Rashba splitting, Photon-recycling

F14.05

Formation of quantum vortex in non-equilibrium superfluid

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Abstract:

Exciton-polaritons in a microcavity are bosonic quasi-particles that are formed as a result of strong-coupling between cavity photons and excitons. Because of their bosonic characteristics, polaritons can condense into a macroscopic coherent state similar to that of a Bose-Einstein condensate. In this condensate, polaritons can host quantum vortices, which are typically found in a superfluid with quantized angular momentum. These quantum vortices can be generated by nonresonant Laguerre-Gaussian pumping in GaAs planar microcavity sample. Unlike more conventional superfluids of 4He or cold atoms, we observed the polariton condensates formed in two different energy eigenstates. The higher energy states has a ring shape in real space and carries 2 pi winding phase corresponding to a singly quantized vortex. The low energy ground state has a Gaussian distribution spatially and have zero angular momentum. This indicates that polariton condensation with different angular momentum can be formed within the polariton lifetime whose relative fraction can be controlled by pumping ring size or power. This phenomenon may is likely to be related to non-equilibrium nature of polariton condensation and angular momentum relaxation process in non-equilibrium superfluid can be studied.

Keywords:

superfluid, vortex, exciton-polariton, semiconductor

F15.01

Temperatures in closed and wormhole spacetimes

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Abstract:

We study how to represent the thermodynamic equilibrium of matter in various static spacetimes which could have closed space or wormholes. We argue that the asymptotic temperature is ill-defined for such spacetimes and the local temperature describes only limited situations of local thermodynamic interaction of a small statistical system. Based on these observations, we design a `generalized' temperature for the thermal equilibrium and a {₩it thermodynamic} temperature describing the local thermal interactions. We present a few examples which justify the use of them.

Keywords:

Wormholes, Thermodynamics, general relativity

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F15.02

Wormholes and quantum gravity: can a wormhole be created from nothing?

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Abstract:

We investigate the possibility to create a wormhole from nothing. For several gravity models, this is possible via Euclidean wormhole solutions; we explicitly demonstrate several models. One more fascinating observation is that the Euclidean wormholes can be analytically continued in two ways: inhomogeneous way (Lorentzian wormhole) and homogeneous way (creation of two universes). Finally, we discuss several interesting future research topics on wormholes with quantum cosmology and quantum gravity.

Keywords:

wormhole, quantum gravity, quantum cosmology, instanton

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F15.03

Wormholes in Einstein-Born-Infeld gravity

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Abstract:

We consider a new approach to constructing wormholes in Einstein-Born-Infeld gravity, which does not require exotic matters in the Einstein equation. We also discuss the stability of the perturbation by computing the quasinormal modes of a massive scalar field in the wormhole background.

Keywords:

wormhole, Einstein-Born-Infeld garvity

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F15.04

The Gravitational Perturbation of a Morris-Thorne Wormhole and the Newman-Penrose Formalism

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Abstract:

The gravitational perturbation of the Morris Thorne wormhole has been derived by using the Newman-Penrose Formalism. We apply Teukolsky equation to the wormhole spacetime, compute the perturbed Weyl scalars and obtain its master equation, decomposed in spin weighted sphyerical harmonics with spin weight -2. For simplicity, we consider the perturbation, provoked by a single gaussian pulse of pressureless dust matter.

Keywords:

wormhole, gravitational perturbation, Newman-Penrose Formalism, wormhole, gravitational perturbation, gravitational wave, Newman-Penrose Formalism

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F15.05

Wormhole Spacetime in Relativity

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Abstract:

In this talk, we will look at the creation and role of wormholes in spacetime and their similarities and differences with other astrophysical compact objects, such as black holes. We investigate various wormholes with hair and discuss their characteristics and space-time structure from the motion of paticles around the wormholes.

Keywords:

wormhole, spacetime

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F16.01

HOLOTOMOGRAPHY TECHNIQUES FOR NON-INVASIVE LABEL-FREE 3D IMAGING OF LIVE CELLS AND MATERIALS

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Abstract:

Holotomography (HT) provides label-free and real-time three-dimensional (3D) imaging capability. HT uses laser interferometry to measure 3D refractive index (RI) distribution. Thus, 3D images of live cells without any molecular labeling, such as dye staining or DNA transfection, can be obtained with high spatial resolution (resolved to 110 nm). Furthermore, HT images can be analyzed to provide quantitative information of a specimen — volume, surface area, dry mass of proteins and lipids.
In this seminar, numerous applications of 3D live cell imaging that have been enabled by HT's unprecedented correlative and quantitative bioimaging capabilities will be introduced. Recent studies about protein aggregates and coacervates demonstrated that the HT imaging is an exclusive technique for real-time quantification of protein concentrations during liquid-liquid phase separation. I will also introduce representative studies which integrate artificial intelligent (AI) technologies for measuring the area and the local concentration of immunological synapse between T cells and the target cells based on the HT images.

References

[1] Park et al., Quantitative phase imaging in biomedicine, ***Nature Photonics*** 12, 578–589 (2018)
[2] Lee et al., DeepIS: deep learning framework for three-dimensional label-free tracking of immunological synapses, ***BioRxiv*** preprint (2019)

Keywords:

3D imaging, Protein quantification, Quantitative Phase Imaging, Holotomography, Microscopy

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F16.02

Time-resolved pH-induced protein dynamics studies of influenza viral hemagglutinin

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Abstract:

Time-resolved (TR) protein dynamics studies have been mostly limited to light-responsive proteins. However, many biological macromolecules are not light-responsive, and the TR crystallographic studies for such non-light-responsive proteins, which are still rare, suffer from insufficient time resolution, significantly slower than the characteristic lifetimes of structural intermediates. Our ultimate goal is to study pH-induced conformational changes of influenza virus hemagglutinin (HA) protein whose dynamic features have been elusive over the last two decades. We have recently established a UV laser-driven pH jump platform using a protein with pH-induced reversible conformational changes, for which a caged molecule, *ortho*-nitrobenzaldehyde (*o*-NBA) is essential to release protons upon exposure to UV light. As a preliminary study, we examined here the protein dynamics at the initial stage of the irreversible fusion process, using HA as a biological model and the pH jump TR-SFX as a tool, at a time point of 1 μs. Considering that many proteins are pH-dependent, this new framework of pH-jump TR-SFX will have a great potential for addressing critical gaps for dynamics studies of many important biological processes.

We acknowledge technical support from the staffs at the PAL-XFEL NCI beamline, and PLS-II 11C. This work was supported by grants from the strategy (NRF-2016R1E1A1A01942558, K.H.K.), SGER (NRF-2018R1D1A1A02049225, J-H.L.) from the National Research Foundation (NRF) funded by the Korean government.

Keywords:

Time-resolved (TR), pH-induced conformational change, XFEL (X-ray free electron laser), influenza virus

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F16.03

Advanced Molecular Dynamics Simulations That Rationalize Small Molecule – Protein Interactions

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Abstract:

Understanding the selectivity and potency of small molecular inhibitors poses significant challenges to biophysical scientists. This is because the binding of molecules can cause conformational changes to target proteins, that are difficult to predict based on the simple lock–and–key model. Moreover, these changes are occurring in time scales that are difficult to trace using conventional molecular dynamics (MD) simulation techniques. We introduce free energy MD)simulation methods that can accelerate otherwise slow conformational changes and quantify the Gibbs free energy differences between distinct conformational states of proteins. The advanced methods include thermodynamic integration (TI), metadynamics, and accelerated MD (aMD) simulations. We will discuss the theoretical background of the methodologies. The utilities of the methods will be demonstrated in details by introducing two of worked examples: 1) influences of drug-resistant mutations to the binding affinities and target structure selectivities of epidermal growth factor receptor (EGFR) inhibitors and 2) conformational dynamics of the ligand-binding domain of androgen receptor (AR) bound to anti-androgens. The computational results provide detailed understandings of the consequences of the small molecule–protein interactions and suggest directions to improve the efficacy of the inhibitors.

References
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[2] Hyo Jin Gim, **Jiyong Park**, Michael E. Jung, and Kendall N. Houk, "**The Differences in the Conformational Dynamics of Androgen Receptors bound to Agonists and Antagonists**," *in preparation*

Keywords:

Molecular dynamics simulation, Protein dynamics, Protein Drug Interaction

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F16.04

Noble parylene-based microfluidic systems and Chip calorimeters

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Abstract:

Parylene is a unique polymer material that can be deposited in the vapor phase. It has attracted much attention not only for coating material for electronics and medical tools but also for microfluidic device material due to its superior material properties including high chemical resistance, biocompatibility, and high thermal and electrical resistances. I will introduce parylene microfluidic systems and molding and bonding methods using initiated chemical vapor deposition (iCVD) which allows fast and robust thin-film channel fabrication. We have used parylene microfluidics for many applications including rollable microfluidic tuning and microfluidic chip calorimeters.
Microfluidic chip calorimeters can provide high-throughput measurements using a small sample volume, which can greatly reduce the time and cost for a broad range of biomedical applications including high-throughput biochemical reaction measurements, metabolic heat sensing (physiometer) and medical radiation sensing. Despite the importance, it has been challenging for chip calorimeters to provide both high sensitivity and precise sample-manipulation capabilities that are needed for such applications. Parylene microfluidic system enabled one of the most important breakthroughs in microfluidic chip calorimeters by providing vacuum-insulation of the thin-film microfluidic channel. High mechanical strength and low gas permeability of parylene allows vacuum insulation surrounding the measurement chamber. In addition to the vacuum insulation, low thermal conductance of thin-film structure leads to superior thermal insulation enabling measurements of the heat of reaction from pL scale samples with ~10 pW scale resolutions. We also improved temperature resolution using a vanadium oxide (VOx) based thin-film thermistor, which allows temperature coefficient of resistance (TCR) > 3 %/K and temperature resolution of $\Delta T < 0.1$ mK.

Keywords:

microfluidics, parylene, chip calorimeter, biosensor, vanadium oxide

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F2.01

Status of COSINE-100 experiment

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Abstract:

COSINE-100 is a direct dark matter detection experiment testing DAMA/LIBRA's observed annual modulation. COSINE-100 has been collecting physics data from September 2016 with ~106 kg of 8 NaI(Tl) crystals submerged in a ~2 tonne of liquid scintillator at Yangyang underground laboratory. In this talk, status of COSINE-100 experiment and preparation for the next phase will be presented. I will also discuss recent analysis in lowering the energy threshold to 1 keV and with three years of data.

Keywords:

COSINE-100, annual modulation, dark matter searches

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F2.02

COSINE-100 muon modulation analysis results

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Abstract:

A study on cosmic-ray muons has been performed concerning the COSINE-100 dark matter searches at Yangyang underground laboratory starting from September 2016. We have measured the muon flux at 1670 m.w.e. to be 37.928 $₩pm$ 0.030(stat.) $₩pm$ 1.107 (syst.) x 10^(-4) /s×m^(2). A seasonal modulation was measured with a relative amplitude of 0.51 $₩pm$ 0.19 and phase to be 179 $₩pm$ 19 days, corresponding to the maximum at 27^{th} of June. Using the global atmospheric models, the muon rate is positively correlated with atmospheric temperature and pressure above Y2L. A diurnal modulation also observed with higher modulation than annual modulation. Measurements of annual and diurnal modulations with seasonal cycle of atmospheric temperature will be presented.

Keywords:

plastic scintillator, COSINE-100, cosmic-ray muons, muon modulation

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F2.03

Study of Low Energy Region in the COSINE-100

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Abstract:

Recently, the DAMA/LIBRA collaboration has released an updated result with their energy threshold lowered from 2 keV to 1 keV. It still shows an annual modulation phenomenon that is consistent with their previous results. The main goal of COSINE-100 is to test the annual modulation signal observed by the DAMA/LIBRA experiment with the same NaI(Tl) target material. Thus, lowering the threshold to 1 keV is a significant issue for a direct comparison with the DAMA/LIBRA results. In this presentation, we report on effort of lowering the COSINE-100 threshold to 1 keV including development of a trigger simulation for analysis in very low energy region. In addition, we present also possibilities for a 0.5-keV analysis threshold, which would be useful not only for low-mass WIMP searches but also for measurements of neutrino coherent scattering.

Keywords:

dark matter, low threshold, NaI(Tl)

F2.04

Development of low-background NaI(Tl) crystal for COSINE-200 experiment

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Abstract:

COSINE is a WIMP dark matter search experiment using ultra low-background NaI(Tl) crystals as a goal to revisit DAMA/LIBRA experiment. COSINE-100 is running with a 106 kg array of low-background NaI(Tl) crystals, which shows approximately 3 counts/kg/day/keV background, with about three times higher background of the DAMA/LIBRA crystal. For the unambiguous conclusion of the DAMA/LIBRA's observation, it is essential to have lower background crystal at least level of the DAMA/LIBRA crystal. The Center for Underground Physics starts low-background NaI(Tl) crystal growing since 2018 and succeed to produce low-background Tl-doped crystal. We also develop crystal machining, polishing, and detector assembly techniques as well. Home-made detectors have measured at Yangyang underground laboratory.
In this presentation, measurement of the CUP-grown crystals and their performance will be discussed.

Keywords:

Dark matter, WIMPs, COSINE-100, COSINE-200, NaI(Tl) Crystal

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F2.05

Measurement of a NaI(Tl) crystal characteristics using a SiPM at low temperatures

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Abstract:

A rare event experiment such as dark matter WIMP search requires low background and low energy threshold. SiPM (Silicon Photomultipliers) has a low radioactive background level and high detection efficiency compare to the photomultiplier tube as well as a low noise rate at low temperatures. With a method of ultra-low background encapsulation of the crystal and the SiPM, the detector can reach to an energy threshold below keV, which leads to a big improvement in sensitivity of searching dark matter. In addition, NaI(Tl) is known to have higher light yield and longer decay time constants at low temperatures than room temperature, which makes particle identification better. We have performed measurements of light yield over a temperature range of 130-300 K, and scintillation decay time constant at the selected temperatures was also estimated. In this talk, details and results of measurements will be presented.

Keywords:

NaI(Tl), SiPM

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F2.06

Setup for low temperature measurement of NaI(Tl) crystal using silicon photomultiplier

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Abstract:

NaI(Tl) crystals are widely used as calorimetric detector including dark matter search experiments. Even though higher light output at 150K and 250K were reported in literature, detailed studies of NaI(Tl) crystals depending on the temperature has merely performed. We built a new cryogenic vacuum chamber using liquid nitrogen to control the temperature from 130 K to 300K. A silicon photomultiplier (SiPM) has been tested to understand gain and dark current rate depending on the temperature. Finally, we design a detector that encapsulate the NaI(Tl) crystal attached with SiPM. In this presentation, the setup of the low temperature chamber as well as the NaI(Tl) detector with SiPM will be discussed with results of SiPM measurement.

Keywords:

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F2.07

SiTrInEO: Silicon Tracker with International Education Objective

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Abstract:

The Silicon Tracker with the International Education Objective (SiTrInEO) project intends to design and build a tabletop tracker for educational purpose. The driving idea consists in providing an easy-to-handle and open instrumental platform, which students can use for experiments to understand the principle of the tracking system. The SiTrInEO project is conducting joint research with Hubert Curien Pluridisciplinary Institute (IPHC), supported by the Korea-France Cooperative Development program (STAR) and the France-Korea Particle Physics Laboratory (FKPPL). Currently, the hardware experimental setup including CMOS pixel sensors, signal processing board, and a magnet have been installed in each institute of the collaboration i.e. Kyungpook National University in Daegu (Korea) and IPHC in Strasbourg (France). It was successful to take signals from the electron emitted by the beta-decaying sources in the hardware operation. At the same time, the studies based on GEANT4 simulations are being conducted to develop tracking algorithms. The both study of hardware and simulation will be presented in this talk.

Keywords:

Education, Tracking system, GEANT4, France-Korea collaboration

F2.08

Development of low threshold detectors using metallic magnetic calorimeters for rare event experiments

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Abstract:

We report recent progress on the detector development with low detection threshold based on metallic magnetic calorimeters (MMC) readout. This detectors can be achieve to a single photon sensitivity with an efficient phonon amplification by the Neganov–Luke effect. We discuss the design and empirical factors determining the amplification gain in light detection at 60 mK in an adiabatic demagnetization refrigerator. We also present the energy threshold of the detector and possible applications of this kind of low-threshold detectors to rare event search experiments such as direct detection of dark matter and search for neutrinoless double beta decay.

Keywords:

Low temperature detector, Direct dark matter detection experiments, Neganov-Luke effect, light detector

F2.09

Graphene-based Josephson Junction Detector for keV-Range Super-Light Dark Matter

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Abstract:

We propose a new concept of a dark matter direct detector using the graphene-based Josephson junction microwave single-photon detector, a "state-of-the-art" technology. It was recently demonstrated in the laboratory that the device is sensitive even to sub-meV energy deposited at π-bond electrons in graphene. Therefore, the associated detectors are, for the first time, capable of sensing (warm) dark matter of sub-keV mass scattering off electrons, more specifically of $m_\chi \gtrsim 0.1$ keV. We expect not only that the proposed detector serves as a complementary probe of super-light dark matter but that due to the extremely low energy threshold it can achieve higher experimental sensitivities than those of other proposed experiments featured by a low threshold, with the same target mass.

Keywords:

Dark Matter Direct Detection, Super-Light Dark Matter, Graphene-based Josephson Junction

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F3.01

Development of Water Cherenkov Detector for J-PARC H-dibaryon Search Experiment

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Abstract:

We have developed a Water Cherenkov Detector (WC) for the J-PARC H-dibaryon search experiment (E42). The WC is designed to suppress low-momentum protons and to discriminate kaons from protons so that it enables us to reduce the online trigger rate at a managable level. The WC will be installed behind the TOF array in 2 layers. each consisting of 10 slats, which covers a whole area of the TOF array. Each slat is composed of a 188 cm long acrylic rectangular hollow structure with a cross sectional area of 257 x 207 mm^2 and the thickness of the vessel is 2 cm, filled with pure water whose refractive index n = 1.33. Cherenkov light is reflected randomly on a diffuse reflective sheet, covering the inner surface of the vessel in two layers, and reaches two PMTs at both ends. We use a special type of PMT with Super Bialkali (SBA) photocathode and UV-transmitting glass (UVT) to enhance the detection probability of Cherenkov photons.

We have tested the WC using 460 MeV positrons of beam rate up to 1 kHz by changing the incident position and angle of the beam on WC. We will present the result of the beam test of WC and simulation results on $K^-p \rightarrow K^*(892)^-p$ reactions.

Keywords:

Cherenkov Detector, SBA-UVT PMT, K-p reaction, K-p → K*(892)-p, J-PARC E42

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F3.02

Development of a Beam Hodoscope with Fast Scintillators and MPPC Readout for J-PARC E42

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Abstract:

We have developed a beam hodoscope (BH2) consisting of 10 fast scintillators and MPPC readout circuits for J-PARC E42 The BH2 triggers provides time-of-flight information on incident beam particles and also defines the start time of charged particles traveling downstream to a forward ToF counter. The BH2 should satisfy good timing resolution below 100 ps with fine segmentation in a cross-sectional area of 190 x100 mm2. Each scintillator (EJ-232) with a dimension of 13 x 5 x 100 mm3 is read out by 6 MPPCs at both ends. Three MPPC signals from one end are first individually amplified with adjustable operating voltage using trimmers, and fed into a summing amplifier, followed by a unity-gain inverting amplifier. For fast signal amplification, we employ ultrafast opamps AD8000 and AD8003. We will present a detailed design of the fast timing readout circuit for MPPCs and bench test results of the BH2, as well as the expected performance of the BH2 with Geant4 simulation on the K1.8 beamline at J-PARC.

Keywords:

MPPC, J-PARC, E42, Time resolution

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F3.03

Development of HVCM program for JSNS^2 experiment

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Abstract:

Photo Multiplier Tube(PMT) is a useful device for light detection of very weak signals in many experiments. The high voltage (HV) system for the PMTs is important for the detector, in order to ensure the stability of the PMT gain. So Programs which control and monitor high voltage system are required to operate them. LabVIEW can be an alternative to develop these programs. It provides tools to connect with high voltage system and make graphical user interface program. Here we present 'High Voltage Control and Monitoring (HVCM)' program which developed by LabVIEW for JSNS^2 experiment.

Keywords:

JSNS2, neutrino, sterile neutrino, LabVIEW

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F3.04

LAMPS 중성자 검출기의 PMT신호 파형해석을 통한 multi-hit event 의 식별성능 평가

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Abstract:

LAMPS 중성자 검출기는 중이온 핵반응에서 생성되는 중성자의 입사위치와 TOF를 측정하여 에너지와 운동량 분포를 측정한다. 이를 위해 중성자 검출기의 성능으로 시간분해능과 위치분해능이 기본적으로 요구된다. 현재 중성자 검출기의 시간분해능과 위치분해능은 우주선 이벤트 해석을 통해서 301 ps, 4.6 cm 가 얻어져 있다.
중성자 검출기에 요구되는 또다른 성능으로서, multi-hit event의 식별능력이 있다. 특히 LAMPS 중성자 검출기는 동시에 여러 중성자가 입사할 경우를 대비하여 한 레이어에 가로 세로방향, 두방향으로 배치된 검출기 두 면을 두어 동시에 입사한 입자를 구분할 수 있는 능력을 높였다. 또한 LAMPS 중성자 검출기는 모든 PMT의 신호를 500 MHz FADC로 기록하는데, 이를 통해 하나의 모듈에 입자가 두개 입사할 경우 파형해석을 통해 이를 분리할 수 있을 것으로 생각된다.
장기간에 걸쳐 취득한 우주선데이터를 파형해석에 이용하여 중성자 검출기의 multi-hit event 식별성능을 평가하였다. 중성자 검출기의 파형해석 및 multi-hit event 식별능력에 대하여 발표한다.

Keywords:

LAMPS, 중성자 검출기, 파형해석

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F3.05

In-gas-cell laser spectroscopy of $^{194,196}Os$

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Abstract:

We performed in-gas-cell laser spectroscopy of $^{194,196}Os$, which were produced by multi-nucleon transfer reaction at the KEK Isotope Separation System (KISS). The nuclei of interest were identified through decay spectroscopy and a newly applied MRTOF-MS. From the study of laser resonance spectra, isotope shifts (IS) of $^{194,196}Os$ were measured for the first time. The change in the mean-square charge radius and the quadrupole deformation parameter were deduced from the IS measurements. The results were compared with the theoretical calculations.

Keywords:

in-gas-laser spectroscopy, isotope shift, 194Os, 196Os

F3.06

HPGe measurements of detector material samples at Yangyang underground laboratory

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Abstract:

The AMoRE searching for neutrinoless double beta decay and the COSINE searching for WIMP dark matter are two main experiments of the Center for Underground Physics running at Yangyang underground laboratory. To control the experimental sensitivities of the two rare event search experiments, two 100% high purity germanium (HPGe) detectors were used in measuring respective detector materials. The HPGe detectors had efficiency calibration confirmed with Geant4 simulation toolkit. We will present measurements results of the detector material samples.

Keywords:

HPGe detector, Radioactive assay, Y2L, CUP, Geant4 simulation

F3.07

The development of LAMPS starting counter

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Abstract:

Starting counter 란 입자 출동 실험을 진행 할 때 입사 입자의 기준 시간을 정해주는 검출기이다. 두 입자간의 충돌 이후 여러 방향으로 산란되는 파편 입자는 시간 투영 챔버(TPC)나 중성자 검출기 같이 다른 검출기들을 통하여 입자를 식별 할 수 있다. 이러한 입자 식별 과정에서 필수적인 정보가 바로 기준 시간이다. 현재 LAMPS 에서는 중이온 입자 빔(Beam)을 통하여 충돌 실험을 진행 할 예정이다. 입자 빔의 세기는 단위 시간당 약 10^{11}개이다. 입자 빔 내의 각각의 개별 입자의 기준 시간을 파악하기 위해서는 좋은 시간 분해능(Timing resolution)을 갖는 Starting counter 를 만드는 것이 필요하다.
본 연구에서는 Scintillator 물질을 통하여 Starting counter를 개발하였다. 광전자 증배관(Photo-multiplier)과 다중 픽셀 광자 검출기 (Multi-pixel photon counter)를 사용하여 Starting counter를 각각 구성하였고, 뮤온과 아메리슘 소스를 통하여 각각의 신호를 측정하였고 DAQ 과정을 통해 시간 분해능을 비교하였다.

Keywords:

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F3.08

Neutron Application for the Quantitative Analysis of Microelements by Nuclear Capture Reaction

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Abstract:

The atomic concentration for elements can be estimated by neutron capture reaction. When certain target elements undergo neutron absorption reactions, they emit prompt gamma rays or energetic charged particles such as alpha, proton, heavy ions and etc. Reaction rates are theoretically determined by the number of target elements, nuclear cross-section, and the neutron flux. Experimentally, this reaction rate can be determined by measuring the count rate of the gamma-ray or charged particles from the unstable nuclide induced by the neutron absorption. The quantitative analysis methods from the reaction rate for gamma rays and charged particles are PGAA (Prompt Gamma Activation Analysis) and NDP (Neutron Depth Profiling), respectively. In the case of the charged particle measurement, the energy spectrum of the charged particles shows broadening because of the energy loss of those charged particles escaping the surface of the target material. The energy loss is determined by the stopping range of the charged particles. Therefore the energy spectrum can be converted to the thickness of the sample. That is why the quantitative analysis method using a charged particle detection called NDP.

The 3rd generation KAERI (Korea Atomic Energy Research Institute)-NDP system with the neutron flux monitoring system was installed at the end of CG1 (Cold neutron Guide1) at HANARO (High-flux Advanced Neutron Application ReactOr). This system is available for the PGAA analysis and NDP as attached the HPGe (High Purity Germanium) and Si ion implanted detector. For the accurate estimation of the reaction rate, the in-situ neutron flux monitoring is required. In the case of the neutron monitor with boron, the neutron flux can be estimated by measuring the emission rate of the α particles, which is generated from the $^{10}B(n,^{4}He)^{7}Li$ reaction. For the design of the inside of the chamber, the neutron transmission ratio for the value higher than 95 % and count rate of α particles from $^{10}B(n,^{4}He)^{7}Li$ as changing the thickness were calculated by MCNP (Monte Carlo N-Particle) transport code. As a result, the thickness of the B was calculated to 1 μm. The B film was prepared by RF sputtering. To make elaborate samples, the surface of the samples was analyzed by using AFM (Atomic Force Microscope) as changing the sputtering conditions, which are the Ar partial pressure, RF power, and heating temperature. The difference in peak to peak and RMS value of B film are 4 nm and 200 pm, respectively.

Keywords:

Neutron Application, Neutron Activation Analysis, Neutron Depth Profiling, Neutron Capture Reaction

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F3.09

실리콘 검출기 시뮬레이션

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Abstract:

실리콘 검출기는 뛰어난 위치 분해능과 빠른 반응속도 때문에 핵물리 분야를 포함하여 광범위하게 사용되고 있다. 하전된 입자가 실리콘 검출기를 지나면 검출기 내부에 전자-정공 쌍이 생성되어 검출기 내부의 전기장분포에 따라 각 전극으로 이동하게 된다. 이 연구에서는 n형의 벌크에 얇은 p형이 결합된 실리콘 검출기에 대한 시뮬레이션을 수행하였다. 역전압의 크기, 입자의 입자 위치 및 각도에 따른 검출기 내부의 퍼텐셜을 격자에 대해 계산하여 각 위치의 전기장을 구하고, 최소 이온화 입자(MIP)가 입사하였을 때의 유도전류를 Shockley-Ramo 정리에 기반하여 계산한다. 또한 이것을 Technology computer-aided design (TCAD) 및 Garfield 시뮬레이션과 비교하여 소개한다.

Keywords:

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F4.01

Basal-plane anisotropy in van der Waal $NiPS_3$

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Abstract:

Single ion anisotropy defines the easy magnetization axis of antiferromagnetic ordering in $NiPS_3$. The magnetic and anisotropic studies of quasi-two-dimensional antiferromagnetic $NiPS_3$ were carried out using SQUID and torque magnetometry measurements. The results provide comprehensive information about the magnetic anisotropy and spin reorientations along with the different crystallographic directions in response to high external magnetic fields ($\boldsymbol{H}$ > 7T). The results demonstrate that sample order antiferromagnetically below $\boldsymbol{T}_\mathrm{N}$ and show a very small magnetic anisotropy along the in-plane direction with some projection of the spins along the $\boldsymbol{c}$-axis. The system shows some spin-flop like feature at certain angles well below $\boldsymbol{T_N}$ and higher applied magnetic fields where the applied $\boldsymbol{H}$ compel the spins to lie along the in-plane direction. The fitting results of the in-plane angle-dependent torque $\boldsymbol{\tau}(\boldsymbol{\varphi})$ show that the sample possesses easy-axis type anisotropy along the in-plane and spins are oriented more along $\boldsymbol{b}$-axis than $\boldsymbol{a}$-axis.

Keywords:

NiPS3, Torque measurements, Magnetic field effect, Magnetic anisotropy

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F4.02

Strain-engineering of the magnetic multipole moments and anomalous Hall effect in pyrochlore iridate thin films

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Abstract:

The recent observation of the anomalous Hall effect (AHE) without significant magnetization in antiferromagnets has suggested that the ferromagnetic ordering is not a necessary condition. Thus, new theoretical studies have proposed that higher-rank magnetic multipoles formed by clusters of spins (cluster multipoles) can generate the AHE without magnetization. Despite such an intriguing proposal, controlling the unconventional AHE by inducing such cluster multipoles has not been thoroughly investigated. Here, we demonstrate that the strain can manipulate the hidden Berry curvature effect by inducing the higher-rank cluster multipoles in spin-orbit coupled antiferromagnets. Observing the large AHE on fully strained antiferromagnetic $Nd_2Ir_2O_7$ thin films, we prove that strain-induced cluster T_1-octupoles are the only source of observed AHE. Our results provide a new pathway for generating the unconventional AHE via strain-induced magnetic structures, and establish a platform for exploring undiscovered topological phenomena via strain in correlated materials.

Keywords:

Anomalous Hall effect, Strongly Correlated system, Antiferromagnetism

F4.03

Controlling anomalous and topological Hall effects in $SrRuO_3$ ultra-thin film by tuning electric field on the surface

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Abstract:

$SrRuO_3$ (SRO) ultra-thin films capped with $SrTiO_3$ (STO) layers are studied by controlling the thickness of SRO and STO layers on STO(001) substrate. As STO layers are capped on 4 uc SRO thin film, the sign of the anomalous Hall effect (AHE) changes and the topological Hall effect (THE) which is originally reported in 4 uc SRO thin film disappears [1]. Moreover, we successfully reduce the critical thickness of the metal-insulator transition into 3 uc by capping STO layers. We observe the emergence of AHE and THE in STO-capped 3 uc SRO thin films and control the size of AHE and THE by tuning the number of STO capping layers and by performing ionic liquid gating experiment. We speculate that the mechanisms of controlling AHE and THE are related to surface rumpling of Ru atom which is intrinsically induced due to inversion symmetry breaking in the thin-film system.

[1] B. Sohn et al., arXiv:1810.01615 [cond-mat.str-el]

Keywords:

Ultra-thin film, SrRuO3, Topological Hall effect, Ionic liquid gating, Anomalous Hall effect

2020 KPS Spring Meeting
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F4.04

Sign-tunable anomalous Hall effect induced by symmetry-protected nodal structures in ferromagnetic perovskite oxide thin films

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Abstract:

Magnetism and spin-orbit coupling (SOC) are two quintessential ingredients underlying novel topological transport phenomena in itinerant ferromagnets. Especially, when spin-polarized bands support nodal points/lines whose band degeneracy can be lifted by SOC, the nodal structures can become a source of Berry curvature that leads to large anomalous Hall effect (AHE). Here we show that two-dimensional spin-polarized band structures generally support symmetry-protected nodal lines and points, which govern both the sign and the magnitude of AHE. To demonstrate this idea, we performed angle-resolved photoemission spectroscopy studies on ultrathin films of $SrRuO_3$, a representative metallic ferromagnet with SOC. We show that the sign of the AHE can be controlled by changing film thickness, magnetization, and chemical potential. Our study provides the first direct evidence relating the topological band structure of two-dimensional spin-polarized bands and the corresponding AHE, which sheds light on the advent of new switchable devices based on ferromagnetic ultrathin films.

Keywords:

Anomalous Hall effect, SrRuO3, ultrathin film, Pulsed Laser Deposition, Berry curvature, ferromagnetic oxide perovskite

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

F4.05

Visualizing orbital content of electronic bands in anisotropic 2D semiconducting $ReSe_2$

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Abstract:

Many properties of layered materials change as they are thinned from their bulk forms down to single layers, including the case of indirect-to-direct band gap transition in 2H semiconducting transition metal dichalcogenides. Here, we use angle-resolved photoemission spectroscopy to study the electronic bands structure of monolayer $ReSe_2$, a semiconductor with a distorted 1T structure and in-plane anisotropy. By changing the polarization of incoming photons, we demonstrate that for $ReSe_2$, in contrast to the 2H materials, the out-of-plane transition metal d_{z^2} and chalcogen p_z orbitals do not contribute significantly to the top of the valence band which explains the reported weak changes in the electronic structure of this compound as a function of layer number. By surface-doping our sample with potassium, we also place a lower bound of 1.41 eV on the magnitude of the electronic band gap, a value that is comparable with measured optical gaps. Our results, supported by density functional theory calculations, provide insight into the mechanisms behind polarization-dependent optical properties of rhenium dichalcogenides.

Keywords:

anisotropic 2D semiconductor, rhenium diselenide, orbital-selective electronic structure, transition metal dichalcogenides, two-dimensional materials

2020 KPS Spring Meeting
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F5.01

Tunable quantum interference effect on magnetoconductivity in few-layer black phosphorus

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Abstract:

In this study, we develop a systematic weak localization/antilocalization theory fully considering the anisotropy and Berry phase of the system, and apply it to various phases of few-layer black phosphorus (BP), which has a highly anisotropic electronic structure with an electronic gap size tunable even to a negative value. The derivation of a Cooperon ansatz for the Bethe-Salpeter equation in a general anisotropic system is presented, revealing the existence of various quantum interference effects in different phases of few-layer BP, including a crossover from weak localization to antilocalization. We also predict that the magnetoconductivity at the semi-Dirac transition point will exhibit a nontrivial power-law dependence on the magnetic field, while following the conventional logarithmic field-dependence of 2D systems in the insulator and Dirac semimetal phases. Notably, the ratio between the magnetoconductivity and Boltzmann conductivity turns out to be independent of the direction, even in strongly anisotropic systems. Finally, we discuss the tunability of the quantum corrections of few-layer BP in terms of the symmetry class of the system.

Keywords:

Weak localization, Weak antilocalization, Black phosphorus, Lattice anisotropy

2020 KPS Spring Meeting
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F5.02

Detecting Fractional Statistics on Integer Quantum Hall Edges

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Abstract:

Fractional charge and statistics are hallmarks of low-dimensional strongly-correlated systems such as fractional quantum Hall systems. In non-interacting integer quantum Hall systems (IQHs), fractional charged excitations can still occur if we adjoin the system to the strongly correlated one [1] or bias the lead in a time-dependent manner [2]. We demonstrate that the fractional excitation has the fractional statistics, and propose a way to detect the statistics.

Here, we focus on the fractional mutual statistics between a fractional excitation and an electron, and propose a Mach-Zehnder interferometer (MZI) for detection of the mutual statistics. While a fractional excitation is injected to the MZI, an electron, instead of another fractional excitation, thermally tunnels at a quantum point contact of the MZI, resulting in a double exchange with the fractional excitation. We find the condition under which such a process dominates the interference current. The double exchange can be read out by the phase shift of the Aharonov-Bohm oscillation of the interference current. We expect that the large controllability of the IQH system enables us to observe the phase shift and to confirm the fractional statistics.

[1] E. Berg, Y. Oreg, E.-A. Kim, and F. von Oppen, Fractional Charges on an Integer Quantum Hall Edge, Phys. Rev. Lett. 102, 236402 116-119 (2009)
[2] J. Dubois et al. Integer and fractional charge Lorentzian voltage pulses analyzed in the frame of Photon-assisted Shot Noise, Phys. Rev. B 88, 085301 (2012)

Keywords:

Fractional statistics, Anyon, Integer Quantum Hall Edge

2020 KPS Spring Meeting
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F5.03

Universal scaling of multi-channel Kondo entanglement at finite temperature: a numerical renormalization group result

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Abstract:

Kondo effect, which happens as a spin-1/2 impurity is entangled with conduction electrons, is an important topic of condensed matter physics. When the impurity is screened by multiple conduction electron channels, the multi-channel Kondo effect occurs. The effect shows a non-Fermi liquid behavior and results in fractional quasi-particles such as a Majorana fermion at the impurity, at low temperature.

We study entanglement in the multi-channel Kondo effect and analyze the temperature dependence of the entanglement by using the numerical renormalization group method. We use entanglement negativity to compute the entanglement at finite temperature. We discuss how the entanglement negativity can be numerically computed efficiently. We study the entanglement in the single-, two-, and three- channel Kondo effects, and find that it shows different thermal scaling behavior. This numerical result is in accord with the prediction given by the boundary conformal field theory.

Keywords:

Kondo effect, Entanglement, Numerical renormalization group

Quasi-One-Dimensional Higher-Order Topological Insulators

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Abstract:

Quasi-1D materials Bi_4X_4 (X = Br, I) are prototype weak topological insulators (TI) in the β phase. For the α phases, recent high-throughput database screening suggests that Bi_4Br_4 is a rare higher-order TI (HOTI) whereas Bi_4I_4 has trivial symmetry indicators. Here we show that in fact the two α phases are both pristine HOTIs yet with distinct termination-dependent hinge state patterns by performing first-principles calculations, analyzing coupled-edge dimerizations, inspecting surface lattice structures, constructing tight-binding models, and establishing boundary topological invariants. We reveal that the location of inversion center dictates Bi_4Br_4 (Bi_4I_4) to feature opposite (the same) dimerizations of a surface or intrinsic (bulk or extrinsic) origin at two side cleavage surfaces. Given the superior hinges along atomic chains, the structural transition at room temperature, and the extreme anisotropies in three axes, our results not only imply the possible existence of many topological materials beyond the scope of symmetry indicators but also establish a new TI paradigm and a unique material platform for exploring the interplay of geometry, symmetry, topology, and interaction.

Reference : arXiv:2005.14710

Keywords:

quasi-1D material, higher-order topological insulator

2020 KPS Spring Meeting
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F5.05

Numerical reconstruction of 2D Transverse Magnetic Focusing

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Abstract:

Spatial manifestations of quantum mechanics illustrate some of the most striking examples of wave-particle duality. However, experimental investigations typically remain elusive and theoretical studies are often unfeasible due to the cumbersome and detailed scattering problems. This is particularly true in mesoscopic physics, where boundary effects can be large while device geometries are becoming increasingly complicated. Fortunately, the python package KWANT offers us a highly accessible method to simulate quantum phenomena in the direct space. Here, we present a realistic, numerical study of transverse magnetic focusing (TMF) using KWANT. In the study, we have characterized the simulation as we would for real devices and calculated both the TMF conductivity and corresponding current density. The feasibility of KWANT as a precursor to experimental investigations was confirmed by comparing experimental results to the simulation. Furthermore, we have simulated TMF using quantum dots or multi-channel quantum point contacts.

Keywords:

mesoscopics, magnetic focusing, simulation, KWANT

2020 KPS Spring Meeting
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F5.06

Ultrafast Energy Relaxation of 2D Hot Electrons generated from a Quantum Dot

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Abstract:

From a series of transverse magnetic focusing experiments, we report an ultrafast relaxation in 2D hot electrons when generated by a quantum dot (QD). Similar experiments in the past have used quantum point contacts (QPC) to generate hot electrons. We confirmed that such QPC hot electrons presented negligible energy relaxations up to 1.5 meV above the Fermi level, 7.44 meV, and 3 um in length scale —in good agreement with the non-interacting Fermi gas model. On the contrary, hot electrons generated by a QD presented an increasing energy relaxation that was a sizeable fraction of the tested excitations (up to 55%) within 1 um in length scale. We propose that the relaxation process occurs immediately after the hot electron leaves the QD. A toy model qualitatively explains this process as an energy exchange between the hot electron and the QD via a capacitive coupling inbetween.

Keywords:

transverse magnetic focusing, 2D electron gas, quantum dot, hot electron, energy relaxation

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F6.01

Stabilization of grain boundaries in CdTe by mirror symmetry breaking

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Abstract:

Cadmium telluride (CdTe) has been widely used for photovoltaic applications. The fact that the solar cells made of polycrystalline CdTe outperform those made of crystalline CdTe have convinced researchers to believe that grain boundaries in the CdTe absorber layer are beneficial for photovoltaic applications. To investigate the role of grain boundaries, first-principles density functional theory (DFT) calculations also have been performed, mostly based on the images obtained by transmission electron microscopy (TEM). This approach, however, has difficulty in the construction of a three-dimensional structure from a two-dimensional image. In our study, the atomic structure of grain boundaries was explored using a modified genetic algorithm [1]. Some structures found in this study were more stable than previously reported structures based on the TEM image. We also performed hybrid DFT calculations and found that our grain boundary model does not have deep gap states.

[1] J.-S. Park, Phys. Rev. Materials 3, 014602 (2019).

Keywords:

genetic algorithm, DFT, CdTe, grain boundary

2020 KPS Spring Meeting
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F6.02

High Thermoelectric Performance in Hexagonal 2D PdTe2 Monolayer at Room Temperature

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Abstract:

Motivated by the recent fabrication of the hexagonal PdTe2 monolayer, we investigated the thermoelectric properties of the hexagonal and pentagonal PdTe2 structures using two approaches. The pentagonal monolayer has not been synthesized yet. The hexagonal layer had an indirect band gap of 0.17 eV while the pentagonal structure had an indirect band gap of 1.18 eV. By applying the semiempirical Wiedemann−Franz law to calculate the electronic thermal conductivity, we found that both hexagonal and pentagonal structures had a very high ZT, more than 3. However, the Wiedemann−Franz law underestimated the electronic thermal conductivity, and this resulted in a high ZT. Thus, we employed the Boltzmann transport equation for the electronic thermal conductivity. At high temperature (>500 K), the pentagonal PdTe2 structure showed a better thermoelectric performance than the hexagonal structure. However, both structures displayed the same ZT of 0.8 at 300 K. We propose that the hexagonal PdTe2 can be a potential high performance thermoelectric material at room temperature.
(This research was supported by NRF 2019RA21B5B01069807).

Keywords:

PdTe2 monolayer, Boltzmann approach, thermoelectric, high ZT, room temperature

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F6.03

Microscopic origin of the large shift current in the β-MAPbI3 and α-FAPbI3

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Abstract:

Hybrid halide perovskite solar cells have aroused great interest due to the high power conversion efficiency and excellent optoelectronic properties. In particular, (CH3NH3)PbI3 (MAPbI3) and C(NH2)2PbI3 (FAPbI3) where the band gaps are well matched with the visible light frequency has been creating a surge of research activity. Here, we investigate the electronic origin of a large nonlinear photocurrent, so called shift current, in the β-$MAPbI_3$ and α-$FAPbI_3$. We theoretically demonstrate that the electronic polarization of the hybrid halide perovskite is dominated by the ionic contribution of the organic cation in combination with the marginal atomic displacement of the inorganic frame. Unlike the electric polarization, the photovoltaic property is largely governed by the electronic state near the Fermi level, yielding a comparable shift current even in the absence of the cationic molecules, the important ingredient for the ferroelectricity. We also find the generated photocurrent is attributable to the spatial charge shift from iodine to lead atoms through the visible light and ultraviolet excitations. Our findings provide a better understanding of the optoelectronic properties of the halide perovskites and a theoretical guidance for developing an improved photovoltaic device.

Keywords:

First principles calculation, DFT, Bulk photovoltaic effect, shift current, organic-inorganic hybrid halide perovskites

F6.04

Piezoelectric modification of groupIV-monochalcogenide materials

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Abstract:

Piezoelectric materials can be used for energy harvesting devices and sensors due to their properties of converting mechanical energy to electrical energy. Typically, lead zirconate titanate(PZT) is well known for such piezoelectric materials, but it is also known to be vulnerable under larger strain. That's why researchers try to search for other piezoelectric materials such as TMDCs and group-IV monochalcogenides. Among these materials, the 2D group-IV monochalcogenides have good properties for piezoelectric devices due to their higher piezoelectric coefficients compared to other materials. To investigate and enhance the piezoelectric properties of such materials, we perform first-principles calculations. It is found that the AA-stacking of these group-IV monochalcogenides can be a good strategy for enhancing the piezoelectric coefficients further. We find that the piezoelectric coefficients of the AA-stacked bilayer become larger than twice of those values of mono-layer group-IV monochalcogenides. It is assigned to the strain induced by AA-stacking. Our results suggest how to modulate piezo-coefficients in the group-IV monochalcogenides.

Keywords:

DensityFunctionalTheory, piezoelectric property, group-IV monochalcogenide, first principles calculation

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F6.05

First-principles study of the hydrogen-bond network in water at the biased electrode interface

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Abstract:

A crucial step for the development of next-generation electrochemical devices will be the understanding of the atomic and electronic structures of interfacial waters next to biased electrode surfaces. In this presentation, carrying out first-principles non-equilibrium electronic structure calculation within the multi-space constrained-search density functional theory (MS-DFT) formalism we have recently developed, we study the bias-dependent structural and electronic properties of the hydrogen-bonding network of water molecules at the gold electrode interface. Benchmarking the non-equilibrium force profile of a single water molecule next to the gold electrode obtained from non-equilibrium Green's function (NEGF) calculations, we confirm the practical equivalence between MS-DFT and DFT-NEGF. We also report the advantages of MS-DFT in view of electrochemical device simulations by providing (1) well-defined binding energies and (2) the electrochemical potential profiles. Analyzing the spatial profiles of the electrochemical potentials or quasi-Fermi levels at the gold-water interface at varying bias voltages, we extract several important insights into the nature of hydrogen bond network of liquid water at the biased electrochemical interfaces.

Keywords:

sold-water interface, density functional theory development, electric enthalpy, hydrogen-bonding network, non-equilibrium first-principles calculations

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F6.06

Defect mediated electron transport in MoS_2

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Abstract:

We have investigated the effects of sulfur vacancies in MoS_2 on electronic structures and transport properties using density functional theory (DFT) and non-equilibrium Green's function (NEGF) method, especially focusing on multiple vacancies. The defect states induced by sulfur vacancies can be connected globally when the concentration of sulfur vacancies is above 5 at %. From the analysis of transmission as a function of the distance between two vacancies in the scattering region, the maximum distance was found for transmission through the defect states. Opening defect mediated transport channels and negative differential resistance (NDR) were observed and were analyzed in terms of the local density of states and transmission spectra.

[Acknowledgement: NRF-2018R1A6A1A06024977, UOS-BSIRDF2019]

Keywords:

MoS2, Defect, Charge transport, Density functional theory, Non-equilibrium Green's function method

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F6.07

First-Principle Study on the Oxygen Related Color Centers in Hexagonal Boron Nitride

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Abstract:

As the word itself demonstrates, color centers play an essential role in the light emission from hexagonal boron nitride (hBN). One of the experimental methods to create them is etching the surface of hBN with oxygen plasma, which constructs usually oxygen-related color centers. As a result, several photoluminescence (PL) intensity peaks are observed from 1.6 eV to 3.6 eV. To identify which color center contributes to each PL peak, we investigated several types of oxygen-related defects, which can be generated on hBN, using the first-principles density functional theory. To determine the possibility of forming each color-center, we evaluate the formation energy of each color center. The oxygen substitution for nitrogen (O_N) and the boron vacancy (V_B) next to the ON are the two most stable configurations among the oxygen-related color centers we considered. The formation energies of charged states are also considered, with pertinent correction for spurious long-range Coulomb interaction due to the periodic image charges. Then we scrutinized electronic band structures of hBN with color centers using hybrid exchange-correlation functional, which is well-known for giving an accurate bandgap of hBN, to examine possible light emission from these color centers.

Keywords:

color cetner, hexagonal boron nitride, photoluminescence

2020 KPS Spring Meeting
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F6.08

Phonon softening in the room-temperature organic-Inorganic hybrid Perovskites

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Abstract:

Due to the weak interaction between organic cations and an inorganic sublattice in the organic-inorganic hybrid Perovskite (OIHP), the organic cations can freely rotate at the room temperature. Interestingly, it was reported that the fascinating physical properties of the OIHP, such as long carrier lifetime, are originated from the organic cation rotation. To understand the underlying physical role of the organic cation rotation, it is required to know its dynamical behaviors at room temperature rather than its frozen configuration. Thus we perform molecular dynamics simulation based on first-principles density functional theory and evaluate a time-averaged force constant matrix to calculate room-temperature phonon dispersion relations. We find that the time scale of the molecular rotation is about an order of a few ps and the rotating molecule causes significant phonon softening in the room-temperature OIHPs. Furthermore, we discuss the effects of such phonon softening, which may influence various physical properties, such as lattice thermal conductivity, electron-LO phonon interactions, and static dielectric constants.

Keywords:

Density functional theory, Molecular rotation, Organic-Inorganic hybrid Perovskites, Phonon

F6.09

First-principles study of the electronic properties of cellulose nanocrystal surfaces

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Abstract:

Cellulose, a linear polymer of glucose residues, is the most abundant biopolymer on the planet. In bulk crystalline form, the linear cellulose polymers are linked together by hydrogen bonds to form a van der Waals stacked layered structure. Unlike conventional van der Waals layered materials, however, the surfaces of cellulose nanocrystals (CNCs) have different orientations from that of the constituent cellulose layers. Consequently, at the CNC surfaces, each of the cellulose layers is terminated with -CH_2OH groups, forming two-dimensional (2D) lattices of the exposed functional groups. Here, using first-principles calculations, we investigate electronic structures of two representative CNC surface models of natural cellulose crystals, Iα and Iβ. We show that the 2D lattice of -CH_2OH at the CNC surfaces gives rise to atomically thin surface states below the conduction-band edge of the bulk states. Photocarrier doping of the surface states is proposed. We also show that the asymmetric -CH_2OH configurations on the surfaces causes internal electric field to be induced across the Iα CNC film. These finding may pave a way to develop new functional CNCs with energy and electronics applications.

Keywords:

Cellulose nanocrystal, Density functional theory, band structure

2020 KPS Spring Meeting
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F7.01

High fidelity encoded gate operations for composite superconducting qubit

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Abstract:

Composite superconducting qubit scheme for superconducting transmon qubits explores a non-traditional architecture where the computational states are encoded by the hybridized states formed by a pair of capacitively coupled degenerate transmons. Gate operations can be implemented on the composite qubit using non-adiabatic Landau-Zener control of the small avoided crossing. These require only baseband control, without individual microwave control for each transmon, obviating the need for expensive state-of-the-art microwave equipment for individual qubit operations. Theoretical description along with an experimental realization of this approach will be presented. Even with frequencies far below the effective temperature, high fidelity encoded gates can be achieved utilizing the sweet spot (optimal operating point) and dynamical sweet spot (optimal pulse shape). Further, these composite qubits show immunity to photon number fluctuations in readout resonators, which can be a limiting factor in many transmon-based quantum computing systems.

Keywords:

quantum computing, superconducting qubit, transmon qubit, quantum gate

2020 KPS Spring Meeting
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F7.02

Charge state manipulation of color centers in semiconductors for quantum applications

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Abstract:

When point defects with long-lived spins in wide-bandgap semiconductors behave as atom-like systems, they can be used for quantum metrology, quantum communication, and quantum information processing. The charge state is a key element for defects to be a well-isolated atom-like system because it determines and stabilizes optical and spin properties in solids. Investigation of charge state is, therefore, mandatory for establishing fundamentals of defect-based quantum applications and devices. In this presentation, it will be explained how one can access and manipulate charge state of individual point defects in an optoelectronic device, and the quantum applications related to charge state control will also be introduced. Especially, I will give a focused review on photoionization via charge state switching allowing photoelectrical spin state detection of point defects which can be used for efficient and fast readout of spin-based quantum devices such as quantum processors and quantum sensors.

References
[1] Niethammer, M. et al. Coherent electrical readout of defect spins in silicon carbide by photo-ionization at ambient conditions. Nat. Commun. 10, 5569 (2019).
[2] Widmann, M. et al. Electrical charge state manipulation of single silicon vacancies in a silicon carbide quantum optoelectronic device. Nano Lett. 19, 7173–7180 (2019).

Keywords:

quantum devices, point defect, color center, charge state

2020 KPS Spring Meeting
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F7.03

Fast adoptive quantum measurements in semiconductor quantum dots

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Abstract:

The electron spin degree of freedom in solids form natural basis for constructing quantum two level systems, or qubits. The electron spin qubit offers a route for fast manipulation of spins using magnetic resonance or field gradient induced electric control, but generally suffers from dephasing due to strong coupling to the environment, especially nuclear spin bath, where decoherence dynamics is often non-Markovian. This talk will review experimental progress of fast GaAs based spin qubits and efforts to mitigate or even control the environment nuclear spin bath using hyperfine interaction. Starting from discussing general introduction to quantum transport measurements in quantum dots, circuit design, and need for high-throughput measurement methods for developing highly coherent and scalable qubit platform, the talk will focus on implementations of advanced quantum measurement and control protocols of singlet-triplet qubits including high fidelity singlet-shot measurements and Bayesian estimation-based adoptive control.

Keywords:

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F8.01

Nanoporous gold-palladium films for high catalytic activity of the electro-oxidation of ethanol

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Abstract:

Nanoporous gold (NP-Au) is a promising versatile material that can be used in many fields, a result of its high conductivity, large surface area, and excellent stability. NP-Au is commonly functionalized in combination with other materials; however, difficult syntheses are obstacles to catalyst development. In this presentation, a simple method for the fabrication of binary nanoporous gold-palladium (NP-AuPd) with a tunable Au/Pd ratio is developed [1]. Ternary alloy films of Au-Pd-Mg are prepared by sputter deposition and Mg is dissolved from the alloy to make nanoporous structures. The Au and Pd in NP-AuPd are evenly distributed over the entire structure. The electro-catalytic activity of the developed NP-AuPd is evaluated by oxidizing ethanol in alkaline media. The optimized NP-AuPd shows remarkable electro-catalytic activity and excellent stability. The nanoporous structure not only increases the number of reaction sites and mass transfer, but it also enhances the durability of the catalyst. The developed method can be extended to the preparation of binary nanoporous thin films with controlled compositions and desired catalytic activities.

Keywords:

Nanoporous, Electrocatalysis, gold-palladium, ethanol

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F8.02

Effect of morphologies on optical characterization of micro-nanostructured V_2O_5

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Abstract:

In this study, the fabrication processes, structure, and optical characterization of V_2O_5 micro-nanostructures, including thin films, nanoparticles, micro-nanorods, micro-nanowires, nanospheres, and nanohollows were presented. The wide ranges of band edge absorption and broad PL of V_2O_5 micro-nanostructures are clarified in terms of factors such as the morphology, synthesis method, growth conditions, micro-nano size, and phase transition. The relations among the separation, diffusion, and recombination of the electron-hole pairs in V_2O_5 micro-nanostructures are also discussed. The formation of the mixture of α-β phase V_2O_5 film due to the effect of annealing temperature leads to wide absorption and enhancement of the visible-light. A larger number of V^{4+} oxidation states of V_2O_5 nanospheres strongly enhanced PL intensity compared with other structures that showed weak PL. In particular, V_2O_5 nanospheres showed intense ultraviolet (UV) PL near 394 nm due to strong excitation by UV light, while this PL peak was not observed from other nanostructures.

Keywords:

V2O5, micro-nanostructure, PL

2020 KPS Spring Meeting
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F8.03

Thermoelectric properties of W doped V_2O_5 pellets formed by pressed nanopowder

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Abstract:

현대의 환경오염 문제가 심화되면서, 다양한 장치들의 에너지 효율을 높이기 위한 소재 개발이 관심을 받고 있을 뿐 아니라 그들의 나노구조를 달리하여 장치의 효율을 높이기 위한 연구도 많은 관심을 받고 있다. V_2O_5는 gas sensor, photocatalytic, thermoelectric device 등의 많은 분야에서 관심을 받고 있으며 다양한 형태의 나노구조를 구현할 수 있다. 일차원 나노구조인 nanorod와 nanowire 그리고 이차원 구조인 nanosheet가 대표적인 예이다. 그리고 W, Bi 등을 도핑하여 높은 전기전도도와 낮은 열전도성을 가진 높은 효율의 열전소자를 구현할 수 있다.
본 연구에서는 먼저 ammonium metavanadate(NH_4VO_3,99%)와 Hydrogen chloride(HCl, 36.5~38%)를 혼합하여 환원반응을 일으키고 hydrazine hydrate 용액($N_2H_4 \cdot H_2O$,78~82%)을 첨가하여 3차원 나노구조체를 제작하는 화학반응법으로 250 nm 크기의 V_2O_5 나노파우더와 180 nm 크기의 $W_xV_{2-x}O_5$(X = 0.04, 0.08, 0.12) 나노파우더를 제작하고 프레스를 사용하여 이를 펠릿 형태(직경 φ = 12.7 mm, 두께 d = 3mm)로 만들어 열전특성을 측정하였다. W 도핑에 의한 V^{5+} 원소와 V^{4+} 원소비의 변화와 자유전자농도의 변화로 인한 ZT값의 변화와 MIT 특성의 변화를 분석하였다.

Keywords:

V2O5, Thermoelectric, W, nanopowder, MIT

2020 KPS Spring Meeting
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F8.04

Nanofabrication and Sensor by using a nanopipette/nanorod-combined quartz tuning fork atomic force microscope

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Abstract:

Nanofabrication is one of the essential keyword nowadays in the field of nanoscale science and technology. Normally, there are two ways for nanofabrication as a top-down (photolithography, e-beam lithography, physical/chemical vapor deposition, nano-imprint technique, etc) and bottom-up (self-assembly, vapor-liquid-solid growth catalyst, etc) methods. Among them, scanning probe microscope-based lithography (bottom-up) has several advantages such as direct patterning, on-demand / selective positioning. Nanopipette is one of the useful tool for nanofabrication (bottom-up method) with manipulation and delivery of micro/nanoscale objects such as micro/nanoscale biomolecules, organic/inorganic materials. However, it is difficult to control precisely approaching on the hard surface without tip breaking. Here we show the capability of precise control of the nanopiptte combining with a guidance of quartz tuning fork (QTF)-based atomic force microscope (AFM) which is a versatile tool in the field of nanoscale science and technology [1,2]. Additionally, we demonstrate a nanorod-combined QTF-AFM as a nanoscratching technique with in situ measurement of shear dynamics [3] along with showing sensor capability of bifurcation-enhanced sensitive measurement in ambient conditions [4,5].

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Keywords:

Nanofabrication , QTF-AFM, Nanopipette, Nanorod, Sensor

2020 KPS Spring Meeting
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F8.06

Metal Oxide Transfer Film of UV-Ozone Treated Double Structure TiO_2/SnO_2 and SnO_2/TiO_2 Based Planar Perovskite Solar Cell

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Abstract:

SnO_2 and TiO_2 are popular metal oxide transfer thin films (MOTF) that are used for many applications due to their unique properties. This study rebuilds the importance of the combination of MOTF as electron transporting layers for photovoltaic applications as perovskite solar cells. Surface facile photochemical treatment, such as UV–ozone (UVO) treatment, was applied to double structured TiO_2/SnO_2 and SnO_2/TiO_2 films and FTO, ITO and glass substrates. Double oxide layers can provide that, compared to their individual film, an improved optical and electrical properties. Optical properties showed to enhance the electron extraction, hole blocking and reduce electorn and hole recombination of double MOTF (DMOTF) due to UVO treatment. It was conducted of spectroscopic and microscopic techniques to investigate the physical properties of the samples. The band alignment, surface potential and charge carrier transfer mechanism were explained by Kelvin probe force microscopy and ultraviolet photoelectron spectroscopy. Higher carrier concentration and lower resistivity of DMOTF was displayed by hall measurements when compared with any single layer of SnO_2 and TiO_2. The results suggest that the DMOTF can serve as a better electron transporting layer to promote charge separation and suppress charge recombination. Therefore, these are beneficial for reducing the recombination of carriers, enhancing of perovskite solar cell performance.

Keywords:

Metal oxide transfer thin films, Perovskite, UV–ozone treatment, TiO2/SnO2 double structure

2020 KPS Spring Meeting
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F8.07

Room Temperature Magnetoresistance of the Graphene-based Spintronic Devices

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Abstract:

The discovery of two-dimensional materials has opened up novel horizons in terms of functionality and effectiveness for the next revolution of spintronic devices. In particular, graphene has attracted an endlessly growing scientific community of expects owing to its unique properties: the semimetal band structure, high carrier mobility, the weak spin-orbit coupling, etc. Nevertheless, there has been a lack of understanding of how the spin-orbit proximity effects influence the spin dynamics and the emergence of the spin Hall effect.
In this work, we focused on demonstrating the magnetoresistance (MR) behavior of multilayer graphene-based structures. The 2.5 nm-thick of Co and 3.0 nm-thick of Pt were fabricated as a Hall bar on top of the large-area CVD-grown graphene film using an *in-situ* shadow mask patterning technique by the UHV-MBE system. In order to investigate the interface effects, a 1.2 nm-thick of MgO was introduced in between the graphene and Co as a comparative study of spin transport for the devices with and without an ultrathin MgO film at the Co/graphene interface. Interestingly, the field-dependence MR value of ~0.8% was observed at room temperature for the sample with MgO interlayer larger than that of the sample without MgO ~10 times. Moreover, the MR results of the out-of-plane magnetic field revealed the evidence of the presence of the spin Hall effects in graphene heterostructures. For the microstructure characterization of the hybrid structures, the analysis of interface properties was performed the AFM and the chemical properties were characterized by the Raman spectroscopy.
Our results could provide a deeper understanding of the spin-orbit proximity effects and highlight the potential opportunities for the next revolution of graphene spintronics.

Keywords:

Two-dimensional materials, proximity effects, graphene spintronics

F9.01

Localization of Bogoliubov Excitations in Disordered Gross-Pitaevskii Chains at T=0

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Abstract:

We examine the one-dimensional Gross-Pitaevskii lattice at zero temperature in the presence of disorder. We obtain analytical expressions for the thermodynamic properties of the ground state and compare them with numerical results. We compute the localization length of Bogoliubov modes (BM) by measuring their participation number. We identify a Lifshits glass regime where disorder dominates over the interactions, with the chemical potential located in the Lifshits tail of the spectrum. With increasing particle density the external disorder gets screened by the interaction-modified ground state. This leads to a dramatic increase in the localization length of BMs. We also investigate the zero energy anomaly of a diverging localization length of BMs which is characterized by an interaction-dependent exponent.

Keywords:

Discrete Nonlinear Schrodinger Equation (DNLS), Lifshits regime, disordered Gross-Pitaevskii lattice, ground state, Bogoliubov-de Gennes equations

2020 KPS Spring Meeting
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F9.02

New type of oscillation death in coupled counter-rotating identical nonlinear oscillators

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Abstract:

We study oscillatory and oscillation suppressed phases in coupled counter-rotating nonlinear oscillators. We demonstrate the existence of limit cycle, amplitude death, and oscillation death, and also clarify the Hopf, pitchfork, and infinite period bifurcations between them. Especially, the oscillation death is a new type of oscillation suppressions of which the inhomogeneous steady states are neutrally stable. We discuss the robust neutral stability of the oscillation death in non-conservative systems via the anti-PT-symmetric phase transitions at exceptional points in terms of non-Hermitian systems.

Keywords:

coupled counter-rotating nonlinear oscillators, neutral stability in non-conservative systems, oscillation death

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F9.03

미국의 리츠, 채권 그리고 주식 간의 정보흐름 실증분석

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Abstract:

본 연구의 목적은 미국의 거래소에 상장되어 있는 리츠와 다른 자산들 간의 정보흐름을 파악하고자 하는 것이다. 이를 위해 상장리츠를 지수화한 부동산지수를 포함하여 주가지수와 국채지수의 시계열분석을 바탕으로 시장정보의 흐름을 실증분석 하였다. Granger causality를 이용한 실증 분석의 결과, (a) Granger causality 검정으로는 복잡계를 이루는 투자자산시장에 대한 인과관계를 검정하기에 한계를 보였다. 대안으로 (b) 비선형 시스템 간의 인과관계를 측정할 수 있는 transfer entropy를 분석한 결과 리츠와 채권 간에 상호 정보를 주고받고 있었으나, 리츠와 주식 간에는 뚜렷한 정보의 흐름이 나타나지 않았다. 이는 리츠와 채권 투자자의 경우, 고정수익성격의 투자를 선호하여 양 시장 간 시장수익률과 배당정보를 상호 비교하여 투자하는 특성을 잘 반영하였다고 판단된다. 반면 리츠 혹은 주식 투자자들은 단기 이벤트성의 투기적인 투자가 주를 이루어 연계성이 떨어지는 것으로 보인다.

Keywords:

정보흐름, 인과관계, 정보흐름, 그랜저 인과관계, 전이 엔트로피

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F9.04

전환사채, 채권, 주식 상호간 정보 흐름에 관한 연구

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Abstract:

본 연구의 목적은 주식과 채권의 성격을 모두 갖고 있는 금융자산인 전환사채가 주식시장 및 채권시장과 얼마나 정보를 주고 받음으로써 시장가격에 영향을 주고 받는지를 살펴 봄으로써 전환사채의 성격을 파악하고자 하였다. 연구를 위해 글로벌 인덱스 중에서 각 자산을 대표하는 인덱스의 시계열 자료의 일별수익률을 활용하여 상호간 정보의 흐름을 non-linear causality measure인 effective transfer entropy를 측정하였다. 금융위기와 금융위기 전후의 기간을 분석 대상으로 하여 전환사채가 주식, 채권 중 어떤 자산과 밀접하게 정보 교류가 있었는지 살펴 보았다. 금융위기 이전과 금융위기, 그리고 금융위기 이후의 전환사채, 주식, 채권 간 상호 정보흐름의 변화를 확인하였다.

Keywords:

전환사채, , effective transfer entropy

2020 KPS Spring Meeting
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G1.02

Development of sensitive radon detector for KNO

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Abstract:

There has been much effort in developing a high sensitivity radon detector for KNO(Korea Neutrino Observatory). The radon dissolved into water from air produces a major background at low energies(<5MeV) in a water Cherenkov detector. A next generation of a large water Cherenkov detector, KNO, needs to develop a radon removal system and a highly sensitive radon measurement device. We have completed successful construction of a sensitive radon detector and its calibration. In this presentation we will describe specification and status of the sensitive radon detector and report its calibration results.

Keywords:

KNO, neutrino, Rn, water purification, underground experiment

2020 KPS Spring Meeting
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G1.03

Neutron detection of the System of on-Axis Neutrino Detection in the DUNE near detector

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Abstract:

The System for on-Axis Neutrino Detection (SAND) is a reference detector in the Near Detector complex of the Deep Underground Neutrino Experiment (DUNE). It is composed of a 3-Dimensional Projection Scintillator Tracker (3DST), surrounded by a low-density tracker, an Electromagnetic Calorimeter (ECAL) and a Magnet used for the KLOE experiment. This system aims at detecting all final-state particles including neutrons from neutrino charged-current (CC) interaction , thus providing a full reconstruction of each individual interaction channel. Because the precise information of neutron kinetic energy is largely missed in current neutrino experiments, SAND is unique and unprecedented for the measurement of neutron kinetic energy using the time-of-flight (ToF) technique. Such a measurement can constrain the neutrino interaction and flux uncertainty for each exclusive neutrino interaction channel. In this presentation, the capability of detecting final state neutrons in SAND is demonstrated with a full picture of background and detection uncertainty.

Keywords:

DUNE, neutrino

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G1.04

Search for Sterile Neutrinos at RENO

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Abstract:

The RENO experiment has successfully measured θ_{13} using the disappearance of electron anti-neutrinos in three-flavor neutrino oscillations. We search for sterile neutrinos in four-flavor oscillation model using 2200 days of data collected by the RENO experiment. We have not seen any positive signal and obtain an excluded region of the oscillation parameters. We present an excluded contour plot in $\sin^2(2\theta_{14}) - \Delta m_{41}^2$ space with free $\sin^2(2\theta_{13})$ and constraint on the other oscillation parameters.

Keywords:

RENO, sterile neutrino, reactor neutrino experiment

2020 KPS Spring Meeting
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G1.05

Detector Stability in NEOS-phase2

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Abstract:

NEOS is an experiment to measure the energy spectrum of anti-neutrinos from a reactor core. The experiment has been carried out at 24-m distance from the active reactor core, in the tendon gallery of the Hanbit-5 reactor. In phase1, data were taken for the initial six months of a reactor operation cycle. In phase2, the detector has been operated for the whole burn-up cycle (~500 days). A continuous decrease of light output was found, which degrades the energy resolution. In this presentation, we report the stability of the NEOS detector including light output, the energy resolution and their effects on the analysis.

Keywords:

NEOS, Neutrino, reactor

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G1.06

Observationt of cosmic muon variation at RENO

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Abstract:

Time variation of cosmic muon rate has been observed at two identical RENO detectors with overburdens of 120 and 450 meter-water-equivalent. A cosmic muon rate is known to be varied due to atmospheric pressure and temperature where it depends on muon energy threshold and production ratio between kaon to pion in the atmosphere. Both RENO detectors have measured the correlation coefficient of ₩alpha between muon rate and atmospheric effective temperature. The measured ₩alpha is compared with a model prediction. We also report a diurnal variation of the measured muon rate that is corrected by eliminating the ground-level pressure effect, at near detector.

Keywords:

muon, rate, variation

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

G1.07

Updated results on reactor antineutrino oscillation amplitude and frequency for 2900 days at RENO

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Abstract:

The RENO experiment has precisely measured the amplitude and frequency of reactor antineutrino oscillaion at Hanbit Nuclear Power Plant since Aug. 2011. The previously measured values based on ~2200 days of data were reported for publication in 2018. Since then, an additional ~700 day data has been analyzed with improved methods to obtain an updated result. The additional data were taken during a period of rather minimal thermal power by the reactors, corresponding to only one or two reactors in operation. In that period, we have measured relatively low fluxes of reactor antineutrinos. In this presentation, we report updated measurement of reactor antineutrino oscillation obtained from the 2900 day data and variation of their measured rates.

Keywords:

RENO, neutrino oscillation, 2900day

2020 KPS Spring Meeting
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G1.08

Understanding of NaI(Tl) detector performance for the NEON experiment

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Abstract:

NEON (Neutrino Elastic-scattering Observation with NaI) aims an observation of a coherent elastic neutrino-nucleus scattering (CEvNS) using reactor anti-electron neutrino with NaI(Tl) crystal detectors at Hanbit nuclear power plant in Yeounggwang. Even though CEvNS was observed by COHERENT collaboration in 2017 with the spallation neutron source, the same process with the reactor neutrino has not yet been observed. Its observation probability highly relies on detector performance such as background level and low-energy threshold. We have measured performances of the NaI(Tl) detectors at Yangyang Underground Laboratory. Background level of approximately 7 counts/day/kg/keV and below 0.5 keV energy threshold are already achieved. Further analysis to optimize the low energy threshold is ongoing. In this presentation, the measured performance of the NaI(Tl) detector for the NEON experiment will be discussed.

Keywords:

NEON, NaI, Neutrino

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G1.09

Status of NEOS Phase-II

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Abstract:

NEOS experiment, being carried out in the tendon gallery of the Hanbit reactor unit 5, detects electron anti-neutrinos from the reactor core at 24 m distance to search for sterile neutrinos. The first phase of NEOS experiment with 180-day data (2015-2016) did not show any strong evidence of active-to-sterile neutrino oscillation. NEOS phase-II operating since Sept. 2018 will take 500 days of reactor-on data until late March covering a whole burnup cycle. In this talk, we report very preliminary results of the 500-day data.

Keywords:

Reactor Experiment, Sterile Neutrino, Reactor Neutrino, Reactor Anomaly

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G15.01

Status of the GroundBIRD experiment

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Abstract:

GroundBIRD is a ground-based radio telescope for observing the anisotropies in cosmic microwave background (CMB) polarizations. The final goal is to constrain the amplitude of primordial gravitational waves from the inflation of the universe, by means of its imprint in the CMB B-mode polarization pattern. In 2019, we completed the installation of the telescope and the operation tests at Teide observatory, Spain. The telescope successfully received the first light from the moon with a prototype focal plane. The commissioning runs for improving the focal plane and preparing the sky observations are currently in progress. We present the status of the GroundBIRD experiment, the installation of the telescope and the recent result of commissioning runs including the first light result.

Keywords:

cosmic microwave background, primordial gravitional waves, B-mode polarization

2020 KPS Spring Meeting
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G15.03

Estimation of acceleration noise for SISA (Stellar Interferometer Space Antenna)

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Abstract:

We calculated acceleration noise to calculate the sensitivity curve of the SISA (Stellar Interferometer Space Antenna), a new method of gravitational wave detection. Acceleration noise is the noise that makes it harder to observe in the low frequency range of gravitational wave detection. The total acceleration noise is the sum of noises which are categorized into Brownian noise, pink noise with inversely proportional to the frequency power spectrum density, and white noise with uniform power spectrum for the full range of frequencies. In this calculation we considered three types of different acceleration noise that are expected to be the dominant in SISA experiments: Two pink noises, Interplanetary Magnetic Filed Fluctuations (IMF) and thermal noise, and one white noise, self gravity noise.

Keywords:

Gravitational wave, Acceleration noise, Stellar Interferometer (SI), SISA (Stellar Interferometer Space Antenna)

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G15.05

Search for secluded dark matter with the IceCube neutrino telescope

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Abstract:

The IceCube neutrino observatory is a 3D array of photodetectors installed in the Antarctic ice. It consists of 5,160 photomultiplier-tubes spread among 86 vertical strings. Its total detector volume is more than a cubic kilometer. IceCube detects neutrinos via Cherenkov light of charged relativistic particles from neutrino interactions with the Antarctic ice. IceCube has a particularly high sensitivity to high-energy neutrinos thanks to its size and the spacing of its detector modules. In this analysis a search for dark matter annihilating into metastable mediator particles is performed. These mediators subsequently decay into Standard Model (SM) particles. These models can yield an enhanced high-energy neutrino flux from dark matter annihilations inside the Sun compared to models without a mediator. Other models for dark matter produce signals in the form of standard model particles that get strongly atenuated inside of the Sun. In the models considered here, the mediator can escape the Sun before producing any neutrinos, thereby avoiding attenuation. Due to its good sensitivity to high-energy neutrino signals IceCube is the ideal tool for this type of search. We present the sensitivities of an analysis of six years of IceCube data looking for dark matter in the Sun considering mediator lifetimes between 1 ms to 10 s and dark matter masses ranging from 100 GeV to multiple ten TeV.

Keywords:

IceCube, Dark Matter, Neutrino, Sun, Neutrino Telescope

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G15.06

Cosmic-ray Spectra of Heavy Nuclei Using the ISS-CREAM Instrument

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Abstract:

The Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM) experiment is designed to study high-energy cosmic rays on the ISS. The ISS-CREAM instrument was launched on 14th of August 2017 aboard the SpaceX-12 Dragon spacecraft. It can measure high energy cosmic rays in the energy range from TeV to PeV. The silicon charge detector (SCD) is composed of 4 layers and provides the measurement of cosmic-ray charges with resolutions of 0.1-0.3 e. Each SCD layer consists of 56 × 48 silicon pixels and the dimensions of each silicon pixel are 1.57 cm × 1.37 cm. Because of an array with small pixels, the SCD can measure precise charges of the incident cosmic-ray particles. The calorimeter (CAL) is a sampling calorimeter composed of tungsten plates and scintillators. The CAL provides a high energy trigger and measurement of the incident cosmic-ray energies using shower energy deposited. The top and bottom counting detectors provide a low energy trigger. The hit points in the CAL are used for particle tracking. The extrapolated particle track in the SCD is used to measure charge of the particle. To separate signals from backgrounds and calculate efficiency, Monte-Carlo simulation data are used. We will present preliminary cosmic-ray spectra of the heavy nuclei using the ISS-CREAM instrument.

Keywords:

ISS-CREAM, Cosmic-ray, Heavy nuclei

2020 KPS Spring Meeting
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G3.01

A three-dimensional sampling electromagnetic calorimeter for the KOTO2 experiment with the future extension of J-PARC Hadron Facility

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Abstract:

We present designs of the three-dimensional (3D) sampling electromagnetic calorimeter (ECAL) for the KOTO2 experiment. We model 3D ECAL prototypes with alternative stacking of thin Pb sheets and scintillator slats. The KOTO2 experiment aims at observing high-statistics CP-violating KL0->pi0 nu nu_bar decays. The 3D ECAL will substitute for a CsI detector array of the KOTO experiment, which will measure several hundred MeV photons from pi0 decays with good energy resolution and direction determination. The 3D ECAL prototype is 20 X_0 thick with a face plane area of 50 x 50 cm2, which is composed of 0.2 X_0 thick Pb absorbers and 0.5 cm thick sampling scintillator strips. The plastic scintillator strips have a width of 2 cm and have an alternating X, Y orientation. We will present Geant4 simulation results for the ECAL performance and the prototyping plan.

Keywords:

3D ECAL, KOTO

2020 KPS Spring Meeting
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G3.02

Performance test of LaBr3(Ce) gamma-ray detectors and GCD method for fast-timing lifetime measurements

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Abstract:

In nuclear physics, the precise measurement on the lifetime of the quantum state is essential to understand the many-body quantum system. Specifically, the lifetime information of the first 2+ level in even-Z even-N nucleus provides crucial information on the nuclear structure. As the rare-isotope beams could be produced, the nuclear shell or shape evolution toward the drip-line has become significant to understand the interactions of nucleons in the extreme environment.

A fast-timing gamma-ray detector system composed of the LaBr3(Ce) scintillators is now under development by the Center for Extreme Nuclear Matters (CENuM). This newly developed system aims to investigate the fundamental nuclear structure of the very unstable nuclei, far off the stability region. Currently, twelve detectors are tested to achieve the aimed energy and timing resolutions. Further, we are now developing the Generalized Centroid Difference (GCD) method with four modules for the timing accuracy within few tens of picoseconds. In this talk, recent results of the performance test and GCD method will be introduced together with the future plan and conceptual design of the array.

Keywords:

LaBr3 Scintillator performance test, GCD method

2020 KPS Spring Meeting
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G3.03

Development of a threshold aerogel Cherenkov detector for photoproduction of K^+ and K(892)* mesons at LEPS2

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Abstract:

We develop a large array of aerogel Cherenkov (AC) detectors for pi/K particle identification at LEPS2/SPring-8. Compton backscattered photons are incident with linearly polarization in the energy range from 1.4 to 3.0 GeV. A time projection chamber (TPC) and four drift chambers reconstruct trajectories of outgoing charged particles. Particle identification is made using time-of-flight (ToF) information from the resistive plate chamber (RPC) arrays. However, in the polar angles between 40 and 50 degrees, particles with momentum between 1.0 and 1.5 GeV/c travel approximately 1 m only so that we can hardly identify them by using ToF information only. To cover this angular range, the AC array with 30 detector elements will be installed between the TPC and the surrounding RPCs. Due to the limited space and the strong magnetic field, the main issue in the development is the optimization of light guide shape and photodetectors. The prototypes of circuits and light guides for MPPC and MCP-PMT are designed and tested using cosmic rays. Preliminary bench test results will be presented and discussed regarding the photoproduction of K+ and K* mesons.

Keywords:

LEPS2, Silica aerogel, Cherenkov detector

2020 KPS Spring Meeting
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G3.04

Evaluation of the astrophysical rates of the $^{42}Ti(p,g)^{43}V$ and $^{43}V(p,g)^{44}Cr$ reactions

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Abstract:

In this study we estimated the astrophysical rates of the $^{42}Ti(p,g)^{43}V$ and $^{43}V(p,g)^{44}Cr$ reactions and their variations due to mass uncertainties of the ^{42}Ti and ^{43}V exotic nuclei in the rp-process. The associated photodisintegrations related to the (p,γ) – (γ,p) equilibrium is also considered. The results show that the photodisintegration-rate variations of the $^{42}Ti(p,g)^{43}V$ and $^{43}V(p,g)^{44}Cr$ reactions are decreased by higher temperatures. The proton-capture rate variation between those reactions at T_9 = 0.5 is about 35% while it is approximately 60% at T_9 = 2.0. We found that the rate variation less than 20% if the precise mass of 10 keV can be achieved. To reduce the variations of the astrophysical rates, the precise mass measurements using MR-TOF technique at future facility RAON is suggested. Therefore, we also analyzed the resolving power, mass precision, counting rate, timing spread, and the half-life of the exotic isotopes for the MR-TOF technique. It is found that to achieve a mass accuracy of 0.1 ppm at the resolving power 10^5, a counting number of 10^4 is required for the isotopes. In addition, the half-life of the exotic nuclei must be longer than 10 ms for the reflections in the measurements using MR-TOF systems.

Keywords:

mass uncertainty, reaction rates, rp-process, MR-TOF technique, exotic isotopes, timing spread, resolving power.

G3.05

GEM TPC prototype for low-energy heavy-ion beam experiments

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Abstract:

We have developed a small-sized time projection chamber (sTPC) to evaluate the basic properties for low-energy heavy-ion beam experiments at RAON. The sTPC has a drift volume of $10\times10\times15$ cm^3, which is filled with approximately 1 atmosphere P-10 gas. The drift electrons are amplified through triple GEM layers and collected by 8 x 32 rectangular readout pads with the size of 2.7×12.5 mm^2. We measured the transverse and longitudinal spatial resolution as 350 μm and 250 μm, respectively using the cosmic-ray muons. With an ^{241}Am source installed inside the TPC, the alpha-ray energy spectrum was also obtained. In this talk, we will discuss the future active target TPC based on the prototype test results combined with the performance of a new superconducting magnet.

Keywords:

Time projection chamber, Superconducting magnet, RAON

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G3.06

Updates on the development of the multi-reflection time of flight mass spectrograph (MRTOF) at RAON

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Abstract:

Nuclear mass is one of the most important parameters to understand the nuclear shell evolution and the nucleosynthetic pathways such as r-process and rp-process. Most of the nuclei near the dripline are short-lived and therefore their masses still unknown or uncertain. A new mass measurement device, MRTOF-MS is advantageous to study such nuclei of longer lifetimes than a few ms, providing high mass resolving power of 105 ~ 106 comparable to the Penning trap within a few ms measurement time.

A new rare isotope beam factory in Korea, RAON will be able to provide the neutron-rich and -deficient nuclei for nuclear physics and the other applications. An MRTOF-MS has been developed through the RISP and KEK/WNSC collaboration since 2017 and recently succeeded to achieve ~ 10^5 mass resolving power within a few ms measurement time. Additionally, it joined a couple of on-line experiments using rare isotopes of mass A ~ 200 at KISS facility and successfully showed its capability, e.g. direct measurement of the atomic mass and the nuclear isomers and applicability to the hyperfine structure measurements. In this presentation, the updates on the MRTOF-MS, including the results obtained in the on-line experiments, will be shared.

Keywords:

Mass measurement, Time of flight, Rare isotope, Precision measurement

G3.07

Influence of mass uncertainty on the (p,g)-(g,p) equilibrium in the rp-process

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Abstract:

We report on the impacts of mass uncertainty of exotic isotopes on the photodisintegration rates and (p,γ)-(γ,p) equilibrium related to the key reactions in the rp-process. The mass accuracy and life-time of the isotopes are also analyzed for an MR-TOF measurement. It is found that the photodisintegration-rate variations due to the mass uncertainty is reduced by the higher temperatures. The impact of an uncertainty less than 10 keV of the ^{66}Se and ^{72}Kr isotopes does not significantly impact on the ^{66}Se(γ,p)^{65}As and ^{72}Kr(γ,p)^{71}Br reactions while the reverse reactions of the proton captures ^{61}Ga(p,γ)^{62}Ge, ^{61,64,65}Ge(p,γ)^{62,65,66}As, ^{68,69}Se(p,γ)^{69,70}Br, ^{69,70}Br(p,γ)^{70,71}Kr, and ^{75}Rb(p,γ)^{76}Sr, are strongly affected by the mass uncertainties. It is found that the proton captures of ^{64}Ge and ^{68}Se much lower than their photodisintegrations and these isotopes, therefore, have a strong waiting point potential in the rp-process. We confirmed that the mass uncertainty of isotopes should be less than 10 keV for the rate variation lower than 10% at T_9 = 1.0. To achieve this condition, the minimum mass uncertainty of the concerned isotopes must be 6-7 keV if the MR-TOF system has a resolving power of 10^5 and a mass precision of 10^{-7}. We also identified that it is impossible for directly measuring masses of the ^{69,70}Br isotopes using MR-TOF technique due to their short half-lives (less than 10 ms).

Keywords:

mass spectrometer, MR-TOF, proton-rich nuclei, nucleosynthesis, photodisintegration.

G3.08

Modification of reaction rate in the astrophysical plasma using dynamic screening effect

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Abstract:

We investigate the dynamic screening effect on the Big Bang Nucleosynthesis (BBN). The dense electron gases screen the Coulomb interaction between reacting nuclei in the environment of the early universe. In general, the screening effect is considered at static plasma. Since the charged particle has a velocity in the real world, the classical Debye screening effect can be changed. This modified screening effect is called a dynamic screening effect. In this presentation, by using the Poisson-Boltzmann equation with a dynamic screening effect, we show nuclear abundances synthesized in the early universe. We also discuss the possibility whether the distribution of ions in the screening effect can be changed by the kinetic theory.

Keywords:

dynamic screening effect

G3.09

Constraints on the Nuclear Saturation Properties using Experimental Data and Astrophysical Observations

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Abstract:

Taking into the astrophysical observations and terrestrial experiments, we put restrictions on the equation of state (EoS) for neutron stars with hyperons. Using the relativistic mean-field model in SU(3) flavor symmetry, it is found that the recent observations of gravitational wave from binary neutron-star merger and massive neutron stars are very useful to give constraints not only on the dense nuclear EoS but also on the saturation properties, especially the nuclear incompressibility and the slope parameter of nuclear symmetry energy.

Keywords:

nuclear equation of state, neutron star

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Resonant elastic and inelastic X-ray scattering at PLS-Ⅱ

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Abstract:

X-ray scattering technique is a general measurement method to study crystal structure. And it has been developed continuously. One of representative results of development is resonant elastic X-ray scattering (REXS), which is probing the magnetic and orbital properties of materials from the ordering of charge, orbital, magnetic degrees of freedom with the additional scattering cross section near the absorption edge of specific atom due to dispersion correction and tensor terms of atomic form factor.

And as an advanced resonant X-ray scattering technique, resonant inelastic X-ray scattering (RIXS) can probe the elementary excitations in the complex materials such as phonon, magnon, interband transition and etc. RIXS enables us to investigate the electronic structure from the measurement of inelastic loss spectrum. RIXS experiment at 3A beamline was performed with <~ 300 meV energy resolution. Also absorption spectrum of C K-edge was obtained successfully using the X-ray Raman experimental technique with X-rays energy over 10KeV.

In addition, since feasibility of inelastic X-ray scattering measurement is confirmed at PLS-Ⅱ from insistent investigation experience, We are considering exclusive instrumentation setup for RIXS including Inelastic X-ray scattering. And it can be extended as other scientific interesting instrumentation like HXPES, PAX, and Multi-undulator. So I discussed with a short comment on future plan.

Keywords:

Resonant elastic X-ray scattering, Resonant inelastic X-ray scattering

G4.02

Electric Multipole Transitions of Resonant X-ray Scattering for Studying Orbital Specific Magnetization in TmB_4

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Abstract:

We present the resonance energy profile of X-ray scattering for antiferromagnetic TmB_4. Energy profiles of resonant X-ray magnetic scattering intensities were compared at both Tm L_2- and L_3-edges. Near the L_3-edge, one more resonance appears at the pre-edge region below T_N. The spin polarization in 4f and 5d orbital of the magnetic Tm ions with the orbital-selectivity were probed through distinct polarization analysis and azimuthal angle dependence study. Experimental data verified the pre-edge resonance corresponds to E2 transition with a direct sensitivity to the spin polarization of the 4f orbital.

Keywords:

Resonant X-ray scattering, Rare-earth tetraboride, Quadrupole transition, Polarization dependence

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G4.03

Resonant X-ray Scattering Study of Anisotropic Charge Distribution of Gd Ions in GdB_4

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Abstract:

It was investigated how spin ordering affects anisotropic tensor susceptibility (ATS) scattering intensities which are related to charge distribution anisotropy. Temperature dependence of ATS scattering intensities of GdB_4 were measured near L-edges of Gd. The ATS scattering intensities for L_2- and L_3-edges show different temperature dependence below antiferromagnetic transition temperature, T_N. At L_3-edge, the intensities get stronger at lower temperature, reflecting the spin order parameter, while those at L_2-edge do not show noticeable change. This difference is explained in terms of spin-orbit coupling and isotropic distribution of spin-polarized 5d states of Gd ions. Above T_N, the ATS scattering intensities show similar temperature dependence at both L-edges and demonstrate that thermal motion enhances charge distribution anisotropy of Gd 5d states in the paramagnetic phase.

Keywords:

Resonant X-ray Scattering, Rare-earth tetraboride, Spin-orbit coupling, Spin-polarization

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G4.04

X-ray microdiffraction study of local structual changes caused by polling in polycrystal (1-x)$BiFeO_3$-(x)$BaTiO_3$

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Abstract:

Many studies investigating the relationship between lattice strain and ferroelectricity using epitaxial thin films have revealed how to engineering electric properties using lattice strain in ferroelectrics, but detailed observations in poly-crystal conditions have not been yet enough. The limitation of the traditional XRD analysis in poly-crystal specimen is that the data for each grain is not obtainable. In this study, we observed grain-specific strain changes of poly-crystal $BiFeO_3$-$BaTiO_3$ specimens after polling using the X-ray microdiffraction(XMD). A clear correlation was observed between grain orientation and the direction of the electric-field during polling. Also specimens with different composition showed different trends. In addition, the XMD results had correlation with the trends in the P-E loop measurements. Our new observations may open new road to future studies of ferroelectric materials in the form of poly-crystals.

Keywords:

BiFeO3-BaTiO3, X-ray microdiffraction, XMD

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G4.05

Designing morphotropic phase boundary by La-doping in Bi-site of $BiFeO_3$-$BaTiO_3$ lead-free piezoceramics

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Abstract:

Three different series of lead-free piezoelectric ceramics $(1\text{-}y)Bi_{1.03(1\text{-}x)}La_xFeO_3\text{-}yBaTiO_3$ with (y = 0.27, x = 0.00-0.12), (y = 0.30, x = 0.00-0.10) and (y = 0.33, x = 0.00-0.08) were prepared by solid-state reaction process. From the X-ray diffraction and electrical properties measurement, two different morphotropic phase boundaries (MPBs) were found in all three ceramics systems. The first MPB-I exhibited between rhombohedral (R) and tetragonal (T) phases, while a second MPB-II was formed between T and cubic-like (CL) phases. The highest direct piezoelectric coefficient (d_{33}) for a specific composition attributed to the typical MPB-I between two polar phases. However, a large converse piezoelectric coefficient (d_{33}^*) obtained due to the extrinsic effect for those compositions particularly located near to the MPB-II. La-substitution creates the soft ferroelectric effect by lowering Curie temperature (T_C) and improve ferroelectric polarization switching under the applied field. A significant enhancement in dielectric constant at low temperature associated with the local structural heterogeneity by La^{3+}-doping that acts as a cornerstone for the high piezoelectric strain response. Based on the crystal structure, dielectric, ferroelectric and piezoelectric properties a phase diagram was developed for La^{3+}-modified BF-BT ceramics. Hence, this study will provide a path for designing and optimization of lead-free BF-BT piezoceramics for the high-temperature commercial applications.

Keywords:

Morphotropic Phase Boundary, Lead-free, Piezoelectric, Bismuth Ferrite, Barium Titanate

2020 KPS Spring Meeting
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G4.06

Enhanced ferroelectric properties in Si doped HfO_2 thin films via oxygen vacancies controlling

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Abstract:

Ferroelectric HfO_2 thin film has been investigated intensively as an alternative to perovskite materials in ferroelectric random access memory due to the advantages for nonvolatile memory applications, such as good scalability, compatibility with conventional complementary metal-oxide-semiconductor (CMOS) process technology. However, the utilization of the ferroelectricity in HfO_2 film is still illusive in the view of stabilizing ferroelectric phase. Especially the underlying effect of the oxygen vacancies in ferroelectric HfO_2 is still controversy. Diverse researches significate the role of oxygen vacancies to the formation of ferroelectric phase and others insist oxygen vacancy act as defect and/or trap site degrading ferroelectric properties.
Here, we report enhanced ferroelectric properties in Si doped HfO_2 via oxygen vacancies generation. The X-ray photoemission spectroscopy and electron energy loss spectroscopy indicated macroscopically and microscopically enlarged fraction of oxygen vacancies during high temperature annealing. The grazing-incidence X-ray diffraction spectra indicated reduced lattice parameter due to the oxygen vacancies without observable phase transformation. The macroscopic and microscopic ferroelectric hysteresis loops indicated enlarged remnant polarization value and coercive field due to the enlarged oxygen vacancies. The switching dynamics indicated expedited switching time with uniform distribution in the oxygen vacancy rich film. The theoretical calculation demonstrated the reduced energy barrier for single dipole flip in ferroelectric HfO_2 due to the oxygen vacancies. Monte-Carlo simulation demonstrated the reduced energy barrier induced accelerated and homogeneous switching properties.

Keywords:

HfO2, Ferroelectric, Oxygen vacancy

2020 KPS Spring Meeting
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G5.01

Higher-Order topology in Twisted Bilayer Graphene

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Abstract:

There have been numerous works attempting to develop a general theory of the twisted bilayer graphene. So far, most of the previous theoretical works rely on the small-angle limit, where a simple Dirac model is approximable. However, there exist, in principle, infinitely many numbers of the large commensurate angles that do not fit in this small angle limit. In this talk, we tackle the problem of the twisted bilayer graphene at arbitrary angles. We show that all moiré patterns of twisted bilayer graphene share the same non-trivial higher-order band topology, which is irrespective of the specific angles as long as the underlying symmetries are intact. This result is based on the unique parity structure which all commensurate moiré patterns have in common. In addition, we also discuss the effect of the disorder, the strain and the incommensurability on the higher-order topology.

Keywords:

Twisted Bilayer Graphene, Higher-order topological insulator

G5.02

Hofstadter butterfly and quantum Hall effect in twisted double bilayer graphene

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Abstract:

With the recent observation of unconventional superconductivity in twisted bilayer graphene [1] and also in twisted double bilayer graphene (TDBG, a pair of Bernal-stacked bilayer graphenes stacked with a rotational stacking fault) [2], two-dimensional van der Waals heterostructures have attracted much interest for studying the phases of strongly correlated electrons.
In this talk, we will discuss the energy spectrum and quantum Hall effect in TDBG. The electronic band structures of TDBG with AB-AB configuration and AB-BA configuration look similar in the absence of magnetic field, but their topological nature are different [3]. Therefore, the twins of AB-AB and AB-BA TDBG exhibit very different spectrum in magnetic field [4]. For example, the first gap in the electron side of AB-AB TDBG remains opened in increasing magnetic fields, while that of AB-BA TDBG vanishes at some points due to the non-zero valley Chern number in AB-BA TDBG. Thus, the energy spectrum in magnetic field directly reveals the difference in Chern number of the two pair structures. We will also discuss the degeneracy and electron-hole symmetry in terms of the lattice symmetry as well as the symmetry of the Hamiltonian.
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[3] M. Koshino, Phys. Rev. B 99, 235406 (2019).
[4] J. A. Crosse*, N. Nakatsuji, M. Koshino, P. Moon†, in preparation.

Keywords:

twisted double bilayer graphene, landau level, hofstadter butterfly, quantum Hall effect, band topology

2020 KPS Spring Meeting
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G5.03

Concomitant enhancement of electron-phonon coupling and electron-electron interaction in graphene decorated with ytterbium

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Abstract:

Electron-phonon coupling (EPC) is one of the well-studied many-body effects in various condensed matters via numerous experimental tools, as it drives superconductivity. In this sense, the EPC in graphene has also attracted research interests as it can potentially drive superconductivity in an atomically thin two-dimensional material. Especially, when realized, the Dirac fermionic behavior of charge carriers in graphene is predicted to make it even more interesting, because another exotic quasiparticles such as Majorana fermion can be realized. However, while numerous studies report the enhancement of electron-phonon coupling in graphene via foreign atoms, the origin of the enhancement is still under debate. Here we report that the electron band structure of graphene decorated with ytterbium observed using angle-resolved photoemission spectroscopy. The linear dispersion of graphene shows an enhanced electron-phonon coupling by ytterbium. At the same time, the dispersion shows a steeper slope around Fermi energy, indicating the enhanced electron-electron interaction within the Fermi liquid theory. Our findings suggest that there is a possible interplay between electron-phonon coupling and electron-electron interaction, providing a plausible way to control the possible phonon-mediated superconductivity in graphene.

Keywords:

Graphene, Electron-phonon coupling, Angle-resolved photoemission spectroscopy

G5.04

Commensurate Double Moiré Superlattices in alternating-twisted Trilayer Graphene

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Abstract:

About a decade after the prediction of flat bands in twisted bilayer graphene (tBG) at a so-called magic angle in theoretical approaches [1], it has been reported that an ordered phase at specific carrier density under which is strongly supposed to be an unconventional superconductor is observed in experiments [2,3]. In this work, we study the electronic structure of trilayer graphene with a twisted middle layer that gives rise to commensurate double moiré superlattices. Rather different electronic structures are found depending on the relative stacking vector τ between the top and bottom layers. We use the extended continuum model [4] that takes into account out-of-plane lattice corrugations, and we show that together with a finite out-of-plane electric field. It is possible to generate isolated nearly flat bands with finite valley Chern numbers for a range of twist angles around ~1.5° within the range of 1°~2° for stacking configurations where the top and bottom layers are translated for BA stacking by τ = (0, $-a_G/\sqrt{3}$).

[1] R. Bristritzer and A. H. MacDonald, PNAS 108, 12233 (2011).
[2] Y. Cao, V. Fatemi, S Fang, K. Watanabe, T. Taniguchi, E. Kaxiras, and P. Jarillo-Herrero, Nature 556, 43 (2018).
[3] Y. Cao, V. Fatemi, A. Demir, S. Fang, S. L. Tomarken, J. Y. Luo, J. D. Sanchez-Yamagishi, K. Watanabe, T. Taniguchi, E. Kaxiras, R. C. Ashoori, and P. Jarillo-Herrero, Nature 556, 80 (2018).
[4] J. Jung, A. Raoux, Z. Qiao and A. H. MacDonald, Phys. Rev. B 89, 205414 (2014).

Keywords:

twistronics, twisted trilayer graphene, double moire superlattice

2020 KPS Spring Meeting
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G5.05

Topological surface states in $NiTe_2$

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Abstract:

With the advent of surface states in topological materials, van der Waals (vdW) crystals are attractive with topology. Here, we studied the electronic structure of $NiTe_2$ by angle-resolved photoemission spectroscopy. By combining with density-functional theory, we found inverted-bandgaps driven by interlayer hopping. Topological surface states in $NiTe_2$ were branched from inverted bandgap, and the calculated spin texture shows a chirality of topological surface states. Moreover, there is a type-II Dirac point closed to the fermi-level. Our results suggest NiTe2 as a candidate for novel spintronics devices.

Keywords:

ARPES, Topological Surface States, TMDC

2020 KPS Spring Meeting
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G5.06

Many-body approach to non-Hermitian physics in fermionic systems

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Abstract:

In previous studies, the topological invariants of 1D non-Hermitian systems have been defined in open boundary condition (OBC) to satisfy the bulk-boundary correspondence. The extreme sensitivity of bulk energy spectra to boundary conditions has been attributed to the breakdown of the conventional bulk-boundary correspondence based on the topological invariants defined under periodic boundary condition (PBC). Here we propose non-Hermitian many-body polarization as a topological invariant for 1D non-Hermitian systems defined in PBC, which satisfies the bulk-boundary correspondence. Employing many-body methodology in the non-Hermitian Su-Schrieffer-Heeger model for fermions, we show the absence of non-Hermitian skin effect due to the Pauli exclusion principle and demonstrate the bulk-boundary correspondence using the invariant defined under PBC. Moreover, we show that the bulk topological invariant is quantized in the presence of chiral or generalized inversion symmetry. Our study suggests the existence of generalized crystalline symmetries in non-Hermitian systems, which give quantized topological invariants that capture the symmetry-protected topology of non-Hermitian systems.

Keywords:

Topological phases of matter, Bulk-boundary correspondence, Exact diagonalization, Non-Hermitian systems, Topological invariant

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G5.07

Quantum Nanoelectromechanics with Superconducting Membranes

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Abstract:

We report an experimental study on electromechanical interactions between a 4-GHz superconducting microwave resonator and a 3-MHz free-standing nanomechanical resonator made of superconducting niobium at mK temperatures. The microwave resonator is a LC circuit in which a pair of the nanomechanical resonator and a bottom ground electrode separated by a vacuum gap of hundreds of nanometers forms a capacitor. This capacitor allows for an electromechanical coupling through which the microwave and the nanomechanical resonators are parametrically coupled. In this talk, we discuss the behavior of this hybrid quantum system in different frequency sideband regimes (red- and blue-detuned) at different microwave powers. This hybrid quantum system could be used to investigate fundamental quantum mechanics with mesoscopic systems as well as to realize the conversion between microwave and optical signals.

Keywords:

quantum nanoelectromechanics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

G5.08

Nanomechanics as a New Thermometer for Superfluid Thin Film

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Abstract:

Superfluidity helium4 is a representative macroscopic quantum phenomena made from bosonic particles. Especially, in case of two dimensional superfluidity helium4, it has been succesfully studied as a model system for Berezinskii-Kosterlitz-Thouless transition (BKT transition). However, thermodynamic properties such as heat capacity and thermal conductivity have been measured somewhat limitedly due to lack of proper thermometry which is sensitive only to the superfluid film itself, not the substrate the film resides on. To do this, we have developed a sensitive nanomechanical resonators and present their performance as thermometers. This new thermometric technique will allow us to experimentally explore the thermodynamics of the BKT transition.

Keywords:

BKT transition, thermometry, nanomechanics

2020 KPS Spring Meeting
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G6.01

In-situ Bragg coherent X-ray diffraction imaging of the faceting process of Au nanoparticles

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Abstract:

BCDI (Bragg coherent X-ray diffraction imaging) was carried out to study how Au nanocrystal domains merge and grow into a crystal of well-defined facet shape changes using a 10keV focused coherent X-ray beam with Bragg geometry. The experiment performed at beamline 34-ID-C in Advanced Photon Source in the United States and 9C in Pohang Accelerator Laboratory. Au nanoparticles fabricated by a variety of methods tend to have domains and grains of random orientations. The images of the Au nanoparticles at room temperature are irregular shapes due to laser annealing. Only domains that satisfy the Bragg condition are reconstructed. As the temperature increased near 600℃, reasonable reconstructions were obtained which show the growth of the facets clearly and merge into a single domain. Facets parallel to the substrate was developed first. And then which was followed by the formation of facets in the sides at further elevated temperatures formed.

Keywords:

BCDI, Au nanoparticle, Domain structure, Faceting

2020 KPS Spring Meeting
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G6.02

Reversible transformation of defective domains in VO_2 films using x-ray scattering technique

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Abstract:

For a long time, in transition metal oxides, crystal-structured phase transitions have been observed along with changes in metal-insulator phase with temperature. Among them, Vanadium dioxide (VO_2) is a material that undergoes a metal-insulator phase transition(MIT) near the ambient temperature of about 68℃, and many studies have been conducted due to its properties. However, the understanding of phase transition is not yet complete, and it is very complicated what happens when VO_2 undergoes the MIT when it has several defects.
In this work, we observed how the behavior of VO_2 and its defects progressed during the MIT by using the X-ray diffraction technique. By measuring with a two-dimensional image detector through omega-rocking technique on the bragg peak, the 3-dimensional shape of the bragg peak existing in the reciprocal space can be obtained. It was confirmed that satellite peaks were observed around the bragg peaks due to periodic defects in VO_2. The angle formed by the satellite peak around the center of the bragg peak is a crystallographic angle, so that the twin of VO_2 M1 phase should be made of (100) and ($10\bar{1}$) planes to match the measurement angle of the X-ray diffraction pattern. The phase change behavior according to the temperature of 2 domains with different twin types and (020) bragg peaks was slightly different. This is considered to be the difference due to the existence of energy that changes from M1 to Rutile during phase transition and energy that eliminates defects. On the other hand, in the off-specular (011) peak, the presence of an anti-phase domain was prominent, and in the thin film VO_2, strain was not released, and this was also confirmed by an X-ray diffraction pattern.

Keywords:

VO2, XRD, satellite peak, twin, defect

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G6.03

A Single-Ion Conducting Borate Network Polymer as a Viable Quasi-Solid Electrolyte for Lithium Metal Batteries

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Abstract:

Lithium-ion batteries have remained a state-of-the-art electrochemical energy storage technology for decades now, but their energy densities are limited by electrode materials and conventional liquid electrolytes can pose significant safety concerns. Lithium metal batteries featuring Li metal anodes, solid polymer electrolytes, and high-voltage cathodes represent promising candidates for next-generation devices exhibiting improved power and safety, but such solid polymer electrolytes generally do not exhibit the required excellent electrochemical properties and thermal stability in tandem. Here, an interpenetrating network polymer with weakly coordinating anion nodes that functions as a high-performing single-ion conducting electrolyte in the presence of minimal plasticizer, with a wide electrochemical stability window, a high room-temperature conductivity of 1.5×10^{-4} S cm^{-1}, and exceptional selectivity for Li-ion conduction (t_{Li+} = 0.95) is reported. Importantly, this material is also flame retardant and highly stable in contact with lithium metal. Significantly, a lithium metal battery prototype containing this quasisolid electrolyte is shown to outperform a conventional battery featuring a polymer electrolyte.

Keywords:

Solid state electrolyte, Porous aromatic framework, Single-ion conducting polymers

G6.04

Autonomous Atomic Force Microscope

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Abstract:

Artificial intelligence (AI) makes a difference in our everyday lives as well as in our research equipment. Here we present an autonomous atomic force microscope (AFM) that can automatically perform the equipment initialization, surface imaging, and image analysis. We employ an AI technique, which recognizes objects in the experimental system through installed cameras, self-calibrates and initializes the system for the subsequent automated topography imaging. The present AI technique not only automates the time-consuming manual process, but also minimizes the operator-to-operator variation, prevents damage to consumables, and greatly reduces operation time in performing atomic force microscopy.

Keywords:

Atomic force microscope, Artificial intelligence, Automated initialization

2020 KPS Spring Meeting
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G6.05

Hysteresis compensation for a high-speed atomic force microscopy scanner

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Abstract:

Hysteresis limits the tracking performance of piezoelectric actuators (PEAs). To improve performance, the operation of PEAs can be limited to a small linear range. However, in applications where the maximum available range is already severely limited by design constraints such as in high-speed atomic force microscope (HS-AFM) scanners, such a solution becomes impractical. This work presents compensation for hysteresis in HS-AFM scanners in order to improve its tracking accuracy and measurement precision. We compensate a homemade HS-AFM scanner and measure the tracking errors over the bandwidth of the scanner. We then scan a Blu-ray disc in contact mode using custom HS-AFM controller, scan-head and the compensated lateral scanner.

Keywords:

atomic force microscopy, piezoelectric actuator, hysteresis compensation

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G7.01

Synthesis of freestanding complex-oxide membranes via graphene-assisted molecular beam epitaxy

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Abstract:

Freestanding complex-oxide membranes are promising building blocks for creating artificial layered heterostructures with novel functionality and phenomena. We demonstrate the synthesis and transfer of single-crystalline freestanding membranes via graphene remote epitaxy. Complex-oxide thin films were deposited on graphene-coated oxide substrates using reactive molecular beam epitaxy. Later, single-crystalline oxide films with millimeter-scale lateral dimensions were mechanically peeled-off from substrates. These flexible and freestanding membranes can be integrated with other membranes or substrates and lead to layered oxides which have not been possible via traditional epitaxy alone. In addition, the application of strain on ferroelectric or ferromagnetic membranes beyond the epitaxial limit can drastically alter electrical or magnetic properties.

Keywords:

Oxide, MBE, Graphene, Molecular Beam Epitaxy, Remote Epitaxy

G7.02

Growth of Single Crystalline $Hf_{0.5}Zr_{0.5}O_2$ thin film and its potential applications as a memristor

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Abstract:

The hafnia based thin films with ferroelectricity are greatly attractive due to silicon compatibility, lead-free and scaling-down, etc. However, there is still a lack of analysis of the mechanism how ferroelectricity emerges related to structure. Although it is necessary to grow single crystalline hafnia based thin films to reveal the relationships between ferroelectricity and structure, it is still challenging to obtain reliable ferroelectric properties. Therefore, we herein investigated the growth of single crystalline Zr doped-HfO_2 (HZO) thin film depending on several parameters of pulsed laser deposition (PLD) method. To analyse crystallinity and crystal structure of grown films, we carried out out-of-plane scan and azimuthal scans using X-ray Diffraction (XRD). In addition, electrical characteristics of grown films based on P-E loops and I-V curves measurement were investigated. As a result, we suggest a growth window to obtain single crystalline orthorhombic phase HZO thin film. Additionally, we show resistive switching behavior in HZO thin film as a memristor.

Keywords:

HZO, Ferroelectricity, PLD, memristor

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G7.03

Reduction of Annealing Temperature of $Hf_{0.5}Zr_{0.5}O_2$ Thin Films via Deep-Ultraviolet Irradiation

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Abstract:

The hafnium oxide (HfO_2) based thin film shows high ferroelectric performance in a form of ultra-thin film (< 10 nm).[1] Especially, Zr-doped HfO_2(HZO) shows the ferroelectric properties in orthorhombic phase. Generally, as a way of inducing the ferroelectric characteristics, the HZO films should pass the annealing process at a high temperature above 550°C. This makes HZO films not-applicable for thermally labile system, thus the research to reduce the heating temperature is essential. In this study, the effects of deep-ultraviolet light (DUV) irradiation HZO thin film were investigated, and the purpose of this study is to reduce the annealing temperature of the ferroelectric HZO film by DUV irradiation. The 10 nm-thick $Hf_{0.5}Zr_{0.5}O_2$ thin films between TiN capping layers are fabricated using atomic layer deposition (ALD) technique. To find the critical crystallization temperature for the orthorhombic phase formation without DUV irradiation, the HZO films were annealed using rapid thermal annealing (RTA) in low-pressure N_2 condition (0.3 torr). The annealing temperature was narrowed down between 350℃ to 550℃ temperature range. After finding the critical temperature, DUV irradiation process was added before the annealing process to give the photochemical activation to the film. The grazing incidence X-ray diffraction (GIXRD) and transmission electron microscope (TEM) were used to investigate the structural characteristics of the film. Polarization-voltage (P-V) hysteresis test and capacitance-voltage (C-V) measurement were used to observe the electrical properties of the film.
The samples without DUV irradiation showed the critical temperature between 450℃ to 500℃ by the orthorhombic peaks from GIXRD measurement, and the remnant polarization (P_r) value. However, the samples irradiated by DUV before the annealing showed the orthorhombic peaks and ferroelectric hysteresis curve over 400℃ annealing temperature, which is decreased by the effect of DUV. From this study, we found that the DUV irradiation effects to the crystallization of HZO. This finding has shown that the DUV irradiation can assist to reduce the annealing temperature, which can be applicated to various thermo-labile electric devices.

1. Chernikova, A., et al. (2016). Ultrathin Hf0. 5Zr0. 5O2 ferroelectric films on Si. *ACS applied materials & interfaces*, *8*(11), 7232-7237.

Keywords:

Hafnium Oxide, Deep UV, Photochemical Activation, Annealing Temperature

G7.04

Advanced synthesis of pristine and nitrogen doped graphene and its gas sensor

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Abstract:

To enhance productivity of graphene and modulate its properties, we invented conveyor type CVD system and own recipes. Our system produces 12 samples of phone-sized graphene in 3 hours. The liquid carbon sources have low dehydration temperature, which help rapid synthesis. Doped graphene is synthesized using carbon compound containing nitrogen. Various growth temperatures and growth times were evaluated using Raman spectroscopy, electron transport characteristic and X-ray photoelectron spectroscopy. The gas sensors is made of pristine graphene and nitrogen doped graphene. The absorption and desorption of gas molecules affects two types of graphene sensors in the opposite way.

Keywords:

graphene, doping, gas seonsor

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G7.05

Self-assembly of polyhedral plasmonic nanoparticles for unnaturally high refractive index optical metamaterial

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Abstract:

Since the advent of metamaterials, achieving unnaturally high refractive index has received a great deal of attention. According to previous reports, achievable range of the refractive index is few dozens to thousands by lithographic fabrication of the designed metamaterials particularly at microwave and terahertz (THz) (especially n of 38.64 at THz and about 1800 at microwave which is much higher than the refractive index of optical natural materials). Nevertheless, at the optical regime, achieving unnaturally high refractive index beyond the naturally accessible index is yet to be obtained by using conventional monolithic methods due to the resolution limits. To overcome these limitations of lithographic technic, in this work we use 60-85 nm polyhedral plasmonic nanoparticles as the meta atom and bottom-up self-assembly technic to achieve few nanometer gaps. Thorough these benefits of soft self-assembly processing, we successfully obtained 2 dimensionally arrayed plasmonic superlattices with few nanometer gaps over the large area (< 25 mm^2). Furthermore, we demonstrated the unnaturally high refractive index at optical regime especially 6.4 at the resonant regime (near-infrared) and 4.5 at off-resonant (mid-infrared) regime which has not been reported.

Keywords:

Metamaterials, Plasmonic colloids, Self-assembly, Effective medium theory

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G8.01

Nano network formation in metal-PC molecules via PEDOT:PSS

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Abstract:

We introduce the mixture effect of TS-metal Pc (phthalocyanine−tetra-sulfonated acid tetra-sodium salt) molecules and PEDOT:PSS used as the hole transport layer of p-i-n structured CH3NH3PbI3 perovskite solar cell. The nanostructure formation was induced by the low pH of PEDOT:PSS. To elucidate the detail roles of TS-metal Pc blended with PEDOT:PSS, we analyzed the AFM (Atomic Force Micoscopy) images, GIWAXS (Grazing-Incidence Wide-Angle X-ray Scattering) patterns and EDS(Energy Dispersive Spectroscopy) data. Solar cell device performance was enhanced to be 14.65% in the mixture of TS-CuPc and PEDOT:PSS in comparison with conventional PEDOT:PSS(11.02%).

Keywords:

perovsktie solar cell, PEDOT:PSS, small molecule HTL

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G8.02

Vertical graphene as a permanent strain sensor

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Abstract:

Graphene has shown diverse intriguing physical properties and led the discovery of attractive two-dimensional materials. For the research purpose and expecting application, the graphene has fabricated and investigated with various structures such as fiber, cloth, yarn, and so on. Among them, vertically oriented graphene (VG) has been considered to be a structure to provide tremendous inspiration and application in electrochemistry and energy/environmental research field due to its unique morphological structure. In this work, we report an attractive application of VG, that is, the possiblity and potential as a strain sensor. VG grown by scalable plasma-enhanced chemical vapor deposition method was comprised with flexible poly-dimethylsiloxane (PDMS) substrate, so that eventually final structure was made as buffer flat graphene on VG on PDMS. When we applied strain perpendicular to the cracks that initially formed at the stage of tearing-off from the SiO_2 substrate, the resistance changed dramatically, which the gauge factor at 10% strain was estimated over 3000. Moreover the resistance showed very stable values under 5000th repeated cycles with strain. Interesting;y, the resistance reached "infinity" at a specific strain value, then recovered to the initial resistance value with decreasing strain. We demonstrate such bevavior of VG strain sensor using in-situ SEM and diversification of crack direction.

Keywords:

Vertical graphene, strain sensor, in-situ SEM, motion sensor

2020 KPS Spring Meeting
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G8.03

Enhancement of thermoelectric performance of silicon nanowires with gold nanoparticles

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Abstract:

열전 발전은 온도차이가 전기를 만들어내는 제백 효과를 이용하여 버려지는 열에너지를 다시 활용하는 에너지 발전이다. 열전 발전은 에너지 수확 분야에서 실용화 가능성이 높은 발전방식으로 꼽히며, 학계에서는 열전 발전 소자의 역률(Power Factor, PF)과 감도지수(Figure of merit, ZT)를 높이기 위한 연구가 진행되고 있다.

본 연구는 Si nanowire에 금 입자를 흡착시켜 열전 효과를 상승시켰으며, 이를 실제 실험과 모사실험을 통해 교차검증했다. 금 나노 입자가 흡착되면 Si nanowire의 전기 전도도는 감소하지만, 열전도도의 감소와 제백 계수의 증가로 ZT와 PF가 향상됐다. 연구팀은 SIESTA와 Wannier90 프로그램을 활용하여 앞에 기술한 요소들을 교차 검증했으며, COMSOL 프로그램을 활용하여 금 입자를 기반으로 열 에너지들이 Si nanowire에 수직하게 빠져나가는 것을 확인하였다. 본 연구 결과가 열전 소자 제작에 새로운 돌파구가 될 거라 예상한다.

Keywords:

Thermoelectrics, seebeck effect, silicon nanowire, gold nanoparticle

2020 KPS Spring Meeting
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G8.04

Unidirectional alignment of AgCN microwires on 1T' layered crystals

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Abstract:

A two-dimensional (2D) crystal can be utilized as a template for various nanostructure assembly. Our previous works have demonstrated that one-dimensional (1D) atomic chains, such as AgCN and AuCN, align themselves along the zigzag lattice directions of various hexagonal 2D crystals. The preferential alignment is observed as a tri-axial alignment of chains on 2D crystals by optical microscopy or transmission electron microscopy (TEM). Although the 1D assembly on 2H phase of transition metal dichalcogenides (TMDCs) crystals has been investigated, a similar alignment and nanostructure assembly on 1T′ 2D crystals is yet to be reported. Here we study the assembly behavior of AgCN microwires on various 1T′ crystals, including $MoTe_2$ and ReS_2. The unidirectional alignment of AgCN microwires is observed on 1T′ crystals, reflecting the symmetry of underlying crystal structures. The misorientation between microwire axis and 1T′ crystallographic lattice direction is investigated by polarized Raman spectroscopy and TEM, which confirms the strong correlation. The assembled microwires can be utilized to easily find the crystal orientation and grain sizes of 1T′ crystals.

Keywords:

1T' 2D crystal, AgCN, 2D template, Microwire, 1D/2D Heterostructure

2020 KPS Spring Meeting
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G8.05

Dewetting process of Co thin films in water environment driven by ns pulse laser

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Abstract:

We report a study of the pulse laser induced dewetting process of Co nanofilms (NFs) in DI water environment. 13.2 nm thick Co NFs underwent grooving dewetting phenomena and finally produced nanoparticles (NPs) as well as nanowalls (NWs), whereas 2 nm thick Co NFs did not undergo clear NPs forming process and only NWs were produced on the surface from Co^{2+} and OH^- in water medium. A possible scenario is proposed; the β-$Co(OH)_2$ NWs in less Co-rich grooving region were generated by Co^{2+} and OH^- precursors at the interface between water and the film surface. Photo-induced dissociation process of Co NFs generate Co^{2+}, whereas dissociation of water generate OH^-. Agglomerated Co-rich region only underwent normal oxidation process to donate CoO.

Keywords:

Dewetting, grooving, ns laser pulse, Cobalt nanofilm

G8.06

Fabrication and Characterizations of MoS_2 Monolayers on Plasmonic Au Nanogratings

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Abstract:

Integration of transition metal dichalcogenide (TMD) materials on plasmonic metal nanostructures have attracted growing attention for novel optoelectronic device applications. Periodic grating structures allow excitation of propagating surface plasmon polariton (SPP) as well as localized surface plasmon (LSP). LSP generates very large electric field intensity at strongly confined region (so called hot spots). In contrast, SPP can induce intense electric field intensity at extended region. In this work, TMD MoS_2 monolayers were transferred on Au nanogratings fabricated by electron beam lithography. The polarization dependence of the reflectivity and numerical simulations showed a clear feature of SPP excitation. Photoluminescence spectra of the MoS_2 monolayers on the Au nanogratings were compared with those on flat SiO_2/Si substrates and Au thin films. The surface potential of the MoS_2 monolayers in dark and under illumination of light was also measured using Kelvin probe force microscopy. All the results show that 3D Au-nanogratings enable us to tune the physical properties of 2D TMD materials.

Keywords:

MoS2, Nanograting, Surface plasmon polariton

2020 KPS Spring Meeting
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G8.07

In-Plane Anisotropic Properties and Thermoelectric power factor of GeSe Nanoflakes

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Abstract:

We investigate in-plane anisotropic electrical properties and thermoelectric power factor of GeSe nanoflakes. Due to its puckered structure similar to black phosphorus, GeSe exhibits interesting in-plane anisotropic optical, structural, and electrical properties. Optical transmittance, Raman spectroscopy, transmission electron microscopy imaging are employed together with electrical characterizations using field-effect transistor geometry. We also measure temperature-dependent and carrier concentration-dependent thermoelectric power factor of GeSe nanoflakes. The nano-devices showing the good ohmic contact are fabricated by e-beam lithography.

Keywords:

GeSe, 2D materials, Thermoelectric device, Seebeck coefficient, anisotropic property

2020 KPS Spring Meeting
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H4.01

Nanosecond electric field-induced phase transition of Co-doped $BiFeO_3$ thin film

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Abstract:

Electric field-induced phase transition *via* an intermediate phase along with polarization rotation has been theoretically predicted as an origin of giant piezoelectricity for classical ferroelectrics near its morphotropic phase boundary (MPB); however, the transition from a stable phase to the intermediate phases has not been experimentally probed due to lack of knowledge on its time scale as well as magnitude for electric field stimulus. Here we report an ultrafast evolution of intermediate phase in BiFe1-*x*Co*x*O3 (BFCO) epitaxial film near the MPB at x = 0.15. Coexisting phases in BFCO, i.e., monoclinic MC and MA, can undergo the transition among themselves under an applied electric field accompanying with the intermediate phase with a giant *c/a* ratio (~ 1.269), which can be observed only at nanosecond scale. The minimum piezoelectric response time of intermediate phase was found to be 26 ns and the lifetime of the transient phase was estimated to be longer than 50 ns and even shorter than 1 μs.

Keywords:

ferroelectric, thin film, X-ray diffraction

2020 KPS Spring Meeting
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H4.02

Antiferromagnetic ordering in 2 dimensions studied with Raman spectroscopy

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Abstract:

Magnetism in low dimensional systems is an interesting topic for the fundamental physics as well as a promising candidate for numerous applications. Intense interest in 2 dimensional magnetism followed the discovery of ferromagnetism in atomically thin materials, but antiferromagnetic ordering is much more difficult to study because the lack of net magnetization hinders easy detection of such phenomena. Neutron scattering, which is a powerful tool to detect antiferromagnetic order in bulk materials, cannot be used for atomically thin samples due to the small sample volume. Raman spectroscopy has proven to be a powerful tool to detect antiferromagnetic ordering by monitoring the zone-folding due to the antiferromagnetic order or other magnetically-induced changes in the Raman spectrum. In this talk, I will review recent achievements in the study of antiferromagnetism in 2 dimensions using Raman spectroscopy. $FePS_3$ exhibits an Ising-type antiferromagnetic ordering down to the monolayer limit, in good agreement with the Onsager solution for 2-dimensional order-disorder transition. The transition temperature remains almost independent of the thickness from bulk to the monolayer limit, indicating that the weak interlayer interaction has little effect on the antiferromagnetic ordering. On the other hand, $NiPS_3$, which shows an XXZ-type antiferromagnetic ordering in bulk, exhibits antiferromagnetic ordering down to 2 layers with a slight decrease in the transition temperature, but the magnetic ordering is suppressed in the monolayer limit. Furthermore, a Heisenberg-type antiferromagnet $MnPS_3$ exhibits ordering down to 2 layers.

Keywords:

Raman, Antiferromagnetism

2020 KPS Spring Meeting
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H4.03

Nonlinear optical imaging of micro- and nano-scale polar phases

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Abstract:

Photon-based spectroscopic techniques have long been developed and served as a powerful tool in understanding electric and magnetic properties of condensed matters. In this presentation, we discuss how nonlinear optical spectroscopy, in particular, optical second harmonic generation technique is used to investigate spatial distributions of polar phases in oxide thin films. We cover two topics: (i) a lateral distribution of ferroelectric phases in $BiFeO_3$ thin films, and (ii) atomic-scale polar phases formed at the hetero-interface in $SrRuO_3$ thin films.

Keywords:

oxide thin film, nonlinear optics, polar phase

H4.04

Probing the conventional magnetic states by magnetic force microscopy

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Abstract:

Recently, skyrmions have drawn much attention for physics and applied science since they provide a venue for domain manipulation with an ultra low current density. Skyrmions, originally, were found at the non-centrosymmetric crystals, such as MnSi and FeGe, originating from competition between ferromagnetic exchange and Dzyaloshinskii-Moriya interactions. However, a couple of recent results show skyrmion behavior in highly anisotropic magnetic materials with inversion symmetry, which opens a wide span of practical applications. In this talk we will show skyrmion-like domains in centrosymmetric crystals, probed by magnetic force microscopy. We employ a home-built MFM operating at ultra-low, He-3 temperatures within a vector magnet with 2-2-9 T maximum fields in *x*-*y*-*z* direction. We highlight the evolution of tree-like domains into skyrmion-like bubbles with a variety of fields and temperature in the bilayer LSMO and CeRu2Ga2Bsingle crystals.

Keywords:

Skyrmion, MFM, magnetic domains

2020 KPS Spring Meeting
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H4.05

Atomic Electron Tomography: A Novel Approach for Atomic-Scale 3D Imaging of Ferroic Materials

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Abstract:

Ferroic materials not only play imporant roles in modern technology and devices, but also exhibit interesting couplings between structure, orbital, charge and spin degress of freedom, being a system of immense scientific importance. In many case, their properties are strongly related to their internal structures; for example, ferroelectric ordering is mostly governed by cation displacement, and chemical ordering and asymmetry stongly influence the magnetic orderings. For crystalline materials, traditional crystallography was able to provide their atomic structure with high precision. However, real materials, especially miniatured systems in nanoarchitecture regime, usually show largely non-crystalline features including grain boundaries, dislocations, strain and defects. Therefore, to truly understand ferroic properties and functionality at the most fundamental level, it is essential to precisely determine their 3D atomic arrangements without crystallinity assumption. Here, a novel approach named atomic electron tomography (AET) will be introduced as a tool for locating 3D coordinates of individual atoms and their dynamics with picometer precision and with elemental specificity [1-3]. Using ferromagnetic Iron-Platinum (FePt) nanoparticles as a target system, I will show that complex atomic structures can be measured with 3D atomic-level details; including grain boundaries, chemical order/disorder, and point anti-site defects. I will further demonstrate that AET can also be applied to capture the 4D atomic structural dynamics, unveiling nucleation process at the atomic scale. The atomic resolution 3D structural information AET can now provide will open a neww door for fundamental understanding of ferroic properties at the single-atom level.

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[2] Pryor et al., Sci. Rep. 7:10409 (2017).
[3] Zhou et al., Nature 570, 500 (2019).

Keywords:

Electron tomography, chemical ordering, atomic structure, magnetic anisotropy

Correlation between Structural Phase Transition and Surface Chemical Properties of thin film $SrRuO_3/SrTiO_3$ (001)

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Abstract:

In the fields of advanced electronic devices, $SrRuO_3$ (SRO) thin film has attracted much attentions due to its exotic electronic/magnetic properties, i.e., ferromagnetism, superconductivity, charge ordering, etc. The SRO/STO thin film with ~ nm thickness is known to show the structural phase transition (SPT) from monoclinic phase (M-SRO) to tetragonal phase (T-SRO) near ~200 ℃. [1] While both the oxygen vacancy at the interfacial layer between SRO and STO and its interfacial constraint have been pointed out as possible origin of the SPT, the clear understanding behind the SPT has not been clearly known yet.

To find out the correlation between the SPT and oxygen vacancy in SRO thin films, *in situ* X-ray diffraction (XRD) and ambient pressure X-ray photoelectron spectroscopy (AP-XPS) were utilized across the SPT temperature. [2] *In situ* XRD shows that the SPT occurs from a M-SRO phase to a T-SRO phase near ~ 200 ℃ regardless of atmospheric pressure environment. On the other hand, significant core level shifts are found in both the Ru and Sr photoemission spectra under ultra-high vacuum (UHV), but not under oxygen pressure environment. We found the close relation between the properties of the core level shift of Ru and Sr and the formation of oxygen vacancy across the SPT temperature of SRO. The analysis of *in situ* XRD and AP-XPS results provides an evidence of the formation of metastable surface oxide possibly due to migration of internal oxygen atoms across the SPT temperature, indicating the close relationship between oxygen vacancy and SPT in SRO thin films.

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[2] Kim, Dongwoo, et al. *The Journal of Chemical Physics* 152.3 (2020).

Keywords:

SrRuO3, Structural phase transition, Oxygen vacancy, Ambient pressure XPS, X-ray diffraction

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H5.03

MoS_2 triboelectric nanogenerators using depletion layer formation

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Abstract:

We developed MoS_2 triboelectric nanogenerators (TENGs) using a large-sized monolayer MoS_2 grown by chemical vapor deposition. To investigate the effect of a depletion layer formed across a Schottky or pn junction on the output performance of MoS_2 TENGs, three types of TENGs having different contacts, i.e., an ohmic contact, a Schottky contact, and a pn junction, were investigated. During pressing, the TENGs with the Schottky contact and pn junction generated a higher power efficiency than that with the ohmic contact. Additionally, they exhibited self-rectified behaviors. This was ascribed to the diffusion of charges, which resulted in the formation of a depletion layer across the Schottky or pn junction. When ferroelectric polyvinylidene fluoride (PVDF) was used to transfer MoS_2, the power efficiency of the TENGs with the Schottky contact or pn junction was further enhanced by the synergistic effect of the depletion layer and the ferroelectric PVDF.

Keywords:

MoS2, triboelectric nanogenerators, depletion layer, ferroelectric

2020 KPS Spring Meeting
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H5.04

STM studies of endohedral metallofullerene: Gd@C_{82} on Au(111)

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Abstract:

Endohedral metallofullerene is known for its property which protects inside spin system from environment and ensures longer coherence time [1,2]. Especially, Gd@C_{82} has various potential application such as magnetic resonance imaging (MRI) contrasting agents, cancer cures, and so on [3]. Here, we investigate the structural and electronic properties of Gd@C_{82} on Au(111) using scanning tunneling microscopy (STM).
We investigate the adsorption of molecules on Au(111) depending on the coverage of Gd@C82 on the surface. In low coverage, we find isolated molecules at the step edge and the elbow sites of the Au(111) herringbone reconstruction. As increasing the density of molecules on the surface, Gd@C_{82} on step edge forms dimer, and once the step edges are fully covered, the molecules start to form islands. The high-resolution STM images at different bias voltages show the intramolecular structure of Gd@C82 molecules, giving us understandings of the molecular absorption geometry at different absorption sites. We also compare the electronic states of Gd@C_{82} at different absorption sites (step edge, terrace, and elbow) using scanning tunneling spectroscopy (STS). These results may serve as a guide in the construction of surface architectures based on Au's surface energy.

[1] W. Harneit, *Phys. Rev. A* **65,** 032322 (2002)
[2] Z. Hu et al., *J. Am. Chem. Soc.* **140**, 1123−1130 (2017)
[3] J. Zhang et al., *Nat. Chem.* 5, 880−885 (2013)

Keywords:

Scannig Tunneling Spectroscopy (STS), Scanning Tunneling Spectroscopy, Metallofullerene

2020 KPS Spring Meeting
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H5.06

Atomic Scale Study for 2D materials using high resolution Atomic Force Microscopy

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Abstract:

Black phosphorus (BP) is a promising two-dimensional (2D) material for future electronic devices due to unique properties of high carrier mobility and large tunability of band gap. However, thinner crystalline BP is more readily degraded under ambient conditions. For BP-based electronic devices, degradation of the exfoliated BP is a key issue. However, the nanometer scale study of BP degradation is rare so far. Herein, we report an atomically resolved degradation process of the BP surface using atomic force microscopy under temperature- and humidity-controlled environments. The atomically resolved crystal surface of BP deteriorated due to surface etching after cleavage, and showed monolayer etching. The etching process is accelerated by applying bias voltage to BP via a conductive tip. After the voltage-assisted BP etching, the BP etching product shows crystalline BP confirmed by Raman spectroscopy and atomic force microscopy. Our atomic scale study of BP will be useful for the future 2D-based electronic devices to overcome conventional silicon-based electronic devices.

Keywords:

2D materials, Black phosphorus, Atomic Force Microscopy

2020 KPS Spring Meeting
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H5.07

A plausible method of preparing the ideal p-n junction interface of a thermoelectric material by surface doping

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Abstract:

A high quality *p-n* junction interface can be realized using two-dimensional materials that can introduce excellent device performance such as high electron mobility. Here we report that such an interface can be prepared by a simple surface treatment via direct measurement of an electron band structure using angle-resolved photoemission spectroscopy. The valence band maximum of as-prepared *p*-doped SnSe gradually shifts towards higher binding energy upon depositing Ta on its surface. The shift is attributed to charge transfer from Ta to SnSe that is highly localized to the topmost layer due to the layered structure of SnSe. As a result, Ta deposition leads to an *n*-doped surface while the bulk remains as *p*-doped. Our finding suggests the possible formation of a well-defined *p-n* junction interface with an atomically thin *n*-region that can be potentially applied to high-performance thermoelectric devices.

Keywords:

SnSe, Angle-resolved photoemission, p-n junction, charge transfer, Tantalum

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H5.08

Enhanced Anti-Stokes Photoluminescence at Nano-Pyramidal Tips Under Acoustic Phonon Pumping

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Abstract:

Involvement of acoustic (AC) phonons in generating anti-Stokes photoluminescence (ASPL) has been scarcely investigated, contrary to its optical counterparts [1] and two-photon absorption (TPA) [2]. We experimentally report on the enhanced ASPL efficiency in pyramidal arrays with nanoscale tips fabricated on top of the GaN-based quantum structure, attributing to the phononic up-conversion. The AC phonons are externally generated under the strong ultrafast laser excitation on the five InGaN multiple quantum wells (MQWs), incased by a 200 nm thick GaN capping layer, as investigated previously [3]. The linear response of the ASPL intensity with increasing carrier density (n), which is the well-known feature for phononic origin, while the nonlinear dependence with n implies the role of TPA in inducing ASPL [1]; indeed, the linearity with n was confirmed in our experimental result with the excitation energy being set far below the GaN bandgap. Moreover, the main role of LO phonons in generating ASPL was revealed with the exponentially ascending ASPL intensity with temperature, as reported earlier [4]. Notably in this work, an abnormal temporal correlation between AC propagation and ASPL features was observed in the time-resolved schemes using streak camera and transient differential reflectivity spectra (DRS) where a strikingly long delay (e.g., ~75 ps in ASPL measured at ~3.44 eV, matching the propagation from MQWs to the pyramidal tips) has been repeatedly seen and could be possibly interpreted as the AC phonons additionally contributing to the optical phonon in assisting the ASPL process. In the context of DRS measuring AC propagation dynamics [3], the increasing signal of DRS further indicated the ascending AC propagation toward the tip side of the pyramids, then, followed by a plateau and decreasing features via the AC scatterings near the tip sides. Not only the correspondence of this AC propagation and the inherent accumulation of phonons due to the tapered pyramidal shapes but also the recent report on the important role of AC phonons in three-phonon scatterings to elevate LO phonon energy supports our scenario [5,6]. Our work proposes a novel route to comprehend the influence of the low-energy phonons in the ASPL.

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Acknowledgments: This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning(2018R1A2B6008101).

Keywords:
GaN pyramid, Anti-Stokes Photoluminescence, Acoustic Phonon, Phonon Up-Conversion, Time-Resolved Spectroscopy

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H5.09

Identification of the absorption geometries and electronic structures of VOPc molecules on Au (111) surface

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Abstract:

Vanadyl Phthalocyanine (VOPc) molecules are considered as a potential candidate for the quantum manipulation using its 1/2 spin characteristics. VOPc is a planar molecule with vanadium atom at the center in addition to the oxygen atom on top of vanadium normal to molecular plane. To explore the spin structure of single VOPc molecules, we deposited the molecules on Au (111) surfaces with low coverage condition. The imaging of the single molecules is performed using low temperature scanning tunneling microscopy (STM). Molecules have preferred absorption sites, elbow or bulged sites of the reconstructed Au(111) surface. We figured out that VOPc have two geometric configurations when they are absorbed: Oxygen pointing toward the vacuum (O-up) with the Pc laying on the surface, and oxygen pointing toward the surface (O-down). To figure out which molecules are O-up or O-down configurations, we measured bias dependent topographic images, differential conductance maps, and tunneling spectroscopy. Using bias voltage of +100 mV, O-up is bright at the center and O-down is bright around Pc ligands. O-down molecule is tilted toward one direction in topographic image and mechanically less stable. In addition, configurations of the molecules were confirmed by the calculated results using density functional theory. In this poster, different electronic structures depending on the absorption geometries will be discussed.

Keywords:

Single molecule, Vanadyl Phthalocyanine (VOPc) , Low temperature scanning tunneling microscopy (STM), Electronic structures of VOPc

H6.01

Nearly Flat Bands in Twisted Graphene on Bilayer Graphene (tGBG)

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Abstract:

We investigate the band structure of twisted graphene on bilayer graphene (tGBG), or twisted monolayer-bilayer graphene, as a function of twist angle and perpendicular electric field in search of optimum conditions for achieving narrow bandwidth isolated low energy bands. Narrow bandwidths W comparable or smaller than the effective Coulomb potentials satisfying $U_{eff}/W \geq 1$ are expected for twist angles around 0.3° −0.8° and 1.1° −1.5° in the presence of appropriate perpendicular electric fields. The valley Chern numbers of the electron-hole asymmetric bands depend intrinsically on the details of the hopping terms in the bilayer graphene, and extrinsically on factors like electric fields, or by average staggered potentials of ~20 meV gap in monolayer graphene that can model alignment with hexagonal boron nitride. This tunability of the band isolation, bandwidth, and valley Chern numbers makes of tGBG a more versatile system than twisted bilayer graphene for finding nearly flat bands prone to strong correlations.

Keywords:

Nearly Flat Bands, Twisted Graphene on Bilayer Graphene

H6.02

Quantum hybridization negative differential resistance in vertical graphene heterostructures from ab initio

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Abstract:

Vertically stacked van der Waals heterostructures, made of few layers of hexagonal boron nitride (hBN) channel sandwiched by single-layer graphene electrodes (graphene/hBN/graphene), exhibit negative differential resistance (NDR), which so far could not be treated within *ab initio* calculations. Here, carrying out the multi-space constrained-search density functional theory (MS-DFT) calculations, we study the nonequilibrium electronic structures of vertical graphene/hBN/graphene junctions. Contrary to nonequilibrium Green's function (NEGF) formalism, the main advantage of MS-DFT is that the finite graphene monolayer electrodes can be handled. Among various pristine hBN layers, we observe the NDR behavior at the single-layer hBN channel that originates from the quantum-mechanical hybridization between two graphene electrodes in low bias regime (V_b = 0.5 V). Concurrently, we also observe a linear background current in all pristine hBN layer cases due to the tunneling that, resulted from a single ring of $\vec{k}$ points between two shifted graphene Dirac cones. Finally, by adopting the carbon substitutional defect at central hBN layer nitrogen atom (C_N) in a three-layer hBN channel, we demonstrate that the defect states can mediate the NDR in multi-layer hBN channel sandwiched by single-layer graphene electrodes.

Keywords:

Vertically stacked van der Waals devices, Nonequilibrium electronic structres, Multi-space constrained-search DFT, Negativ differential resistance

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

H6.03

First-Principle Study on diffusion behavior of nickel in graphene-capped silicon thin film

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Abstract:

We study the energetics of Ni atoms in graphene-capping silicon surface using the first-principles calculations. First, we explore the diffusion paths of Ni atoms in bulk Si by evaluating the Ni binding energies on various sites. It is found that the most stable site is the center of the triangular (TA) site composed of 3 Si atoms belonging to an octahedron. A modified nudged elastic band method is used to study the diffusion barrier between any two local energy minima resulting in the migration barrier of 70 meV. We find that Ni atoms may diffuse mainly along the [111] direction. We also investigate the diffusion process of the Ni atom on a Si(110) surface by evaluating its diffusion coefficient using the harmonic transition state theory. The direction of the surface diffusion depends significantly on the surface geometry of the Si(110) surface with a strong anisotropy, and the estimated migration barrier is 0.56 eV. Furthermore, graphene capping suppresses the Ni diffusion on the surface increasing the surface diffusion barrier up to 1.09 eV. We also study the diffusion mechanism in several nickel silicides which can form at the interface of Ni-Si thin films. Our results may explain the role of graphene in the Ni diffusion observed at the interface of Si-Ni thin foil.

Keywords:

DFT, diffusion coefficient, nickel diffusion, silicon, nickle silicide

2020 KPS Spring Meeting
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H6.04

Impact of W thickness on Perpendicular Magneto-crystalline Anisotropy of Pt/Co/W(111) Superlattices

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Abstract:

Tri-layer superlattice with reflection asymmetry in the spirit of Rashba effect has attracted a great deal of interest in spintronics. Pt/Co/W (111) superlattice is studied by performing *ab initio* calculations to elucidate experimental results, where perpendicular magnetocrystalline anisotropy (PMA) exhibits W thickness dependence. Moreover, the enhancement of PMA compared to Pt/Co due to non-magnetic W is also examined. Our calculations results reveal that the thickness dependence of PMA is evident, whose maximum takes place when W is three monolayers. The orbital hybridization at interfaces with W is responsible for strong PMA. Notably, interface layers contributes to PMA with appreciable orbital magnetic anisotropy, which is in good agreement with the so-called Bruno relation, $E_{PMA} \sim m^{\perp}_{orb} - m^{\parallel}_{orb}$. To figure out the physics origin, k-resolved PMA demonstrates that most contribution comes from the Γ with *d* orbitals of *m* = ±2, where *m* is the magnetic quantum number. In addition, PMA is also analyzed in the framework of second-order perturbation theory indicating that the coupling$\langle |m|=2|L_z||m|=2 \rangle$dominates.

Keywords:

magnetocrystalline anisotropy, superlattices, thickness dependence

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

H6.05

First-principles study of effects of local Coulomb repulsion and Hund's coupling in ferromagnetic semiconductor $CrGeTe_3$

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Abstract:

Recently, the 2D magnetic van der Waals material has drawn attention for its academic interest as an ideal magnetic model and its application of spintronics and magnetic sensors. One of the materials is 2D Ising-like ferromagnetic semiconducting $CrGeTe_3$ (CGT). We use the Liechtenstein U approach to investigate the electronic structure of CGT in the noncollinear PBE+U+SOC method. The effect of d^3 Cr octahedron distortion on the bandgap is discussed using structures modified by strained lattice constants.

Keywords:

2D van der Waals magnetic materials, CrGeTe3, bandgap, octahedron distortion

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

H6.06

Tunability of Magnetism and Half-metallicity of Heusler Mn_3Ga upon Co-Substitution

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Abstract:

Structure and magnetism of $Mn_{3-x}Co_xGa$ (x = 0~1) is studied using *ab initio* calculations. Ferrimagnetic Mn_3Ga possesses two inequivalent Mn sites, octahedral Mn-I and tetrahedral Mn-II, where Co substitution into Mn-II site is favorable leading to novel physics. Notably, structural transition from tetragonal to cubic phase occurs around at x = 0.50~0.68. Especially, Co moment is extraordinarily small in tetragonal phase, which results in reducing total moment with Co concentration. In contrast, in cubic phase Co moment is almost 1.0 μ_B: Magnetic moment enhances with x following the Slater-Pauling rule of Heusler compounds, $M = N_V - 24$, where M is total magnetic moment, N_V is total number of valance electrons. In particular, x = 0.5 and 1.0 are half-metallic with integer total moment. Moreover, extraordinarily small Co moment for tetragonal phase is analyzed phenomenologically in the framework of magnetic-force theorem (MFT), where Heisenberg model is employed, and two Mn sites exhibit opposite behaviors in the exchange coefficients.

Keywords:

Heusler compounds, Slater-Pauling rule, half-metallicity, exchange interaction, magnetic-force theorem (MFT)

2020 KPS Spring Meeting
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H7.02

A historic pigment for spin thermoelectric generator

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Abstract:

Spin Seebeck effect in a magnetic insulator allows a unique architecture for the thermoelectric energy conversion as the heat generated magnon flow can be converted into current via the inverse spin Hall effect. This alternative thermal energy conversion based on the bilayer of magnetic insulator and metallic film has promising potential as it is free from the fundamental limitations to the conventional thermoelectric figure of merit. Despite this advantage, the spin thermoelectric energy conversion suffers from high crystallization temperatures and low productivity of inorganic magnetic insulators. Here, we introduce a new class of magnetic insulator for spin thermoelectric applications, which is a molecule-based magnetic thin film of Cr-Prussian blue analogue (Cr-PBA). The deposition of Cr-PBA was achieved via room temperature electrochemical deposition, which can be easily adopted for large-area-, low-cost-, and mass-production. Cr metal layer was used as an electrode for the deposition of Cr-PBA, introducing the formation of a new substantial heterojunction. To exhibit figure of merit in spin-charge conversion, we developed spin thermoelectric generator, which shows large spin Seebeck voltage ~ D$\boldsymbol{V}_{LSSE}$/D$\boldsymbol{T}$= 27.1 uV/K, comparable to that of epitaxial $Y_3Fe_5O_{12}$. Furthermore, the ferromagnetic resonance study exhibits low damping constant suggesting long distance magnon transport, suitable for various magnon-based spintronic applications.

Keywords:

Spin Seebeck effect, ferrimagnetic insulator, molecule-based magnet, thermoelectric energy conversion, spin Seebeck effect, Ferromagnetic resonance (FMR)

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

H7.03

Study of magnetism in polycrystalline $PrBaCo_2O_{5.76\pm x}$

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Abstract:

Desorption and absorption characteristics of the double perovskites can often trigger their modulation in magnetic ground states. Thus, it would be interesting to see the relation between oxygen contents and magnetism. Among many double perovskites, we chose $PrBaCo_2O_{5.76\pm x}$ (PBCO), since it is known that it has spin state transition and tunable magnetism by oxygen contents. As-synthesized PBCOs were prepared by solid state reaction in air. For controlling oxygen contents, heat treatments were performed in an environment-controlled tube furnace under forming gas at annealing temperature (T_a) 100, 150, 200, 300 ^{o}C for reduction, and under pure oxygen at annealing temperature (T'_a) 300^{o}C for oxidation. Oxygen contents of PBCOs were determined by iodometric titration, and the results showed we could control oxygen contents in the range of $-0.51 \le x \le 0.07$. From x-ray diffraction and Rietveld refinements, we characterized structural property at first. From temperature dependent magnetization data, we observed various magnetic phase transition. Oxidized PBCO (T'_a = 300^{o}C) showed only paramagnetism to ferromagnetism transition. However, as reducing oxygen contents, antiferromagnetism started to be shown in PBCO. Below T_a = 150^{o}C, para – ferri – antiferromagnetism transition was observed, eventually, when T_a = 300^{o}C, antiferromagnetism is stabilized in PBCO. In addition, we will discuss detailed magnetic structure of PBCO using SQUID magnetometry and neutron diffraction.

Keywords:

double perovskites, oxygen vacancy

H7.04

Adsorption, diffusion and penetration of boron and nitrogen atoms near the Pt(111) surface.

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Abstract:

Recently two-dimensional (2D) layered materials are very attractive in various fields because of their interesting properties. h-BN films are grown on catalytic metal surface using chemical vapor deposition (CVD). It is very important to understand the detailed atomic process for growth of thin films of good quality. In this paper, we investigate the adsorption and diffusion of boron and nitrogen atoms separated from the precursor molecules on Pt(111). The boron atom is adsorbed the three fold hollow sites. Furthermore, the energy decreases when the B atom occupied a subsurface site by 0.45 eV. The barrier for this penetration is only 0.35 eV. Due to this penetration, the B atom diffuse on the surface and below the surface, whose barriers are 0.49 eV and 0.56 eV, respectively. The Nitrogen atom also occupied three fold hollow site. The surface diffusion barrier of nitrogen is 0.84 eV on the Pt(111) surface, slightly lager than those of boron. Our results show that the B and N atoms diffuse very rapidly at the h-Bn growth temperatures. We discuss the CVD growth mechanism in relation with our results.

Keywords:

Pt(111), hexagonal boron nitride, Density functional theory, Chemical vapor deposition, h-BN

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

H7.05

Achieving superconducting Sr_2RuO_4 thin films by controlling structural defects

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Abstract:
The layered perovskite superconductor Sr_2RuO_4 (bulk T_c ~ 1.5 K) has been studied extensively since it is considered as a strong candidate for *p*-wave superconductor with chiral gap function ($p_x \pm ip_y$) [1]. The possible topological superconductivity of Sr_2RuO_4 are interesting with not only the physical advances, but also providing fruitful device application such as quantum-computing circuits [2]. In this respect, Sr_2RuO_4 thin film is highly required by revealing its odd parity superconductivity, as well as providing a platform for micro-fabrication so that enabling next generation devices. However, superconducting Sr_2RuO_4 film growth has been limited since the superconductivity of Sr_2RuO_4 is extremely vulnerable to structural defects, especially out-of-phase boundaries (OPBs) [3]. So far, reliable growth was only allowed by MBE growth [4,5].
In this presentation, I will present superconducting Sr_2RuO_4 films growth by pulsed laser deposition (PLD) technique, focused on the suppression of OPBs. By controlling the chemical impurities and structural defects carefully, we succeed to achieve epitaxial Sr_2RuO_4 films with high crystallinity confirmed by X-ray diffraction and atomic resolution transmission electron microscopy. With reduced OPBs, we observed superconductivity up to 1.2 K, which is the highest among the unstrained Sr_2RuO_4 films. By this work, we suggest a new method to obtain superconducting Sr_2RuO_4 film by PLD, which offers broad opportunities to explore various oxide heterostructure more easily.

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Keywords:

Superconductivity, Sr2RuO4 thin film, pulsed laser deposition, oxide thin film, unconventional superconductivity

포스터발표논문

Poster session abstracts

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P1-ap.101

촉매 이온종 변화에 따른 제조된 그래핀 양자점의 구조 및 특성 변화

HA Jun Mok *[1], LEE Seoung Ho [1], HWANG Young Seok [1], LEE Chan Young [1], SUK Jae Kwon [1], JUNG Myung Hwan [1], YEO Sun Mog [1], LEE Jae Sang [1]
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Abstract:

수~수십 나노미터 이하의 직경을 가지는 0차원의 탄소 기반 나노물질인 그래핀 양자점은 독특한 발광 및 전기전자 특성으로 인해 바이오 이미징, 약물전달체, 광촉매, 센서 등 산업 및 의료 분야 등 다양한 분야의 활용에 주목을 받고 있다. 특히, 그래핀 양자점의 생체 적합성, 낮은 독성, 우수한 용해성 등의 고유한 특성은 의료 분야 활용에 더 큰 관심을 끌고 있다. 하지만, 현재 그래핀 양자점의 제조 방법은 모두 산이나 인체에 유해한 화학물질을 이용한 방법이기 때문에, 인체에 적용하기에는 아직 위험성이 크다고 할 수 있다. 이에, 본 연구팀은 산이나 인체 유해 화학물질을 전혀 사용하지 않고 단지 이온빔만을 이용해 순수 그래핀 양자점만을 제조하는 기술에 대해 연구하고 있으며, 본 학회에서는 촉매 이온종 변화 시에 제조되는 그래핀 양자점의 구조 및 특성 변화에 대한 결과를 발표하고자 한다.

Acknowledgement
This work has been supported through National Research Foundation (NRF) of Korea (No. 2018R1D1A1B07050951), KAERI Research Project, and KOMAC operation fund of KAERI by MSIT (Ministry of Science and ICT).

Keywords:

이온빔, 그래핀 양자점, 촉매 이온종, 생체 적합성

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.103

Synthesis of correlated oxides applicable for temperature sensors via tailoring doping profile

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Abstract:

Vanadium dioxide (VO_2) is well known for metal-insulator transition (MIT) phenomena occurred at near room temperature of ~67℃. Various physical properties of VO_2 change dramatically across the MIT phase boundary. However, the current scope of VO_2-based applications has been limited by the transition temperature higher than the normal operation temperature of modern electronics and the narrow transition regime. Therefore, in order to enhance the applicability of VO_2, diverse approaches for modulating the MIT temperature, T_{MIT}, are undergoing: substitutional doping, irradiation, mechanical engineering, etc. Above all, cation doping with W^{6+} enables the efficient and detailed reduction of T_{MIT} throughout the entire doped regions stably. Here, we have developed a novel two-step synthesis process for achieving high-quality W-doped VO_2 thin films with a fine control of doping level. Further, we have successfully widening their phase transition regimes substantially by spatially gradual doping with W dopants inside thin film structures in the direction perpendicular to the film surfaces. The temperature resistance coefficients (TCRs) of gradually W-doped VO_2 thin films were observed to be superior to those of conventional pure and uniformly W-doped VO_2 thin films. The nanoscale compositionally graded VO_2 thin films may be closely relevant to developing novel temperature and heat sensors.

Keywords:

doping effect, metal insulator transition (MIT), vanadium dioxide(VO2), substitutional cation doping, TCR

2020 KPS Spring Meeting
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P1-ap.104

광전기화학 전지 응용을 위한 Cu_2O (111) 구조체의 구조적, 광학적 특성

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Abstract:

제일산화구리 Cu_2O는 2.17 eV ~ 2.62 eV의 에너지 밴드 갭을 갖는 p형 반도체로 알려져 있다. 구리가 지구상에 풍부하게 존재하고 있어 Cu_2O는 생산원가도 낮으며 독성이 없고 10^5/cm 정도의 높은 흡수계수를 가지고 있으므로 광전지, 광촉매, 박막트랜지스터, 가스 센서 등의 많은 소자 이용에 널리 사용되고 있다. 소자의 기능은 소자에 사용된 물질의 품질에 의해 의존하므로 많은 연구자들이 고품질 Cu_2O 박막을 만들기 위해 구리 호일의 열산화, 펄스 레이저 증착, 스퍼터링, 화학증기증착, 전기침전, 등 여러 가기 방법을 시도해 왔다. 그러나 대부분 제이산화구리인 CuO 상을 함께 가지고 있거나 다결정 Cu_2O 박막을 얻었다. 또한 광전기화학 반응은 표면적이 넓으면 넓을수록 효율이 높기 때문에 반응의 효율성을 높이기 위해 덩어리나 평평한 박막보다는 와이어, 기둥, 침 등의 구조체를 만들기 위해 노력하였다.
본 연구에서는 RF 스퍼터링 방법으로 증착 한 고품질 Cu(111) 박막을 80°C의 물에서 산화시킨 후 고온(500~800°C) 급속 열처리 공정 (RTP: rapid thermal process) 과정을 통하여 표면적이 넓은 Cu_2O(111) 구조체 박막을 얻고자 하였다. 열처리 공정의 온도와 시간 등을 변화시키며 만든 Cu_2O 구조체 박막을 X선 회절(XRD) 분석을 통하여 구조적 특성을 연구하고 주사전자현미경 (SEM)과 원자힘 현미경 (AFM)을 통하여 표면을 연구하였다. 또한 UV-vis spectroscopy 통하여 Cu_2O 구조체 박막의 투과도 실험을 진행하여 광흡수도, 에너지 밴드 갭을 구하고 Cu_2O 구조체 박막의 광전기화학 소자로의 응용 가능성을 연구하였다.

Keywords:

산화구리, Cu2O

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.105

Metal Insulator Transition Properties of V_2O_3 Film Controlled by Crystallographic Texture

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Abstract:

Understanding the mechanism of metal to insulator transition (MIT) in V_2O_3, which is ore of strongly correlated electron systems, is an interesting and challenging issue. Due to the complexity of the involved parameters, exact origin of the MIT is still under intense studies both experimentally and theoretically. In this paper, we investigate the correlation between crystallographic aspects of the V_2O_3 film such as the preferred orientations of grains, lattice parameters and electrical transport in the thin films. The results suggest anisotropic MIT behavior with respect to the crystal structure. Texture-controlled growth of V_2O_3 films was demonstrated by adjusting oxygen gas partial pressure during the film growth procedure. We confirmed that the lattice parameters of strongly textured V_2O_3 affect both stability of metallic phase and MIT critical temperature. In addition, tailoring of crystallographic texture in the V_2O_3 film could induce adjustment of MIT behaviors. We proposed that the degree of overlapping of egπ e_g^{π} orbitals, that varies depending on the distance between V atoms in the basal plane, affects not only the room temperature resistivity (RTR) but also the overall MIT.

Keywords:

V2O3, metal to insulator transition, crystallographic orientation

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.106

LASER scribed carbon nanomaterial on polyemer films for gas sensor

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Abstract:

In this study, carbon nanomaterial was locally pattern-synthesized into a desired shape at a desired location by using a laser scribing process and a laser assisted CVD equipment combined with a vacuum chamber, and the gas sensor application study of the synthesized carbon nanomateria was studied. In the built-in LASER assisted CVD equipment, a specific polymer thin film was coated on various substrates such as metal foil, quartz, and metal thin film-coated quartz, or the polymer film was used as a solid carbon source for carbon nanomaterial synthesis. In the prepared substrate, pattern synthesis of carbon nanomaterial by a laser (λ = 1064 nm, pulse) local heating method was performed in a vacuum chamber, and each sample was evaluated for characteristics by Raman spectroscopy to optimize synthesis conditions. On metal substrates, the thermal conductivity of metal was good, so it was difficult to synthesize carbon nanomaterial patterns, but on the quartz substrate or polymer film, the optimum synthesis conditions were found depending on conditions such as output power, scan speed, frequency, and number of exposures.
Using this synthesized carbon nanomaterial channel, put a sample in a self-made chamber capable of gas sensor experimentation, and change the conductivity of carbon nanomaterial in real time through methane, propane, nitrogen dioxide, ammonia gas, etc. through computer interface through a LabVIEW program. By monitoring, the possibility of using the gas sensor of LSC (LASER Scribed Carbon-nanomaterial) was studied. More details will be presented at the poster section.

Keywords:

LASER, Carbon nanomaterial, Sensor, Polymer film

2020 KPS Spring Meeting
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P1-ap.107

Polarized Raman study on GaTe

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Abstract:

GaTe, a low symmetry layered material with monoclinic structure, was investigated by using polarized Raman spectroscopy. Polarized Raman spectra of GaTe in both parallel and perpendicular polarization configurations showed in-plane optical anisotropy. XRD data confirmed that our GaTe samples were of high crystal quality. We were able to observe 15 Raman modes, for the first time, among the possible 18 Raman active modes. Their Raman intensities as a function of the polarization angle with respect to the crystal axis were consistent with the Raman tensors of either A_g or B_g symmetry.

Keywords:

GaTe, Polarized Raman

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.108

Raman study on magnetic excitations in $RuCl_3$

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Abstract:

The Kitaev spin system consists of a network of *s*=1/2 spins on a honeycomb lattice and it is known to harbor topological quantum spin liquid (QSL). The emergence of Majorana fermions in single crystals of $RuCl_3$, the signature of an experimental realization of the Kitaev spin system, was recently demonstrated. Nonetheless, the behavior of Kitaev spin system in the 2-dimensional limit is yet to be investigated. In this work, mechanically exfoliated few-layer $RuCl_3$ flakes were studied by using Raman spectroscopy. The layer-thickness dependence of the Raman spectrum showed that the quasi-elastic scattering was significantly suppressed for the flakes thinner than 4 layers. Temperature dependence of the magnetic excitations in 2D limit was compared with that in bulk $RuCl_3$. The electronic Raman features, observed from 1,200 to 4,400 cm^{-1}, showed interesting layer-thickness dependence while not incurring a Mott state.

Keywords:

Kitaev spin system, quantum spin liquid, Majorana fermion, RuCl3, Raman

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.109

Effect of on-surface molecular absorption on magnetic properties of ultrathin Co film

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Abstract:

Heterostructures have been considered as interesting subject on account of unique physical or chemical properties distinguished from constituent bulk materials. In particular, organic semiconductors (OSCs) on ferromagnetic metal (FM) films can tune the magnetic characteristics of underlying FM film driven by charge transfer and hybridization at the interfaces. But their impact on ferromagnetic transition and magnetotransport at the FM/OSC interfaces remains largely unexplored. In this work, we investigated manipulation of magnetic properties of ultrathin Co film by on-surface absorption of small molecules, such as C_{60} and copper phthalocyanine (CuPc). Results showed that considerable charge transfer near Fermi level at Co/OSCs interfaces modifies the magnetic characteristics of the Co film through migration of valence electrons in the Co atoms. Hall measurements exhibited variation of a hole channel at the surface of Co, which was initially formed by oxygen contamination on Co films. As a results, the on-surface absorption of OSCs enhanced perpendicular magnetic anisotropy (PMA) and raised magnetic hardening of the underlying FM film. The demonstrated tuning of magnetic properties on metal/organic interfaces will stimulate fundamental studies of organic spinterfaces for future spintronic applications.

Keywords:

ferromganetic metal/organic heterostructure, ultraviolet photoelectron spectroscopy, charge transfer, anomalous Hall effect, transition temperature

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.110

Effects of Sputtering Conditions on Stoichiometry and Crystallinity of MoS_2 Thin Film

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Abstract:

Compared to thermal CVD, sputtering has an advantage of synthesizing a large and uniform MoS_2 thin film. However, due to the high sensitivity to sputtering conditions, the research for optimized conditions should be conducted. In this study, we investigate the effects of sputtering conditions on stoichiometry and crystallinity of MoS_2 thin film. MoS_2 films were prepared from the RF magnetron sputtering system by using a MoS_2 target. The stoichiometry of the MoS_2 film was confirmed by XPS and EDS characterization. We found that RF power and operating pressure determine their chemical compositions. In addition, Raman and XRD results show that substrate temperature strongly influences film crystallinity and the formation of sulfur vacancies. Through this study, we found that all the sputtering parameters are closely related to forming a highly crystalline MoS_2 thin film with the appropriate extent of sulfur vacancies.

[Acknowledgement: NRF-2018R1A6A1A06024977, UOS-BSIRDF2019]

Keywords:

MoS2, RF magnetron sputtering, Raman Spectroscopy, X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive X-ray Spectroscopy (EDS)

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.111

Effect of MgO RF Power Sputtering on Time Dependent Dielectric Breakdown(TDDB), R-V curve Characteristics for Double MgO Based Perpendicular-Magnetic-Tunneling-Junction

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Abstract:

Recently, various non-volatile memory has been improved to replace dynamic random access memory (DRAM) for use in the neuromorphic device of neurons and synapses and embedded memory for the Internet of Things. Among these non-volatile memories, the perpendicular-spin-transfer torque magnetic random access memory (p-STT MRAM) has received considerable attention because of its many advantages such as fast switching speed(~10ns), extremely low power consumption(~1 pJ/bit), high write endurance(>) and scalability.[1] High performance of the p-STT MRAM is closely related to the perpendicular anisotropy of the magnetic tunneling junction (p-MTJ) of the p-STT MRAM which affects parameters such as tunneling magnetoresistance ratio (TMR ratio), thermal stability and switching current. The most common p-MTJ uses MgO tunneling barriers to obtain a high TMR ratio due to the coherent tunneling of the electrons. The MgO tunneling barriers must be very thin (~1.0 nm) for STT switching of the p-MTJs, however, thin insulators are susceptible to electrical trap sites or thermal stresses which can cause a breakdown of MTJ cells and reliability problems.[2] Therefore, it is crucial to improve the crystallinity of the thin MgO tunneling barrier to obtain high performance of the p-STT MRAM cells.

In this study, we compared the double MgO-based p-MTJ spin-valves depending on the RF sputtering power of the MgO tunneling barrier (290W, 320W, 350W). We investigated the effect of the RF sputtering power on the magnetic properties of the spin valve by vibrating the sampling magnetometer(VSM) and R-V curve. The crystallinity of the MgO tunneling barriers was confirmed by transmission electron microscopy (TEM). Finally, the time-dependent dielectric breakdown(TDDB) by the constant voltage stress(CVS) method was measured to compare the reliability of the MgO tunneling barriers depending on the RF sputtering power.

Reference

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Acknowledgements

This work was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2017R1A2A1A05001285) and Brain Korea 21 PLUS Program in 2014.

Keywords:

Perpedicular-Magnetic Tunneling Junction(P-MTJ), MgO RF Power sputtering, Time-Dependent Dielectric Breakdown(TDDB), R-V Curve, Vibrating sampling magnetometer(VSM), Transmission electron microscopy (TEM)

2020 KPS Spring Meeting
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P1-ap.112

Dust collecting efficiency of V-doped ZnO coated mesh

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Abstract:

Based on environmental friendly characteristics of lead-free ferroelectrics, studies about applications of ZnO-based ferroelectrics are essential. While ferroelectricity commonly arises from non-centrosymmetric structure of hexagonal wurzite ZnO crystal, metal ion doping such as Co or Fe can be used to induce non-centrosymmetric structure by shifting Zn^{2+} position from central plane. Among metal ions, vanadium especially can increase remnant polarization than the other dopants due to a smaller ion radius than that of Zn^{2+}. Here we present an increase in dust collecting efficiency of V-doped ZnO coated-mesh.

In this work, zinc acetate dihydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$) and vanadyl acetylacetonate ($C_{10}H_{14}O_5V$) were dissolved in 2-methoxyethanol ($C_3H_8O_2$) with 2-dimethylaminoethanol ($C_4H_{11}NO$) as a stabilizer for mixing. Mixed solution was stirred at 75°C for 2 hours, and then aged for 1 day. The V-doped ZnO film was spray-coated on a stainless steel mesh. The UV ozone treatment, preheating, and annealing were sequentially conducted to crystallize spray-coated film. Crystallinity of ZnO film strongly depends on the annealing temperature. With an increase of ZnO (002) peak intensity, fine dust collecting efficiency increases along with an increase of remnant polarization.

Keywords:

Ferroelectricity , Dust collection, Thin film, sol-gel

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.113

EPR Parameters of Cu^{2+} Complex with CuO Content in K_2O-B_2O_3-CuO Glasses

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Abstract:

Electron Paramagnetic Resonance(EPR) investigations have been carried out for Cu^{2+}ions in xK_2O-B_2O_3-yCuO glasses (x=K_2Omol%/B_2O_3mol% and y=CuOmol%/B_2O_3mol%) with x=0.1, 0.3 and y=0.01~0.07. EPR spectrum consists of four hyperfine lines characteristic of Cu^{2+}ions. Spin Hamiltonian parameters(SHP) such as $g_{\parallel}$, $g_{\perp}$, $A_{\parallel}$ and $A_{\perp}$ have been evaluated from the EPR spectra and this indicate that the Cu^{2+}ions in the glasses are coordinated by six ligands (CuO_6 complex) and exist in tetragonal distorted octahedral site with $d_{x^2-y^2}$ orbital($^2B_{1g}$ state) as the ground state. Variation of Δg and $g_{\perp}/A_{\parallel}$ values with CuO content was determined and observed on the changes in the environment of Cu^{2+}ions in K_2O-B_2O_3-CuO glasses.

Keywords:

EPR, copper ions, borate glasses

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.114

Using Non-plasmonic Semiconductor Substrates to Explain Chemical Enhancement Mechanism of SERS

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Abstract:

Surface enhanced Raman scattering (SERS) is a technique which overcomes a low intensity of Raman scattering by adsorbing molecules on metal or semiconductor substrates. There are two different mechanisms in SERS, one is electromagnetic enhancement (EM) and the other is chemical enhancement (CE). By using the semiconductor as a substrate, we can study CE mechanism by excluding EM mechanism.
In previous non-metallic SERS studies, it was claimed that energy difference between molecular orbitals (HOMO or LUMO) and band edges of semiconductor is important. In our experiment, we used compound III-V semiconductor (ZnO and GaN) microstructure and 2-dimensional transition metal dichalcogenide (WS_2) nanoflower structure as substrates to study charge transfer (CT) transition. We adsorbed 3 different molecules (4-MBA,4-MPY,4-ATP) on ZnO and GaN substrates and R6G molecules on WS_2 substrates. Using these samples, we found charge transfer from semiconductor's valence band to molecule's LUMO is more dominant than the charge transfer from molecule's HOMO to semiconductor's conduction band. From these experimental results, we suggest that there is a preferential direction in CT mechanism.

Keywords:

SERS, Raman scattering, Chemical enhancement, Charge transfer mechanism

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.116

Synthesis and characterization of $Li_xTi_yO_{2-z}$/CNT as an active material for the negative electrode in secondary lithium-ion batteries

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Abstract:

Lithium-ion rechargeable batteries normally use graphite or carbonaceous materials as the negative electrode, but present severe safety risks of dendrite growth due to its low operating voltage; this may bring risks due to long-term stability and safety issues. To overcome this, this work describes a potential anode material for lithium-ion batteries (LIBs), namely, a lithium titanium oxide $Li_xTi_yO_{2-z}$/CNT, tested with three different compositions of (x, y) as an anode material for lithium secondary batteries. (LTO)-type compounds, as an anode material for lithium-ion battery, presents a very good cycle performance and the volume change of LTO during insertion and deinsertion of lithium-ion is very small, so the cyclability is very high but presents a very low conductivity which is one of the weak points of this type of materials. In this experiment, CNT was added to increase the low conductivity of LTO. The material was synthesized by a conventional solid-state reaction method calcined in two steps. The phase composition, micro-morphology and elemental composition analysis of the compound are characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS), respectively. Their electrochemical performances as anode material in lithium-ion batteries were investigated by galvanostatic cycling, and rate capability measurements.

Keywords:

Lithium secondary battery, LTO, Anode Material, CNT

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.202

Helical magnetic field-driven chiral self-assembly of magnetoplasmonic nanoparticles

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Abstract:

Helical magnetic field-driven self-assembly is introduced to build chiral superstructures. As a building units, magnetoplasmonic Ag@Fe_3O_4 core-shell nanoparticles (NPs) were used. The chirality of the assembled helical structures and optical activities were successfully modulated, and the handedness of the assembled structures has been dynamically switched depending on the chirality of external magnetic field. The helical magnetic field-induced chirality modulation can open a novel strategy that can control the polarization state of light so that it can be a significant breakthrough for chiral assembly of MagPlas nanomaterials to progress into further practical applications in optical devices such as next generation of meta-liquid crystal display.

Keywords:

helical magnetic field, magnetic self-assembly, plasmonic chirality, dynamic, tunable

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.203

Development of hydrogen gas filter using proton beam and application of microbial fuel cell

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Abstract:

Hydrogen fuel is being actively researched to solve the current environmental problems and replace fossil fuel energy. However, since hydrogen exists as a gas at normal temperature and atmospheric pressure, its energy density per volume is low, transportation and storage are difficult, and its stability is low. Therefore, research to obtain high concentration of pure hydrogen gas is still needed. In order to develop the hydrogen gas filter, the energy was investigated at 20 MeV between 10^{11} to 10^{14} protons/cm^2. Silicon wafer (100) and (111) specimens with different crystal structure characteristics. The SRIM simulation was performed to confirm that it penetrates the entire surface of the silicon wafer. It is assumed that there is a hole in the silicon wafer. To clarify the hydrogen gas filter characteristics, the relevant experiments were carried out for the silicon wafer irradiated with the proton beam. We identified that we could hydrogen gas with the device by PH experiments, TEM observations, etc. In order to verify the permeability of hydrogen gas through the hole, hydrogen gas formation was confirmed by using a silicon wafer irradiated with a proton beam instead of a NAFION membrane in a microbial fuel cell, and the applicability of the microbial cell was also verified. Through this study, we confirmed the possibility of manufacturing a very fast, cost-effective hydrogen gas filter using the proton beam.

Keywords:

proton beam, hydrogen, microbial fuel cell

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.204

Characteristics of a movable hybrid III-V/Si optical resonator

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Abstract:

We propose a movable hybrid III-V/Si optical resonator that consists of a tapered III-V nanoblock (NB) and a two-dimensional (2D) silicon (Si) photonic crystal (PhC) grooved waveguide. We numerically investigate key optical properties of the hybrid resonator using finite-difference time-domain (FDTD) method. First, we consider an III-V high-index semiconductor gain material (e.g., InGaAsP) with central emission wavelength of ~ 1550 nm to design a linearly tapered NB with total length of 3,000 nm, and thickness of 300 nm. Second, we exploit a 2D triangular Si PhC structure with a 100-nm-wide grooved line defect to host the NB on top and complete the hybrid resonator structure. The structural parameters of the Si PhCs are as follows; lattice constant is 370 nm, regular hole size is 100 nm, slab thickness is 250 nm. In simulation, we systematically controlled the cavity parameters (i.e., air hole size, lattice constant) and observed that the designed hybrid III-V/Si resonator supports various strong resonant modes. The resonant mode in the Figure revealed a high quality factor of ~ 2,000 and a small mode volume $V \sim 3.57(\lambda/n)^3$. We also investigated variations of optical properties of the resonant mode as the NB was translated along the grooved waveguide to show the possibility of movable optical resonator.

Keywords:

resonator, III-V, FDTD, photonic crystal waveguide, nanoblock

P1-ap.205

Colorimetric Strain Sensor by Magnetoplasmonic photonic crystal array on flexible substrate

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Abstract:

Wearable devices have become one of the biggest industry in recent years. Along with the rapid development of wearable/portable electronics, colloidal photonic crystals have drawn increasing interest because of their non-photobleaching structural color and high efficiency in energy consumption. Herein, we demonstrated a low-power, flexible mechanochromic sensor based on the magnetic/plasmonic colloidal photonic crystals on the PDMS substrate. It has the capabilities of sensing and visualizing its mechanical deformation simultaneously, by using physical force to regulating the inter-particle distance of the colloidal photonic structure. It exhibits dynamic color switching in the full visible to near-IR (from red to violet) range, fast optical response within the large working range. This mechanochromic sensor provides a display platform for convenient and immediate, long-lasting wearable devices with low power consumption.

Keywords:

Magnetoplasmonic film, stretching sensor, nanoparticle, photonic crystal

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.206

Hole transport mechanism of high ionization energy hole transport layer in inverted organic photovoltaics

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Abstract:

To increase the power conversion efficiency of organic photovoltaics (OPVs), efficient charge transport is required. For this, the charge transport level of the organic semiconductor and the Fermi level of the electrode should be aligned without formation of an energy barrier. In many cases of the anode side, the MoO_3 layer is used owing to its high work function. However, a recent study reported that the MoO_3 layer is not enough to make Ohmic contact and the additional organic layer with a high ionization energy (IE) should be inserted. However, despite several results of hole-only devices, the effect of these high IE HTLs on the device performance of OPVs have not reported yet.
In this study, we investigated the role of the high IE HTL in OPVs. First, we studied the hole transport mechanism in hole-only devices of poly(3-hexylthiophene-2,5-diyl) (P3HT) and poly(N-9′-heptadecanyl-2,7-carbazole-alt-5,5-(4′,7′-di-2,thienyl-2′,1′,3′-benzothiadiazole) (PCDTBT) with N,N′-di(1-naphthyl)-N,N′-diphenyl-(1,1′-biphenyl)-4,4′-diamine (NPB) and tetraphenyldibenzoperiflanthene (DBP) HTLs. NPB and DBP have the same IE, but different electron affinities. We fabricate inverted OPVs bulk heterojunction active layer with NPB and DBP HTLs. So, the charge transport and recombination mechanism at the interface could be different. By combining the electronic structures of these materials, we discussed the changes in the hole transport mechanism caused by HTLs.

Keywords:

organic photovoltaics, hole transport layer, Ohmic contact

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.207

The effect of PiG thickness for fabrication with sintering energy drop

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Abstract:

The commercial phosphor-converted white-LED (WLEDs) can be produced by the combination of blue LED chips and yellow $Y_3Al_5O_{12}:Ce^{3+}$ (YAG:Ce^{3+}) phosphor embedded with organic resins. However, as practical use of high power LED or LD has increased, organic encapsulants, which has poor thermal properties, cause some problems such as reduction of luminous efficacy (LE), the shift of chromaticity, and the degradation of long-term reliability. As an alternative, the phosphor-in-glass (PiG), that a certain amount of phosphor is dispersed in a glass matrix, is a promising color convertor due to excellent heat and humidity resistance.

In this study, we simply fabricated the PiG by using microwave irradiation method. Sintering energy drop is also investigated by adding powdered sodium silicate in the PiG fabrication. Depending on the sample thickness, optimization has processed by investigating microscopic observation, luminescent properties and thermal properties.

Keywords:

PiG, Microwave irradiation

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.208

In-plane hyperbolic dispersion of ZrN stripes

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Abstract:

Hyperbolic dispersion relation allows highly confined local photonic density of states and strong field confinement [1]. We study the dispersion properties and near-field profiles of emission properties of striped ZrN nanostructure and in-plane unidirectional light propagation. The ZrN nano lattice supports hyperbolic dispersion of perpendicularly-polarized light at several visible wavelengths formed by stripes, which allows highly variable and compact platform for metasurface-based photonic devices and circuits.

Keywords:

Metasurface, Hyperbolic dispersion

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.209

Micro-post위에 전사한 micro-disk laser

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Abstract:

높은 굴절률을 갖는 III-V 반도체 물질은 높은 광 구속력을 가지고 있어 광원, 광 공진기 등의 광소자로 제작되었을 때 많은 장점이 있다. 이러한 장점을 가지고 있는 물질로 microcavity를 만든다면 적은 공간에 효율적으로 광자를 구속할 수 있어 고직접 광회로의 광원으로서 매우 유리하다. 그 중 microdisk 공진기는 높은 Q-factor를 갖는 다양한 whispering galley modes (WGMs)를 갖는데, 주로 microdisk 공진기 외각에서 WGM 모드가 발현된다. 따라서 높은 굴절률 대비 광구속을 위해서는 microdisk의 중심부를 지지하여 공진기 외각부분이 기판으로부터 분리될 수 있는 post 구조가 필수적이다.

본 연구에서는 중심파장 1550 nm를 가지고 다중양자우물 구조를 포함하고 있는 InGaAsP wafer를 사용하여 microdisk를 만들었고, wafer 기판에서 post가 존재하는 구조에서 레이저가 발진됨을 관측하였다. 레이저 발진 관측 후 우리는 PDMS micro-tip transfer 방법으로 microdisk를 wafer기판에서 떼어내 silicon-on-insulator (SOI) wafer 위에 전사하였는데, post 구조가 없는 상황 하에서 레이저 발진을 관측하지 못하였다. 이에 우리는 추가적으로 silicon wafer를 식각하여 micro-post 구조를 제작한 후, post 구조 위에 같은 방법으로 전사하였으며, 전사한 microdisk에서 레이저가 발진됨을 관측하였다. 본 연구의 결과를 통해 III-V 반도체 물질을 silicon wafer 위의 광도파로 등의 광소자와 결합시켜 고직접 광회로를 하나의 칩 안에서 구현할 수 있기를 기대할 수 있다.

Keywords:

microdisk 공진기, III-V 반도체 물질, PDMS micro-tip transfer

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.210

Optical modulation spectroscopy study on additive-induced efficiency enhancement of organic photovoltaic devices

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Abstract:

Additives have been known to play an important role for improving the photovoltaic performance of organic solar cells. However, the reasons why additives improve the performance have not been clearly known yet. We employed an electrical modulated optical spectroscopy to investigate the relationship between the photovoltaic performance and additive concentration in organic photovoltaic devices. Our measured modulation spectra of a sample without additive showed both first- ($-\alpha'$) and second-derivative (α'') components of the modulated absorption spectrum. The second-derivative (α'') component in the modulation spectrum increased with the additive concentration. These results indicate that the sample without additive contains both localized (or Frenkel type) and relatively delocalized excitons and the added additive results in a significant increase of the relatively delocalized excitons. We conclude that the increased delocalized excitons lead to a significant additive-induced improvement of the photovoltaic-device performance and these relatively delocalized excitons will be related to charge transfer (CT) excitons.

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.211

Polarized Raman scattering study of methylammonium lead chloride single crystals

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Abstract:

Active research is being conducted on organic-inorganic hybrid perovskite, which is widely used as a solar cell absorber material. It has a high potential for development, because efficiency of perovskite solar cells is rapidly increasing compared with that of other material-based devices. We measured temperature dependence and polarization dependence of Raman response of methylammonium lead chloride ($CH_3NH_3PbCl_3$) single crystals where successive structural phase transitions occur from cubic to tetragonal structure at ~179 K and from tetragonal to orthorhombic structure at ~172 K. With Raman spectroscopy, we found abrupt changes of intensities and linewidths of certain phonon peaks at phase transition temperatures. We also observed anomalous polarization dependence especially in the low temperature orthorhombic phase that can be associated with orientations of methylammonium cations. We report that Raman scattering spectroscopy is highly effective in monitoring unusual structural behavior in perovskite materials.

Keywords:

Raman, perovskite, organic-inorganic hybrid perovskite, Raman spectroscopy, phase transition

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.212

분광계 특성에 따른 SD-OCT 시스템의 영상에서의 차이점

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Abstract:

파장 영역 광단층영상시스템 (SD-OCT, Spectral domain optical coherence tomography)은 측정하고자 하는 시료를 비파괴적인 방법으로 단층 영상을 습득할 수 있는 장점을 가지고 있는 광학 시스템으로써 광대역 광원, 광간섭계, 간섭 신호를 측정하는 분광계로 구성된다. SD-OCT에서 광대역 광원과 분광계는 중요한 핵심요소이며 이 두 광학적 특성에 따라 영상의 깊이 방향 분해능과 영상 구현 가능한 깊이가 결정된다. 이 중 영상 구현 깊이를 결정하는 분광계의 경우 렌즈, 회절격자 그리고 선형카메라로 구성되어 있으며 이러한 광학 부품들의 특성과 설계 조건에 따라 분광계의 성능에 차이를 가지게 된다. 분광계에서 사용하는 이미징 렌즈의 파면 수차에 의해 광이 왜곡되어 선형 카메라에 도달하게 되고 이는 분광계 성능을 저하시키는 문제점을 발생시키게 된다. 본 논문에서는 이러한 문제점을 해결하기 위해 분광기 내부의 이미징 렌즈의 최적 설계를 통해 파면 수차 특성을 개선하여 SD-OCT 시스템의 영상 구현 깊이를 향상시키고자 한다. SD-OCT 시스템의 간섭계는 중심파장이 830 nm 광섬유 소자로 구성하였고 시스템의 영상 깊이 비교를 위해 두 타입의 분광계를 설계하여 제작하였다. 첫 번째 타입의 경우 일반적으로 사용되는 이중 몰색 수차 렌즈를 사용하였고 두 번째 타입의 경우 최적 설계를 통하여 설계된 f-theta 렌즈 사용하여 제작하였다. SD-OCT 영상 깊이의 척도가 되는 Roll-off를 서로 다른 픽셀수를 가지는 분광계에 대해서 측정함으로써 픽셀 수에 따른 분광계의 특성을 분석하고자 한다. 또한 보다 정밀한 분석을 위해 두 타입의 분광계를 이용하여 동일한 시료를 측정하여 영상에서의 특성을 분석하고자 한다.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (grand no. NRF–2019R1A6A3A01095557 & no.NRF-2017R1A2B2009732)

Keywords:

OCT, roll off, spectrometer

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.213

광학적 위상 안정화 기법 기반 디지털 홀로그래피 현미경 시스템

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Abstract:

디지털 홀로그래피 현미경 기법 (DHM, Digital Holographic Microscopy)은 홀로그래픽 기법을 현미경에 적용한 방법으로 전통적인 사진 건판을 이용하는 대신 디지털화된 전기신호를 측정하여 기록한다. DHM은 기계적인 스캐닝의 과정이 없이도 3차원 단차 정보를 얻는데 유용하게 사용되고 있다. DHM 시스템은 간섭계를 기반으로 구성되어 있어 사용하는 광원의 파장보다 짧은 광경로에 해당하는 위상변화에 민감하게 반응하는 특성을 가지고 있고 이를 이용하여 3차원 표면 형상 정보를 얻을 수 있다. 하지만 간섭계는 주위 환경의 변화에 민감하게 반응하는 문제점을 가지고 있다. 위상을 측정하여 분석하는 DHM의 경우에 있어서는 측정 과정동안 위상의 안정화가 보장되어야 측정결과에 대한 신뢰성을 확보할 수 있다. 그러한 점에서 DHM 시스템의 위상 안정화에 대한 다양한 방법들이 제안되었다. 가장 보편적으로 이용되는 방법은 기준단 거울에 미세 거리 조정이 가능한 소자를 부착시켜서 간섭계의 기준단의 광경로를 동적으로 제어하는 방법이다. 위상 차이를 180도 유도하여 위상 제어를 하는 방법도 제안되었다. 또 다른 접근방법으로 디더링(dithering)을 이용하여 위상을 제어하는 방법도 제안되었다.
본 논문에서는 광섬유 간섭계에 펌프광을 입사시켜 위상 안정화를 획득한 결과를 제시하고자 한다. 간섭계에서 발생하는 위상의 불안정성을 펌프광과 이터븀 도핑된 광섬유를 이용하여 제어함으로써 나노미터 수준으로 위상 안정화가 가능함을 보이고자 한다. 제안 방법은 광섬유 내부에서 발생하는 펌프광에 의한 미세 굴절률 변화를 기반으로 한다. 광섬유 광학계로 구현된 간섭계를 마하젠더 형태로 구현하고 간섭계 양팔에 이터듐이 도핑된 특수 광섬유를 삽입한다. 이 특수 광섬유에 펌프광 광세기를 조절하면서 이에 따라 발생하는 위상 변화를 측정하고 시간별로 위상 변화를 기록함으로써 위상 안정화 정도를 분석하고자 한다. 펌프광의 제어에 따라서 위상 변화의 정도가 줄어들게 되고 나노미터 수준가지 안정화되어 되도록 함으로써 이 기법이 적용된 DHM 시스템의 위상 정보에서의 정확도를 크게 향상 시킬 수 있을 것으로 예상하는 바이다.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (grand no. NRF–2019R1A6A3A01095546 & no. NRF-2017R1A2B2009732)

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.214

Highly Tunable Molecular Rectifier Realized by Interfacial Design in Molecular Heterojunction with Two-Dimensional Materials

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Abstract:

Until now, a specifically designed functional molecular species has been recognized as an absolute necessity for realizing the diode's behavior in molecular electronic junctions.[1-4] However, even non-functional molecules can be served for the implementation of molecular diode with employing appropriate energy band alignment in heterostructure molecular junctions. Here, we suggest a facile approach for the implementation of a tailored diode in a molecular junction based on non-functionalized alkyl and conjugated molecular monolayers. A two-dimensional (2D) semiconductor (MoS_2 and WSe_2) was used as a rectifying designer at the alkyl or conjugated molecule/Au interface. From the adjustment of band alignment at molecules/2D semiconductor interface that can activate different transport pathways depending on the voltage polarity, the rectifying characteristics can be implemented and controlled. The rectification ratio could be widely tuned from 1.24 to 1.83×10^4 by changing the molecular species and type and the number of layers of the 2D semiconductors in the heterostructure molecular junction. Our work sets a design rule for implementing tailored-diode function in a molecular heterojunction structure with non-functionalized molecular systems.

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Keywords:

Molecular Electronics, 2D Semiconductors, Molecular Heterojunctions

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-ap.215

One-dimensional organic artificial synapse based on the ferroelectric organic transistor for wearable neuromorphic applications

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Abstract:

A wearable neuromorphic electronic system, that can learn and interpret the non-structural biometric information at extremely low-power, has been brought great attention because of its applicability as the intelligent device that can easily attach onto the human body or any rough surface [1-3]. With this reason, organic-based artificial synaptic devices have been proposed as a potential candidate for wearable neuromorphic applications due to its inherent mechanical flexibility and the material (or device form) variability for the desired functionalities [2,3]. In this study, we designed 1D fiber-shaped multi-synapses comprising ferroelectric organic transistors fabricated on a 100 um Ag wire and utilized them as multi-synaptic channels in an e-textile neural network for wearable neuromorphic applications. The device mimics diverse synaptic functions, including short- and long-term plasticity with 80 states and spike rate- and timing-dependent plasticity. It exhibited excellent reliability even under 6,000 repeated input stimuli and mechanical bending stress. Various NOR-type textile arrays are formed simply by cross-pointing 1D synapses with Ag wires, where each output from individual synapse can be integrated and propagated without undesired leakage. Notably, the 1D multi-synapses achieved up to ~90% and ~70% recognition accuracy for MNIST and electrocardiogram patterns, respectively, even in a single-layer neural network, and almost maintained regardless the bending conditions.

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Keywords:

artificial synapse, ferroelectric organic transistor, neuromorphic, wearable

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.101

Analysis of magnetic hysteresis loss in Z-stacked GdBCO coated conductor strips

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Abstract:

To reducing hysteresis loss of 2G HTS coated conductor, we investigated the magnetic properties of striated HTS C.C in the previous study. Multi-filamentary HTS C.C has less hysteresis loss than single structure in same effective width. And stacking HTS C.C affect its magnetic properties. Thus the investigation of magnetic properties in stacked multi-filamentary HTS C.C is needed. In this study, we patterned GdBCO coated conductors to decoupled double strip structure. We stacked the samples which have same geometry in Z-axis with regular gap. We measured the magnetic properties of the stacked samples using MPMS. We calculated hysteresis losses from the measurement results and compared the stacked samples with the single-layer sample. And we investigated hysteresis losses with various gaps.

Keywords:

Superconductivity, GdBCO, Hysteresis loss, Stacked coated conductor

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.102

$La_{1.85}Sr_{0.15}CuO_4$ thin film growth and in-situ angle resolved photoemission spectroscopy

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Abstract:

Cuprate thin films are showing novel physical properties that are different from bulk, such as strain effects from substrate or proximity effects of heterostructure. And their electronic structures can be directly probed by Angle-resolved photoemission spectroscopy(ARPES). Since ARPES is highly surface sensitive, it requires a flat and clean surface of sample and UHV transfer process to carry out thin film ARPES.
We have grown $La_{1.85}Sr_{0.15}CuO_4$(LSCO) thin film with 15~40 Unit cell(UC) thickness by pulsed laser deposition(PLD). The thickness of the film was monitored with *in-situ* reflection high energy electron diffraction(RHEED), and the film was characterized with X-ray diffraction(XRD), atomic force microscopy(AFM) and physical property measurement system(PPMS). Also with our UHV transfer system connected with PLD and ARPES chamber, we performed *in-situ* ARPES and obtained EDC curve data of the LSCO thin film.

Keywords:

La1.85Sr0.15CuO4(LSCO), PLD, Cuprate thin film, In-situ ARPES

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.103

Analysis of local superconducting properties in GdBCO coated conductor with various narrow paths

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Abstract:

It is necessary to reduce the AC loss caused by the external magnetic field or the applied AC current for commercializing the high-temperature superconductors. In this study, we analyzed local superconducting properties of narrow paths that are fabricated in GdBCO coated conductors. We measured the local magnetization and the local critical temperature distribution of specimens by using the Low-Temperature Scanning Laser and Hall Probe Microscopy. Specimens were patterned as single rectangle bridges which have different widths of narrow paths by photolithography procedure. We studied the local superconducting properties of each specimen at the same reduced temperature.
For comparative we measured the global magnetization by using the Magnetic Property Measurement System (MPMS XL 7), it was confirmed that the magnitude of magnetic hysteresis loss changes according to the width of narrow paths in the ring. We focused on the local superconducting properties for investigating the changing of influence of the various width of narrow paths.

Keywords:

SHPM, MPMS, SLM, GdBCO coated conductor, Narrow path

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.104

Construction of Radio Frequency mK-Scanning Tunneling Microscope

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Abstract:

STM combined with electron spin resonance (ESR) technique enables a direct access to the quantum states of single magnetic atom or molecule on surfaces. We constructed an ESR-STM, which can operate below 10 mK by a dilution refrigerator (Janis Research). We designed the STM head to be able to use microwave for ESR not only as the tip signal but as the sample signal.

We measured the superconducting energy gap on the superconducting Nb substrate at ~few mK temperature. When RF voltage is applied to the tip, transmission function in the tip and sample junction is obtained over a frequency range of 5.5-30.5 GHz. To the sample, RF antenna is capacitively coupled with the sample bias cable. We discovered an indirect way to measure transfer function using the conductance spectrum change according to frequency.

Keywords:

Scanning Tunneling Microscopy, STM, Electron Spin Resonance technique, ESR, ESR-STM

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.105

Developing ultra-sensitive microwave detector with graphene-based Josephson junction

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Abstract:

Sensitive detectors for microwave are necessary in a wide range of fields from observational astronomy and dark matter axion searches to quantum information science. One way of detecting microwave signal is to operate a bolometer that quantifies the microwave power (equivalently, the number of incident microwave photons per unit time) from the temperature rise due to microwave absorption. However, detecting microwave photons are inherently difficult because of their small energy of order of ueV. Our strategy to use graphene-based Josephson junction (gJj) to detect minute photon energy. First, graphene has ultra-low electronic heat capacity due to its peculiar band structure so that temperature rise would be significant even for small energy of microwave photons. Second, the electron gas of graphene has a weak coupling to thermal baths. Third, electrons in graphene thermalizes rapidly in a few pico-seconds at low temperature. These properties are desirable for use as a sensitive bolometer. Here, we demonstrated a niobium nitride (NbN) gJj bolometer embedded in a superconducting resonator of resonant frequency 7.9 GHz with over 99% coupling efficiency. Microwave injected through the input resonator heats up the electron temperature, and consequently breaks the Josephson coupling. From the temperature dependence of the Josephson critical current (I_c), the device achieves a noise equivalent power (NEP) of 7 fW/Hz$^{1/2}$ that is close to the thermodynamic fundamental limit. To obtain lower NEP, we need more sensitive temperature (T) dependence of Josephson coupling. Here, we show that aluminum(Al)-based gJj has a more sensitive temperature dependence of Josephson coupling (|dIc/dT|~2.5 uA/K around T=500 mK), which is about five times better than that of Nb-gJj (|dIc/dT|~0.5 uA/K around T=500 mK).

Keywords:

Bolometer, Graphene, Microwave, Josephson junction

stability of skyrmion vortices in a chiral p-wave superconductor

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Abstract:

We investigate stability of skyrmion vortices in a chiral p-wave superconductor. Theoretically, skyrmion vortices could exist in a chiral p-wave superconductor. Unlike a conventional vortex in an s-wave superconductor, the skyrmion vortex has two flux quanta and no-singularity at its core. By varying phenomenological parameters in the Ginzburg-Landau theory, we study in what parameter range the skyrmion vortex is more stable than the conventional vortex.

Keywords:

chiral p-wave superconductor, skyrmion vortex

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.108

Evidence of Higher Order Topology in WTe_2 from Josephson Coupling through Anisotropic Hinge States

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Abstract:

The noncentrosymmetric Td-WTe_2, previously known as a Type-II Weyl semimetal, is expected to have higher order topological phases with topologically protected, helical one-dimensional (1D) hinge states when their scarcely separated Weyl points get annihilated. However, the detection of these hinge states is difficult in the presence of the semimetallic behaviour of the bulk. Here, we spatially resolved the hinge states by analysing the magnetic field interference of supercurrent in Nb-WTe_2-Nb proximity Josephson junctions. The Josephson current along the *a*-axis of the WTe_2 crystal, but not along the *b*-axis, showed sharp enhancements at the edges of the junction; the amount of enhanced Josephson current was comparable to the upper limits of a single 1D conduction channel. Furthermore, the Josephson effect under microwave radiation, shows voltage doubling of Shapiro steps when Josephson current flows along the *a*-axis of WTe_2 crystal, which implies 4π periodicity of current phase relationship. Our experimental observations provide evidence of the higher order topological phase in WTe_2 and its corresponding anisotropic topological hinge states, in good agreement with theoretical calculations.

Keywords:

Superconductivity, Josephson junction, Topological semimetal,

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P1-co.109

3차원 초전도 마이크로파 공진기의 온도 의존성

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Abstract:

최근 양자 정보 분야에서 초전도 큐비트를 이용한 연구가 많은 진보를 이루었다. 여기에는 상업적으로 발달한 마이크로파 기술의 기여도가 크다고 하겠다. 3차원 마이크로파 공진기(microwave cavity)를 사용하면 초전도 큐비트를 외부와 고립 시켜 결맞음(coherence)을 오랜 시간 유지하면서도 효과적으로 조작할 수 있음이 잘 알려져 있다. 두 개 이상의 양자 시스템을 결합하는 복합시스템(hybrid system) 뿐만 아니라 양자 상태 보존을 요구하는 양자 원격 탐지 시스템 연구에도 3차원 마이크로파 공진기를 적용하고자 한다. 이러한 마이크로파 공진기도 초전도 물질로 제작하였을 때 손실(dissipation)이 적어지며 좋은 특성을 보이게 되는데, 효과적인 설계를 위해서는 초전도 물질과 마이크로파 사이의 상호작용을 이해하는 것이 필수라 하겠다. 이에 알루미늄으로 제작된 마이크로파 공진기의 특성을 온도에 따라 측정하였다. 초전도 임계온도(Tc~1.2 K)에서 공진기의 큐(quality factor) 값이 크게 증가하는 것을 확인할 수 있었다. 또한, 임계온도 이하에서도 공진주파수와 큐값이 온도 의존성을 보이는 것을 관찰하였다. 이 결과는 초전도 상태에서도 공진기의 특성이 초전도 쿠퍼 쌍 밀도(Cooper pair density)에 영향을 받음을 의미한다. 초전도 쿠퍼 쌍과 마이크로파 전자기장 사이의 미시적 상호작용에 대한 깊이 있는 연구가 필요하다 할 수 있다.

Keywords:

초전도 공진기

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P1-co.110

Effect of thermal annealing on magnetic properties of $SrFe_{12}O_{19}$ ceramics

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Abstract:

M-type hexaferrites are well-known for their commercial use in small motors and actuators due to their magnetism at high temperature. However, the performance of its use is limited by their low magnetic moments. Intrinsically, hexaferrites has ferrimagnetism as their magnetic ground state. Thus, perturbing indirect exchange interactions is an important way to enhance its magnetism.
In this work, $SrFe_{12}O_{19}$ is used for our model material. Sample were prepared using solid state reactions in air. We mixed powder $SrCO_3$ and Fe_2O_3. After thorough mixing, the powder was calcined at 1300^{o}C for 6 hours. To see the effect of thermal annealing. The sample was sintered at various temperatures and times: 1200, 1300, 1400 ℃ for 6, 12 ,20 hours. Using X-ray diffraction and vibrating sample magnetometer, we found that structure and magnetic properties changed according to the sintering conditions. When samples were sintered at 1200℃ and 1300℃, structure and magnetic properties were retained. When samples were sintered at 1400℃ we observed about 44% decrease of Magnetic saturation(Ms). When samples were sintered twice at 1300℃ we observed about 30% decrease of Ms. We found three additional peaks on the XRD pattern as the sintering conditions changed. This means a new phase formed by longer sintering and/or higher sintering-temperature. This indicates sintering condition is also a key parameter to control magnetic moments

Keywords:

M-type hexaferrites, magnetism

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P1-co.111

Spin flop induced Anisotropic Magnetoresistance in Antiferromagnetic $Ca_{0.9}Sr_{0.1}Co_2As_2$

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Abstract:

Antiferromagnetic (AFM) spintronics is an emerging field that aims to achieve spintronic functionality by taking advantages of AFM materials such as no stray fields, insensitivity to disturbing magnetic fields, and intrinsically-fast AFM dynamics. The main issue to generate functional spin transport based on antiferromagnets is to manipulate and detect an AFM state.
In this study, antiferromagnet-based spintronic functionality is demonstrated by using highly anisotropic spin states driven by spin-flop transition in $Ca_{0.9}Sr_{0.1}Co_2As_2$ (CSCA). The CSCA reveals the A-type AFM order below T_N = 94 K, in which the Co spins of Co_2As_2 layers are aligned alternatingly along the *c* axis. A magnetic field along the *c* axis induces the spin-flop transition which generates a low resistance state. By rotating the magnetic field, the high resistance state is recovered by the inverse spin-flop transition, which leads to the angle-sensitive anisotropic magnetoresistance. This new mechanism provides a beneficial foundation for fundamental and applied research on AFM spintronics.

Keywords:

Antiferromagnet, Spintronics, Spin-flop

2020 KPS Spring Meeting
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P1-co.112

Effect of Thermal Annealing on Physical Properties of Epitaxial $SrFe_{12}O_{19}$ thin films

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Abstract:

M-type hexaferrites have been developed as sources for low-cost permanent magnet applications. However, their low saturation magnetization due to ferrimagnetic ground state have hampered the broad use of these materials. There is a need to increase magnetic moments. In addition, recently they have gotten interests on their electronic ground states. The insulating state could be originated from either ferroelectricity or quantum paraelectricity, where no electric polarization is observed down to low temperature. Still, there is a continuing controversy on the electronic ground state. To tackle these two issues, we attempted to epitaxial stabilization of M-type $SrFe_{12}O_{19}$ (SrM) on (111) $SrTiO_3$ using pulsed laser deposition. As-synthesized SrM is epitaxial, however its low crystallinity was observed from x-ray scattering experiments. In order to improve the crystallinity of the epitaxial SrM thin film, we performed post-heat treatment at various temperatures, and indeed simple heat treatment enhances magnetic properties (20% increase of saturation magnetization and 95% decrease of coercivity) and crystallinity (70% decrease of full width half maximum value in rocking curve results). For details of magnetism in our thin films, element-specific x-ray magnetic circular dichroism, and SQUID magnetometer were used. Our epitaxial synthesis will be beneficial to study electronic and magnetic ground states of SrM.
Thin film synthesis and structural characterization of this research was conducted at the Center for Nanophase Materials Sciences, which is a DOE Office of Science User Facility.

Keywords:

Iron oxide, Multiferroic material, Thin film growth, Epitaxy

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P1-co.114

Possible magnon excitation of pyrochlore iridate system in Raman study

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Abstract:

We report the magnetic excitation in 5*d* pyrochlore iridates $R_2Ir_2O_7$(R: Y, Eu, Sm) using Raman spectroscopy and first-principles calculations. The sizable spin-orbit interaction and electron correlation in $R_2Ir_2O_7$ trigger the all–in–all–out antiferromagnetic ordering at the Néel temperature $T_N \approx 170$ K. We observe that some excitation peak below T_N that could not be assigned by the phonon mode from DFT calculations. We reveal that these unknown peaks are closely related to the magnetism. Through our analyses based on linear spin-wave theory calculations, we found the relation between the single magnon excitation peaks and the spin Hamiltonian parameter of $R_2Ir_2O_7$.

Keywords:

Pyrochlore iridate, Raman spectroscopy

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P1-co.115

Probing magnetic excitations in $(Ni_{1-x}Fe_x)PS_3$ (x=0, 0.3, 0.6, and 0.81)

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Abstract:

Recently, magnetic van der Waals (vdW) materials have garnered considerable attention as they offer an excellent platform to explore novel two-dimensional (2D) magnetism and hold promise to future applications in spintronic devices. Layered transition-metal phosphorous trichalcogenides MPS_3 (M=Mn, Fe, Co, and Ni) are the recent addition to a class of 2D vdW antiferromagnets, which harbor Ising, XY, and Heisenberg models, depending on M.
Here, we present a magnetic Raman scattering study of $(Ni_{1-x}Fe_x)PS_3$ (x=0, 0.3, 0.6, and 0.81) in order to clarify exchange-frustration effects on magnetic excitations. In the pristine $NiPS_3$, we observe pronounced two-magnon scattering centered around 550 cm^{-1} and Fano-antiresonance, being consistent with the reported data [1]. In addition, we identify one-magnon excitations at about 20 and 30 cm-1. With increasing x, the spectral weight of the two-magnon scattering is systematically suppressed in its high-energy side, and the one-magnon excitations disappear. These results suggest a strong alteration of exchange interaction through the Fe-for-Ni substitutions without fully depressing long-range magnetic order.

References
[1] K. Kim *et al.*, Nat. Commun. **10**, 345 (2019).

Keywords:

Magnetic van der Waals, Magnetic excitations, Raman spectroscopy

2020 KPS Spring Meeting
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P1-co.116

Quantum spin liquid state in the Co-based triangular antiferromagnet $Na_2BaCo(PO_4)_2$

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Abstract:

We present a comprehensive study of the triangular quantum spin liquid (QSL) candidate $Na_2BaCo(PO_4)_2$ using muon spin relaxation/rotation (μSR) and nuclear magnetic resonance (NMR). The ^{23}Na NMR results reveal the absence of long-range order (LRO) down 2 K and the development of weakly correlated spins. We observe a crossover from the quantum paramagnetic state to the field-induced gapped state through H_c = 2 T below 10 K, indicating a field-induced quantum phase transition. The μSR measurements show no LRO down to 80 mK from the lack of muon spin oscillating signals. The ZF-μSR results exhibit persistent spin dynamics of the muon spin relaxation rate, intimating the QSL ground state. Furthermore, the LF-μSR experiments unveil the intriguing spin-spin correlation between Co^{2+} (j_{eff} = 1/2) spins, $S(t) = (\tau/t)^{0.54}\exp(-\nu t)$. Such a spin correlation has been reported in a range of QSL candidates. Our local probe investigations demonstrate the newly discovered triangular antiferromagnet $Na_2BaCo(PO_4)_2$ hosts QSL as a ground state.

Keywords:

Triangular lattice, Quantum spin liquid, Nuclear magnetic resonance, muon spin resonance

An ultra-high vacuum electron spin resonance spectrometer for the investigation of magnetic atoms and molecules on surfaces

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Abstract:

Magnetic atoms and molecules on surfaces are model systems to control and manipulate quantum coherence properties at the smallest scale of matter [1, 2]. Their performance as qubits can be investigated by means of electron spin resonance (ESR) spectroscopy. However, a single layer of diluted spin centers deposited on a suitable surface has 10^{12}-10^{13} spins/cm^2, which is difficult to measure with a conventional ESR spectrometer optimized for bulk materials. In addition, the presence of contaminations at the surface can alter the properties of the spins. Because of the high sensitivity and surface purity required for measuring 2D spin systems, the study of magnetic and coherence properties of surface-adsorbed spins remains challenging.

Here, we propose a novel ultra-high vacuum (UHV) ESR spectrometer designed to measure thin films in a wide range of temperature (2.5 – 300 K) and magnetic field (0 - 3.2 T).

The spectrometer operates at X-band and integrates an UHV sample preparation chamber, allowing growth of thin films via sublimation and *in-situ* transfer of the film samples to the measurement stage to prevent surface contamination. Moreover, we choose a coplanar waveguide (CPW) resonator design for maximum surface sensitivity. Two types of CPW resonators were tested, where the resonator is machined out of 1) commonly used printed circuit board (PCB) and 2) sapphire. Although PCB is easier to handle and fabricate, sapphire has better thermal conductivity at low temperature, lower outgassing rate and higher dielectric constant. The performance of our spectrometer for cryogenic UHV-ESR experiments promises the required surface and spin sensitivity to perform continuous wave (CW) / pulsed ESR measurement on single layers of diluted surface-adsorbed spin centers.

1. F. Donati et al., Science, 2016.
2. K. Yang et al., Science, 2019.

Keywords:

Electron spin resonance, Quantum coherence, Spin magnetism, Molecular spin qubit

P1-co.120

Modeling and Analysis of EM pump as Assistant Tool for the Circulation of LBE in the SMFBR

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Abstract:

SMFBR (Small Modular Fast Breeder Reactor) which is one type of GEN-IV nuclear power plants has advantages such as proliferation resistant, environmental friendly, and accident tolerant technology while large scale nuclear power plants are unstable for technical, economic, and safety limitations. As enhanced safety system, passive cooling to both normal and abnormal operations by natural circulation of coolant is applied to Micro URANUS (Ubiquitous, Rugged, Accident-forgiving, Nonproliferating, and Ultra-lasting Sustainer) which is based on SMFBR. Although natural circulation of coolant is good for safety, cooling performance cannot be enough to be required in URANUS. As one of solutions in the situation, forced cooling using EM (Electro Magnetic) pump as well as natural circulation can be considered.
Because EM pump is developed by Lorentz' force generated from driving current and magnetic field perpendicular to it, it has no internal structure like impellor for pumping. So, in the design of Micro URANUS, the EM pump is attached to lower part of riser, generating developed pressure in annular down comer to downward direction. The characteristics of the EM pump attached to Micro URANUS is predicted from the numerical analysis subject to the MHD (Magneto Hydro Dynamic) conditions such as magnetic field and current density distribution by using ANSYS Maxwell. From the results, developed pressure which is generated by EM pump is 15,381 Pa while developed pressure which is generated by natural circulation is 7,500 Pa.

Keywords:

Electromagnetic pump, SMLFR

2020 KPS Spring Meeting
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P1-co.201

Temperature dependent resistivity behavior of $SrIrO_3$ Films grown at different growth condition

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Abstract:

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It has been found that the characteristics of the temperature dependent resistivity exhibits various states such as “insulater-like”, “metal-like”, and “intermediate” according to the subtle changes in the $SrIrO_3$ grid structure.(Lee et al. 2020) Herein, we examine the condition of the growth condition that causes the change in resistivity behavior on temperature for the $SrIrO_3$ film. We grow various kind of $SrIrO_3$ thin films by changing the laser fluence and growth temperature using PLD (Pulsed Laser Deposition) method and measured the temperature dependence of the resistivity for the samples with a different thickness. With increasing the laser fluence, the resistivity behavior of the $SrIrO_3$ film changed from “metal-like” to “insulator-like”. And with increasing the growth temperature, it also changed from “metal-like” to “insulator-like”. In addition, changes in the lattice parameter were confirmed by measuring X-ray scattering. From these observations, we can conclude that the crystal structure and electrical-transport properties of $SrIrO_3$ film are strongly correlated.

Keywords:

Thin Film, PLD, SrIrO3

Determination of Ti K-edge absorption spectrum in an ultrathin BaTiO3 film on a SrTiO3 substrate using resonant x-ray reflectivity.

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Abstract:

원자층 단위로 조절 하여 쌓을 수 있는 산화물 박막은 매우 다양하고 발전된 형태의 특성을 보이고 있다. 이러한 박막을 연구 하는데에 있어서 많은 관심을 받는 주제가 바로 강유전체 축전기 인데, 최근 SrRuO3/BaTiO3/SrRuO3(SRO/BTO/SRO) 구조를 가지고 있는 강 유천체 축전기에 대해 원자 적으로 매우 깨끗한 SRO/BTO interface를 만든 후 piezoelectric force microscopy를 측정 하였고[1], 결과적으로 BTO의 강 유전성이 3.5u.c 이하 에서 사라 진다는 것이 알려졌다. 하지만 강 유전성이 사라 지는 것 과는 별개로, 이러한 현상에 대한 정확한 이해도는 아직 낮은 편이며, 이러한 강 유전성의 물리적 상태를 연구 하기 위해서는 BTO의 Ti K - edge 에서의 흡수 스펙트럼을 알아야 할 필요가 있다. 대부분의 산화물 박막의 경우 SrTiO3 기판 위에 키워지기 때문에 BTO의 Ti의 spectrum을 분리 해 내기 어렵고, 이러한 점을 극복 하기 위해 표면에 매우 민감한 X선 공명 산란 방법과 컴퓨터 분석을 이용 할필요가 있었으며, 결과적으로 STO 기판과 BTO의 흡수 스펙트럼을 분리 해 낼 수 있었다 . BTO 흡수 스펙트럼에서 뚜렷하게 보이는 pre-edge peak는 BTO가 산소로 이루어진 octahedra의 가운데가 아니라 중심에서 벗어난 부분에 존재 함을 보여 주며, 이는 강유전체 상태임을 의미 한다. 추후에 2.5u.c 에 대해서도 실험을 수행 하여 강 유전성이 사라지는 원인에 대해 정확히 규명 해야 할 것 이다.

[1] Y J Shin, et al, Adv. Mater, 2017, 29, 1602795.

Keywords:

ferroelectric critical thickness, resonant x-ray scattering, metal oxide hetero structure, x-ray spectroscopy

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P1-co.205

Growth and ARPES measurement of monolayer VS2 thin film

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Abstract:

Monolayer VS_2 (ML-VS_2) has recently attracted attention about its peculiar charge ordering property and magnetic ground states in the two-dimensional limit. However, their origins and reproducibility are unsettled and there are difficulties for making ML-VS_2. We used molecular beam epitaxy for growth of ML-VS_2 on graphene/SiC (001) substrate in ultra high vaccum. Here, we present electronic properties of ML-VS_2 films by using systematic angle-resolved photoemission spectroscopy (ARPES) measurements.

Keywords:

VS2, ARPES, Electronic structure

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P1-co.206

Synthesis and characterization of ferroelectric properties in Aurivillius Bi_2WO_6 thin films grown by a pulsed laser deposition

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Abstract:

Aurivillius family is known to show robust ferroelectric properties like high Curie temperature and strong spontaneous polarization. Bi_2WO_6 (BWO) is the simplest member of the Aurivillius family (Curie temperature is 950^{o}C, spontaneous polarization about 50 μC/cm^2)[1]. The most interesting property of BWO is that its ferroelectric domains are aligned along purely the in-plane (IP) direction, showing no out of plane directions. Also, ferroelectric domains of BWO can be switched with low energy costs than other ferroelectric materials. This property is essential for realizing electric device applications with low energy demand [2]. Although BWO has these advantages, a systematic study focusing on the growth condition optimization, and proving the origin of ferroelectricity and atomic-scale domain structure of BWO thin films is still missing.
Here, using the pulsed laser deposition (PLD) technique, we have grown epitaxial BWO thin films on (001)-oriented $SrTiO_3$ substrates and $SrRuO_3$ buffer layer. The structural quality analysis is done by the X-ray diffraction, atomic force microscopy. Atomic-scale displacement and structure are measured by scanning transmission electron microscopy (STEM) to observe the origin of ferroelectricity and domain structure. We also characterize ferroelectric properties using piezoresponse force microscopy techniques. In this research, we will present the growth phase diagram which shows the relation between crystalline quality growth conditions and STEM image of atomic structure and displacement.

Keywords:

Ferroelectricity, Bi2WO6, STEM, PFM

2020 KPS Spring Meeting
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P1-co.207

Stabilizing hidden room-temperature ferroelectricity via a metastable atomic distortion pattern

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Abstract:

Nonequilibrium atomic structures can host exotic and technologically relevant properties in otherwise conventional materials. Oxygen octahedral rotation (OOR) forms a fundamental atomic distortion in perovskite oxides, but only a few OOR patterns are predominantly present at equilibrium. This has restricted the range of possible properties and functions of perovskite oxides, necessitating the utilization of nonequilibrium OOR patterns. Here, we report that a designed metastable OOR pattern leads to robust room-temperature ferroelectricity in $CaTiO_3$, which is otherwise nonpolar down to 0 K. Guided by density functional theory, we selectively stabilize the metastable OOR pattern, distinct from the equilibrium pattern and exceptionally cooperative with ferroelectricity, in heteroepitaxial films of $CaTiO_3$. Atomic-scale imaging combined with deep neural network analysis confirms a close correlation between the metastable OOR pattern and ferroelectricity. This work reveals a hidden but functional OOR pattern and opens new avenues for designing novel multifunctional materials.

Keywords:

ferroelectricity, oxide heterostructure

2020 KPS Spring Meeting
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P1-co.208

A study of NMR in CsH_2PO_4 at high temperatures

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Abstract:

This study investigated hydrogen-bonded CsH_2PO_4 (CDP) solid acid using ^1H and ^{31}P high-resolution nuclear magnetic resonance (NMR). Below the superprotonic phase transition temperature, the temperature dependence of the ^1H NMR spectra was observed with two different hydrogen-bonded networks in the CDP structure. The systematic evolution of the lineshape with temperature dependence indicates hydrogen hopping in the chemical structure of hydrogen-bonded networks in a solid acid lattice. The proton conduction under two types of hydrogen-bonds—interchain and intrachain—in CsH_2PO_4 in the chemical environments of PO_4 tetrahedra is discussed.

Keywords:

Hydrogen-Bonded Networks, CsH2PO4, Magic-Angle-Spinning NMR, Fuel Cell, Electrolyte, High tempeature

P1-co.209

Experimental Realization of Strain-induced Ferroelectricity in $SrMnO_3$ Films via Selective Oxygen Annealing

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Abstract:

Antiferromagnetic-paraelectric $SrMnO_3$ (SMO) has aroused interest because of the theoretical strong coupling between the ferroelectric and ferromagnetic states with increasing epitaxial strain [1]. In strained SMO films, the <110> polarized state and polar distortions have been observed, although high leakage currents and air degradation have limited their experimental verification [2], [3]. We herein provide a conclusive demonstration of room-temperature ferroelectricity and a high dielectric constant (ε_r = 138.1) in tensile-strained SMO by securing samples with insulating properties and clean surfaces using selective oxygen annealing. Furthermore, a paraelectricity and low dielectric constant (ε_r = 6.7) in the strain-relaxed SMO film were identified as properties of the bulk SMO, which directly proves that the ferroelectricity of the tensile-strained SMO film is due to strain-induced polarization. We believe that these findings will not only provide a cornerstone for exploring the physical properties of multiferroic SMO but will also inspire new directions for single-phase multiferroics.

[1] Lee, J. H. & Rabe, M. K. Epitaxial-strain-induced multiferroicity in $SrMnO_3$ from first principles. *Phys. Rev. Lett.* **104**, 207204 (2010).
[2] Becher, C. *et al*. Strain-induced coupling of electrical polarization and structural defects in $SrMnO_3$ films. *Nat. Nanotechnol.* **10**, 661–665 (2015).
[3] Wang, H. *et al*. Direct observation of huge flexoelectric polarization around crack tips. *Nano Lett.* **20**, 88–94 (2020).

Keywords:

Multiferroic, strain-engineering , SrMnO3, perovskite ferroelectrics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.301

Temperature-dependent evolution of hysteretic characteristics in piezoelectric $Bi_{1/2}(Na_{0.82}K_{0.18})_{1/2}TiO_3$ thin films

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Abstract:

$Bi_{1/2}(Na_{1-x}K_x)_{1/2}TiO_3$ (BNKT) is an excellent candidate of lead-free piezoelectric materials due to the structural tunability depending on the compositional ratio between Na and K atoms. The bulk $Bi_{1/2}Na_{1/2}TiO_3$ (BNT) and $Bi_{1/2}K_{1/2}TiO_3$ (BKT), which are the parent materials of BNKT, are structurally rhombohedral (R3c) and tetragonal (P4mm) at room temperature, respectively. It is well known that the crystallographic symmetry of the BNKT compound is manipulated by the Na (1-*x*) and K (*x*) doping levels. At the morphotrophic phase boundary (MPB) (i.e., x=0.18), where its structural symmetry is monoclinic (Cc), high electromechanical responses were previously reported with a structural transition via the bridging monoclinic phase. However, most of earlier works have been limited to the bulk BNKT and thus, a systematic study on the ferroelectric and piezoelectric properties of thin-film BNKT has not been provided, yet. In this work, we found that the ferroelectric hysteresis loops of epitaxial BNKT thin films are strongly dependent on the growth temperature (T) in pulsed laser deposition (PLD). For BNKT thin films deposited at lower temperatures than 570˚C, a single hysteresis loop in conventional ferroelectric materials was observed. In contrast, it was evident that BNKT thin films deposited above 570˚C exhibit double hysteresis behaviors in their polarization-voltage and current-voltage characteristics. More experimental results will be demonstrated in conjunction with possible explanations of the observed double hysteretic characteristics.

Keywords:

thin film, piezoelectric, lead-free, hysteresis, pulsed laser deposition

2020 KPS Spring Meeting
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P1-co.302

Brillouin and Raman Spectroscopic Investigations of $Pb_xBa_{1-x}Nb_2O_6$

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Abstract:

$Pb_xBa_{1-x}Nb_2O_6$ (PBN) is a commonly investigated tungsten bronze(TB) relaxor ferroelectric material In this work, PBN with *x*=0.5 has been studied by Brillouin and Raman spectroscopies. Brillouin and Raman spectra at a backscattering geometry c(aa)$\underline{c}$ have been obtained at different temperatures. Figure 1 (a) shows the Brillouin frequency shift of the longitudinal acoustic (LA) mode with respect to temperature. Acoustic anomalies are observed near the ferroelectric to paraelectric phase transition temperature (*Tc*) of 350°C. The LA mode softening and the increase in full width at half-maximum (FWHM) near the *Tc* indicate the structural ferroelectric phase transition. Raman investigations have also been performed. Figure 1 (b) shows the Raman frequency shifts with respect to temperature. Some Raman bands also show anomalies near the *Tc* consistent with the Brillouin results.

Keywords:

Raman Spectroscopy, Brillouin Spectroscopy, PBN, Relaxor Ferroelectric

2020 KPS Spring Meeting
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P1-co.303

Luminescence properties of valence conversion of Eu ions doped ABaPO4 (A = Li, Na, and K)

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Abstract:

We investigated the emission properties of the Eu ion doped $ABaPO_4$ (A = Li, Na, K). The valence state of Eu ions were changed through the hydrogen and oxygen annealing. We compared the structural difference and luminescence properties that occur when the difference divalent and trivalent Eu ions. In addition, attempts were made to control the valence state of Eu ions through the effect of the gamma-ray irradiation and the hydrogen implantation. And we compared the differences in the various valence conversion methods.

Keywords:

Eu, LiBaPO4, NaBaPO4, KBaPO4, valance state conversion

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.306

High transverse piezoelectric coefficient of Mn-doped $Bi_{0.5}Na_{0.5}TiO_3$ thin films

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Abstract:

Lead-free $(Bi_{0.5}Na_{0.5})(Ti_{1-x}Mn_x)O_3$ (BNTMn-*x*, *x*=0, 0.0025, 0.0050, 0.0100) thin films were fabricated by chemical solution deposition method on $Pt/TiO_2/SiO_2/Si$ substrate. The effects of Mn substitution on crystal structures, surface morphologies and ferroelectric properties of BNTMn-*x* thin films was investigated. In particularly, emphasis was placed on transverse piezoelectric coefficient of BNTMn-*x* films. Mn doping remarkedly improved the ferroelectric properties of BNTMn-*x* thin films. The 0.5 mol% Mn-doped BNT thin film exhibited well-shaped ferroelectric *P-E* hysteresis loops with high remnant polarization of 16 $\mu C/cm^2$ at an applied electric field of 400 kV/cm. The transverse piezoelectric properties of the BNTMn-0.005 cantilever (thickness ~ 1.12 μm) was measured using laser Doppler vibrometer. The $Pt/BNTMn-0.0050/Pt/TiO_2/SiO_2/Si$ unimorph cantilever showed high transverse piezoelectric coefficient (e^*_{31}) of approximately 2.43 C/m^2, comparable to those of other lead-free piezoelectric films. Our results suggest that BNTMn-0.0050 film is a promising material for applications as micro-actuators.

Keywords:

lead free, Bi0.5Na0.5TiO3, transverse piezoelectrics, thin film, cantilever

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.308

Structural and luminescent properties of Eu ion doped $CaHfO_3$

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Abstract:

We investigated the structural and luminescent properties of Eu^{3+}-doped $CaHfO_3$ (CHO:Eu) synthesized in the solid state reaction method. The crystal structures of the samples were analyzed by the Rietveld refinement technique with the X-ray diffraction pattern. Due to the cation vacancies, the unit cell volumes of the samples increased and the local lattice distortions were alleviated with the Eu^{3+} concentration increasing. Under near-ultraviolet photoexcitation, the emission spectra of our samples showed a series of narrow bands which were assigned to the energy transitions of $^5D_0 \rightarrow {}^7F_J$ (J = 0, 1, 2, 3) in Eu^{3+} ions. The luminescence behaviors of the samples were evaluated using Judd-Ofelt intensity parameters, which provided useful information on the local structure around the Eu^{3+} Ions.

Keywords:

CaHfO3, Eu3+, red emission, Rietveld refinement, Judd-Ofelt analysis

2020 KPS Spring Meeting
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P1-co.309

Doping-Site Dependence of Upconversion Emission of Ho^{3+} Ion in $CaHfO_3$

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Abstract:

The Upconversion (UC) emission properties of Ho^{3+} and Yb^{3+} co-doped $CaHfO_3$ ceramics were investigated in terms of the site substitution, i.e., Ho^{3+} and Yb^{3+} ions occupying the Ca- (A-site) and Hf- (B-site) sites. Upon excitation of 980-nm near-infrared light, the Ho^{3+} activators in our samples exhibited sizable green emissions on the assistance of Yb^{3+} ions as sensitizers, together with relatively small red emissions. Interestingly, the A-site doped samples showed much stronger UC emission intensities than B-site doped ones. Because the intensity of the Ho^{3+} emissions increases with the increasing asymmetry in its local environment, our finding suggested that the A-sites should have lower crystalline symmetry than B-sites. The intensity of green UC emission was found to decrease with increasing Ho ion concentration commonly in both A-site and B-site dopings. The non-monotonic temperature dependence of the UC emission might originate from the complexity in the energy transfer and relaxation.

Keywords:

CaHfO3, Ho3+/Yb3+, Upconversion, Doping site, Temperature dependence

P1-co.310

Study on the emissions of Er^{3+} and Yb^{3+} co-doped $SrZrO_3$ nano-crystals under near-infrared and near-ultraviolet excitations

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Abstract:

The upconversion (UC) emissions of Er3+ and Yb3+ codoped SrZrO3 nanocrystals (NCs) were investigated in term of the thermal annealing temperature and concentration of Er3+ ions, compared with the emissions under the near-ultraviolet (near-UV) excitation. The NCs were synthesized by the combustion method, and the as-synthesized NCs were post-annealed at high temperatures. The XRD patterns revealed that the grain sizes and the crystallinity degrees of the samples increased with increasing the annealing temperatures. The PL spectra of our samples exhibited strong green and very weak red emissions with the near-UV excitation, originating from the f–f transitions in Er3+ ions. Interestingly, under near-infrared (near-IR) excitation, we identified sizable visible emissions at 525, 547, and 660 nm in our NCs, which indicated that the UC process occurred successfully in our NCs. These UC emissions were maximized in the NCs with the Er3+ concentration of 0.02 and thermal annealing at 1000 °C. We found that the intensity ratios of red to green emission increased with increasing the annealing temperature. We discussed the differences in the emissions between near-UV and near-IR excitations.

Keywords:

Er3+ and Yb3+ codoped SrZrO3, Upconversion, Downconversion, Nano-Crystals, Combustion Method

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.311

Realization of 6H-Hexagonal Polymorph in $SrMnO_3$ Ceramics by Al_2O_3 Doping

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Abstract:

Ternary strontium titanate ($SrMnO_3$) is known to form three polymorphs: cubic perovskite (Pm-3m), 4H-hexagonal ($P6_3$/mmc), and 6H-hexagonal ($P6_3$/mmc). These polymorphs originate from a difference in both crystallographic symmetry and the stacking sequence. Among these polymorphs, most of the previous works in $SrMnO_3$ compounds are focused on the cubic perovskite and 4H-hexagonal polymorphs due to the challenging synthetic condition of the 6H-hexagonal polymorph (i.e., extremely high pressure and temperature of 150 kbar and 800 ~ 1300˚C, respectively). In previous studies, the 6H-hexagonal $SrMnO_3$ phase is attained under hydrostatic pressure (~152 kbar) produced by the conventional diamond-anvil-cell (DAC) technique. However, in this work, we demonstrate that a stabilize 6H-hexagonal $SrMnO_3$ phase is achievable by simply doping the Al_2O_3 to the $SrMnO_3$ using the conventional solid-state-reaction route. X-ray diffraction (XRD) experiment of the as-sintered Al_2O_3 doped $SrMnO_3$ ceramics clearly shows the structural evolution from 4H-hexagonal to 6H-hexagonal $SrMnO_3$ phase. In the field emission-scanning electron microscopy (FE-SEM) images of the Al_2O_3-doped $SrMnO_3$ ceramics, the Al_2O_3 dopant would form hexagonal $SrAl_2O_4$ ($P6_322$) grains locally. Furthermore, to understand a possible origin of 6H-hexagonal phase in $SrMnO_3$, we performed the XRD measurement of the strontium (Sr) deficient $SrMnO_3$ ceramics. In the XRD pattern of the Sr-deficient $SrMnO_3$ ceramics, interestingly, we observed the same 6H-hexagonal polymorphic phase as recognized in the Al_2O_3 doped $SrMnO_3$ ceramics. However, in the presence of the hexagonal $SrAl_2O_4$ phase (Sr-deficient 4H-hexagonal $SrMnO_3$), it is possible to generate the ultrahigh stress of ~157.7 kbar in proximity to $SrMnO_3$ grains, which allows us to realize 6H-hexagonal polymorph free from the application of external hydrostatic force. The stress value is estimated from the misfit strain arising from the lattice mismatch between 4H-hexagonal $SrMnO_3$ and hexagonal $SrAl_2O_4$ (Sr-deficient 4H-hexagonal $SrMnO_3$). This suggests that the Sr-deficiency in $SrMnO_3$ is playing an important role to realize the 6H-hexagonal polymorph; though, a mechanism for such polymorphic transition is not yet clear. However, this finding broadens the range of realization of a 6H-hexagonal phase in the complex oxide materials via interfacial strain engineering.

Keywords:

Doping, Stress

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-co.312

Highly ordered lead-free double perovskite halides by design

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Abstract:

Lead-free double perovskite halides are emerging optoelectronic materials that are alternatives to lead-based perovskite halides. Recently, single-crystalline double perovskite halides were synthesized, and their intriguing functional properties were demonstrated. Despite such pioneering works, lead-free double perovskite halides with better crystallinity are still in demand for applications to novel optoelectronic devices. Here, we realized highly crystalline Cs2AgBiBr6 single crystals with a well-defined atomic ordering on the microscopic scale. We avoided the formation of Ag vacancies and the subsequent secondary Cs3Bi2Br9 by manipulating the initial chemical environments in hydrothermal synthesis. The suppression of Ag vacancies allows us to reduce the trap density in the as-grown crystals and to enhance the carrier mobility further. Our design strategy is applicable for fabricating other lead-free halide materials with high crystallinity.

Keywords:

Cs2AgBiBr6, leaf-free, double perovskite, single crystal

2020 KPS Spring Meeting
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P1-co.313

Grain by grain analysis of structural changes in polycrystalline (1-x)BiFeO3-xBaTiO3 near MPB region

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Abstract:

(1-x)BiFeO3-xBaTiO3는 페로브스카이트 구조로 두 개의 상이 공존하는 MPB 영역에서 좋은 압전특성을 보인다. 그러나 MPB영역에서 구조가 어떻게 변화하는지는 잘 알려져 있지 않다. 이 연구에서는 방사광에서 나온 X-ray를 집속하여 polycrystal 시료의 구조와 strain의 국지적 변화에 대해 연구하였다.
포항 가속기 연구소의 4B beamline에서 K-B mirror를 이용해 x-ray white beam을 약 1micron으로 집속하여 CCD에 Laue image를 기록하고 이를 분석프로그램으로 구조와 strain 변화에 대한 50x50μm^2 크기의 이미지를 얻을 수 있었다. 다결정 시료에서는 grain이 x선의 침투 깊이 보다 작을 때 하나의 Laue image에는 여러 orientation이 겹쳐진 Laue pattern이 나타난다. 선행연구에서 알아낸 방법을 이용하여 겹쳐진 Laue image를 먼저 grain별로 분리한 후, software를 사용하면 각 image에서 회절 peak을 fitting 하여 lattice parameter와 strain을 얻을 수 있다.
이 연구에서는 (1-x)BiFeO3-xBaTiO3고용체(x=0.3,0.33,0.35,0.4)의 MPB영역 근처에서 구조를 분석하였고, BT조성이 커질수록 deformation angle이 큰 면적이 작아지며 cubic에 가까워짐을 알게 되었다. 또한 한 grain 내에서도 strain이 골고루 퍼져있는 것이 아니라 boundary부분과 center부분에 차이가 있음을 알게 되었다. 특히 그 차이는 x=0.33인 MPB 영역에서 도드라지며 d33값이 가장 큰 BT조성과 일치했다.

Keywords:

X-ray microdiffraction, BiFeO3-BaTiO3, XMD

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P1-co.314

Schottky diodes using all perovskite oxides

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Abstract:

The p-n junctions using high-quality perovskite oxide (ABO_3) thin films have significant potential for electronic devices with multifunctional properties. Alloying Sr ions at the A-sites of perovskite $LaVO_3$, e.g., $La_{1-x}Sr_xVO_3$, can introduce holes at the top of the valence band, resulting in p-type conductivity while maintaining reasonable transparency. Note that both p-$La_{1/3}Sr_{2/3}VO_3$ and n-$SrVO_3$ are metallic with hole and electron carriers at the Fermi surface.
We investigated the properties of p-$La_{1-x}Sr_xVO_3$/n-$SrVO_3$ Schottky diodes. Schottky diodes were grown on TiO_2-buffer-layered Si substrates using RF magnetron co-sputtering deposition with a commercial $SrVO_3$ and La_2O_3 targets at 500 °C with a mixed gas of H_2 and Ar. Film thicknesses were about 100 nm. We used a commercial $SrVO_3$ and La_2O_3 targets. Varying the relative power ratio of the two targets, we controlled the La-composition of the $LaSrVO_3$ thin films. The sputtering pressure was set at 6mTorr with 10 sccm flow of H_2 35% gas. All samples were grown at 400˚~500˚.
The structural and morphological properties of the $La_{1-x}Sr_xVO_3$ films were investigated using grazing-incidence-angle X-ray diffraction, scanning electron microscopy, and X-ray photoemission spectroscopy. The I-V characteristics of $La_{1-x}Sr_xVO_3/SrVO_3$ diode changed from linear (x = 1/3) to rectifying behavior (x > 1/3) as La composition increased. Using spectroscopic ellipsometry, we determined the dielectric functions of $La_{1-x}Sr_xVO_3$ films. The ideality factor (n) is known to depend on both the electronic structure of the p-n junction and the associated mechanism of charge transfer. We find for these Schottky diodes that $n < 5.3$. [1]
[1] L. Hu et al., Adv. Elect. Mater. **4**, 1700476 (2018).

Keywords:

Schottky diode, La1-xSrxVO3/SrVO3 , dielectric function, Hall effect measurement, strong correlation

2020 KPS Spring Meeting
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P1-co.315

Ferroelectric Subloop Behavior of a $Hf_{1-x}Zr_xO_2$ thin film

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Abstract:

Modulation of multiple polarization states in ferroelectric materials enable neuromorphic applications through diverse architectures which is required by recent demand for analogue devices. However due to the complicated switching mechanism of ferroelectric and/or defect-induced uncertainty, the desired accuracy without the cost of delayed switching, fatigue or imprint problem cannot be achieved with perovskite ferroelectric materials. In addition to the CMOS compatibility and scalability of ferroelectric HfO_2, stable subloop behavior without any external and internal factors has been reported in ferroelectric Si-doped HfO_2 [1]. Considering large polarization value, excellent scalability and retention performance in zirconium doped HfO_2, subloop behavior studies in other hafnium-based dopant materials are urgently required.

We report the stability of multi-level polarization states of $Hf_{1-x}Zr_xO_2$ thin films with various zirconium doping rates. Zirconium doping rates of $Hf_{1-x}Zr_xO_2$ thin films were confirmed through X-ray Diffraction and X-ray photoelectron spectroscopy. Multi-level polarization states were controlled through conventional voltage pulses with different voltage heights. To check the reliability issue of each multi-level polarization states, we repeated voltage pulse and analyzed through the Weibull statistics. Regardless of zirconium doping ratio, all multi-level polarization states exhibited good reproducibility compared to the conventional perovskite ferroelectrics and ReRAM devices. The temperature dependence of coercive field indicated large activation energy for ferroelectric switching with small critical volume for nucleation enabling stable multi-level polarization states.

[1] K. Lee, H. J. Lee, T. Y. Lee, H. H. Lim, M. S. Song, H. K. Yoo, D. I. Suh, J. G. Lee, Z. Zhu, A. Yoon, M. R. MacDonald, X. Lei, K. Park, J. Park, J. H. Lee, S. C. Chae. (2019). Stable Subloop Behavior in Ferroelectric Si-Doped HfO_2. *ACS Appl. Mater. Interfaces* ***11***(42), 38929.

Keywords:

Ferroelectric, FeRAM, multilevel, HfO2

2020 KPS Spring Meeting
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P1-co.316

비탄성 레이저 광산란 분광법을 이용한 타우린(Taurine, $C_2H_7NO_3S$) 단결정의 상전이 특성 연구

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Abstract:

타우린은 현대인들이 흔히 마시는 피로회복제에 많이 들어가는 아미노산의 일종으로서 동물의 근육과 기관에 많이 포함되어 있다. 최근 생체조직에 대한 연구가 활발해지면서 생체조직의 근본적 물성에 대한 관심도 높아지고 있다. Taurine 단결정의 구조는 Monoclinic으로써 성장된 단결정은 일정한 morphology를 보여준다. 우리는 타우린 단결정의 탄성 특성과 진동 특성의 온도의존성을 브릴루앙 산란실험과 라만실험을 통하여 넓은 온도 범위(-190°C ~ 190°C)에서 구했고 구조 상전이의 존재 여부를 밝히고자 하였다. Fig. 1은 브릴루앙 산란 실험을 통하여 얻은 종음향모드(LA)와 횡음향모드(TA) 브릴루앙 주파수의 온도의존성이다. 이 결과는 두 모드의 음속도가 온도저하와 함께 커진다는 것을 의미한다. 라만 실험을 통하여 대표적인 진동 모드(25개)들의 주파수의 온도의존성을 조사한 결과 50°C 부근에서 구조적으로 상전이가 일어나는 징후를 확인할 수 있었으나 이에 대해서는 좀 더 면밀한 조사가 요구된다.

Keywords:

상전이, 라만, 브릴루앙

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P1-co.317

Electric Field Cycling-mediated Variations in Defect Distributions Associated with Split-up Behavior of a Ferroelectric Si-doped HfO_2 Thin Film

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Abstract:

Ferroelectricity of HfO_2 film has attracted attention due to the advantages for immediate application for non-volatile universal memory, such as high compatibility with the conventional complementary metal-oxide-semiconductor (CMOS) process and good scalability. However, the utilization of this ferroelectricity is still controversial in view of the thermal stability and reliability during the switching operation. Although the variation of ferroelectric switching mechanism and characteristics under the external bias cycling such as the wake-up or fatigue behavior has been investigated, the recently reported split-up behavior has not been studied rigorously yet.

In this paper, we report variations in the characteristic ferroelectric switching time and interface free carrier concentration associated with the wake-up and split-up behaviors of a 4.2 mol % Si-doped HfO_2 thin film. Prior to the development of split-up behavior, the thin films exhibited wake-up behavior; remnant polarization increased on repeated external bias cycling. After wake-up behavior, Si-doped HfO_2 films exhibited degradation of the remnant polarization values and splitting of the ferroelectric switching current peaks when the external bias was swept; this is referred to as split-up behavior. An investigation of the ferroelectric switching dynamics revealed retardation, followed by recovery, of the characteristic switching time for ferroelectric nucleation, coincident with wake-up and split-up behaviors, respectively. We analyzed the interface free carrier concentration by deriving capacitance-voltage characteristics and revealed that split-up behavior was associated with increased numbers of defects as electric field cycling continued.

Keywords:

ferroelectricity, HfO2, switching dynamics

Simulation of silicon detector using TCAD

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Abstract:

최근 핵물리 실험에서 널리 사용되고 있는 실리콘 검출기는 에너지 분해능과 위치분해능이 높고 시간 반응이 빠르다는 장점이 있다. 실리콘 검출기의 간단한 작동 원리는 다음과 같다. 실리콘 검출기는 P형 반도체와 n형 반도체를 접합한 형태를 가진다. P형 반도체와 n형 반도체의 접합면 주위에서는 전자와 양공이 확산에 의해 섞이게 되어 전하운반자(charge carrier)가 없는 영역이 형성되는데, 이를 공핍 영역(depletion region)이라고 한다. 전하를 띤 입자가 공핍 영역을 통과하게 되면, 입자의 궤적을 따라 전자-양공의 쌍(electron-hole pair)이 형성된다. 이 전자와 양공은 검출기 내부의 전기장에 의해 전극으로 끌려가게 되고, 이것이 전류의 형태로 검출된다. 일반적으로 검출기에는 공핍 영역을 확대하기 위한 역전압이 인가된다.

본 연구에서는 TCAD 프로그램을 이용하여 실리콘 검출기에 전자-양공의 쌍이 생성되었을 때 측정되는 전류를 시뮬레이션하고, 그 결과를 다른 시뮬레이션 결과와 비교하고자 한다. 시뮬레이션을 위한 검출기는 프랑스 소재 GANIL 연구소의 FAZIA 검출기를 바탕으로 하여 구성하였다. 시뮬레이션을 위해 구성한 검출기는, n-type 도핑이 되어 있는 실리콘의 하단에 높은 농도의 p-type 도핑이 되어있는 얇은 판을 접합한 구조를 갖는다. 검출기의 상단과 하단에는 전극이 있으며, 이 전극에 검출기의 공핍 영역을 확대하기 위한 역전압이 가해진다. 본 시뮬레이션에서는 검출기의 모든 영역이 공핍 영역이 되도록 강한 전압을 인가하였다. 그 후 검출기 내부에 전자-양공 쌍을 생성시키고, 그로 인해 전극에 수집되는 전류신호를 측정하였다. 그리고 이론적 모델을 바탕으로 한 계산을 통해 얻은 전류신호, Garfield를 이용하여 같은 조건으로 시뮬레이션을 수행하여 얻은 전류신호와 비교해보았다.

Keywords:

Semiconductor detector, Silicon detector, High energy nuclear physics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.02

Monte Carlo simulations of k_Q factor of ionization chamber (PTW-30013) for proton beam absorbed dose measurement

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Abstract:

With the recent popularization of proton therapy, research activities on the accuracy of Monte Carlo simulations of proton therapy are being performed by comparing simulation results of the k_Q factor, a parameter used for ionization chamber calibration, with the TRS-398 protocol, an international standard for dose measurement.
In this study, the simulations are performed by using TOPAS, one of the Monte Carlo simulation platforms available for particle therapy. Simulation conditions follow the TRS-398 protocol, and the SOBP (Spread Out Bragg Peak) width of the proton beam used in the simulations is 0-15 cm. The ionization chamber (PTW-30013 model) used for the study was placed at a depth of 7.5 cm (middle of the SOBP). Preliminary results of the comparison between simulations and protocol parameter value are presented.

Keywords:

Proton therapy, Monte Carlo simulation

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.03

Study of the jet fragmentation in high multiplicity pp and p-Pb collisions

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Abstract:

In relativistic heavy-ion collisions, a hot and dense medium called a Quark-Gluon Plasma (QGP) is created, and jets produced from hard parton scatterings in the early collision are used to study the QGP. Jet measurements can provide detailed information on how hard partons interact with the medium and fragment into hadrons, and this is crucial to understand the properties of the medium. Interestingly, a collective behavior of produced particles thought to be a strong evidence of the QGP formation has been observed in small collision systems like pp and p-Pb collisions, and the origin of this collectivity in small collision systems is not yet fully understood. To have a comprehensive understanding of small collision systems, it will be useful to extend measurements from the collectivity of soft particles to the response of hard particles like jets. It requires a careful study of underlying events particularly in this high multiplicity pp and p-Pb collisions where a significant flow of soft particles has been observed. We will present the initial study of the jet fragmentation measurement in high multiplicity pp and p-Pb collisions with models.

Keywords:

Heavy Ion Collision, Jet Fragmentation, Small Collision System

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.04

Efficiency simulation and design of $LaBr_3$(Ce) gamma-ray detector array

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Abstract:

The fast-timing gamma-ray detector array composed of 24 $LaBr_3$(Ce) scintillators is now being developed by the Center for Extreme Nuclear Matters (CENuM). In order to design the appropriate configuration of 24 modules, several possible designs have been considered. Subsequently, the Geant4 simulation has been carried out to obtain the expected energy spectra and detection efficiencies with different configurations. In this presentation, the simulation results will be shown based on the different conceptual designs of the detector configurations. Moreover, the final design of the array including the supporting structure will be introduced.

Keywords:

LaBr3(Ce), Supporting structre, gamma-ray detector

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.05

Development of a Technique for the Assessment of Radon Concentration

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Abstract:

Exposure to radon and its progeny is the second leading cause of lung cancer after cigarette. The scientists and researchers are continuing designing and developing methods and techniques for measurements of radon concentration. We are developing a method which can be used to measure the activity concentrations of all three naturally occurring radon isotopes based on liquid scintillation counting technique with photomultiplier tube using delayed coincidence technique and pulsed shape discrimination method implemented by digital charge comparison .This technique can be used to detect three isotopes of radon found in nature which are ^{222}Rn, ^{220}Rn and ^{219}Rn with respect half-life of 3.8 days, 56 seconds, and 4 seconds. They are formed on the alpha decay of their radium parents ^{226}Ra, ^{224}Ra and ^{223}Ra which are members of naturally decay series of ^{238}U, ^{232}Th and ^{235}U, respectively. Ultima Gold AB was used for the detection of radon decay product in 700 mL UG-AB sample in the one liter of SUS container. We measured half-life of ^{214}Po to be 164.3±4μs which is consistent with expected half-life of 164.3 μs. We found the total efficiency of the system of 59.9% of ^{222}Rn (^{238}U decay chain).We calculated the MDA of 1mBq/L of ^{222}Rn (^{238}U decay chain). We will work on other target isotopes in order to calculate the efficiency and MDA of the method for ^{220}Rn (^{232}Th decay chain) and ^{219}Rn (^{235}U decay chain).

Keywords:

Radon, Radon Isotopes, Radon Concentration, Liquid Scintillator

Properties of lifetime on Zircon using TR-OSL

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Abstract:

Zircon has been reported as an attractive natural dosimetric material using luminescence because of internal irradiation at a dose rate much higher than the dose rate from external sources due to high impurity levels of uranium and thorium. In this study, using the technique of TR-OSL, we evaluated the lifetime and examined the lifetime dependence on the thermal treatment applied after irradiation, the radiation exposure and the optical pulse stimulation for Zircon.

Keywords:

Zircon, TR-OSL, Lifetime, Dosimetry

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.07

CLAS12 RICH calibration of DVCS data

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Abstract:

Generalized Parton Distributions (GPDs) are functions which provide new information on the inner structure of the nucleon in terms of quarks and gluons. The electroproduction of a photon on the nucleon, known as deeply virtual Compton scattering (DVCS), is an exclusive process providing access to GPDs.
Jefferson Lab, in the USA, is a research facility with an electron accelerator providing polarized electron beams of up to 12 GeV. The CLAS12 detector was recently built and installed in the Hall B of Jefferson Lab. DVCS fixed-target experiments are being carried out by using the 12 GeV electron beam and the CLAS12 detector.
The CLAS12 detector is composed of various components to detect all types of particles coming out of the target, including a Ring-imaging Cherenkov (RICH) detector. Preliminary results of RICH calibration using recent DVCS data are presented.

Keywords:

CLAS12, Jefferson Lab, RICH detector, Detector calibration

A study on the effects of various sample preparation conditions in accelerator mass spectrometry measurement

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Abstract:

Accelerator Mass Spectrometry (AMS) is an ultra-sensitive means for measuring low concentration of natural isotopic abundances of both stable isotopes and radioisotopes. Because the main advantage of AMS compared to traditional mass spectrometry methods is the use of smaller samples (mg and even sub-mg size), AMS can be applied in the technique of ^{14}C dating in the fields of archeology, geology, biomedicine applications and many others.
A 3-MV tandem accelerator was relocated to KOrea Multi-purpose Accelerator Complex (KOMAC) from Seoul National University in 2017 and is in re-installation. To confirm the feasibility of 3-MV AMS system, we performed a careful investigation on various sample preparation conditions in each steps including chemical pretreatment, CO_2 collection, and graphitization. We plan to determine the adequate sample preparation method of collecting radiocarbon reflecting the sample age. In this report, the current state of an optimized sample preparation method and the results of the acceptance tests for ^{14}C dating performance with the standard samples are presented.

Keywords:

Accelerator mass spectrometry, radiocarbon dating, 3-MV tandem accelerator

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.11

Study on the pulse shape discrimination of thallium-doped lithium iodide crystal

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Abstract:

The demand for thermal neutron detection is of particular interest so far. The lithium iodide crystal scintillator, a member of Li-based single crystal, has been considered and developed. Because of the high thermal neutron capture in ^{6}Li, the neutron signals can be determined via the signal of its products, alpha and triton. The LiI:Eu crystal was developed and commercialized, and used in for thermal neutron detection application, however, it does not have pulse shape discrimination (PSD) capability that neutron-induced signals cannot be separated from the gamma signals. Therefore, in this work, we grow the LiI:Tl crystal by using the vertical Bridgman technique and study its PSD capability between the alpha and gamma signals from ^{241}Am and ^{137}Cs sources, respectively. The figure-of-merits have been also determined and optimized. Based on that, the measurements with the thermal neutron from ^{252}Cf source have also been performed and the PSD capability has been demonstrated.

Keywords:

LiI:Tl crystal, Neutron detection, Pulse shape discrimination, Figure-of-merit.

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.12

Study of Pixelated Silicon Sensor with Junction Field Effect Transistor

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Abstract:

In order to develop medical detectors, we study pixelated silicon array sensors for direct detection of X-rays. The sensor has a PIN diode structure to increase interaction with X-rays and designed with pixels to obtain image. To reduce the number of signal processing channels, a junction field effect transistor (JFET) structure is incorporated into each pixel. All pixels with one row are read in parallel and the next row is then selected by the gate voltage after finishing the reading one row.

We fabricate the pixelated silicon sensor integrated with JFET using a 650 μm-thick, high resistivity (> 5 kΩ·cm) n-type and double-sided polished 6-in silicon wafers.
We define design parameters such as distance between the source and drain, distance between deep p-well under the drain of the JFET and gate, distance between fieldshaper and source and smaller inner radius of source.
In this study we present electrical characteristics of the pixelated sensors and the drain currents as a function of the drain voltage for various the gate voltages. We also measure change of electrical characteristics generated by LED light and X-rays illumination.

Keywords:

Pixelated silicon sensor, Junction Field Effect Transistor

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.13

Characterization of CVD diamond detectors as a thermal flux monitor at the KOMAC

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Abstract:

At the Korea Multi-purpose Accelerator Complex (KOMAC) of Korea Atomic Energy Research Institute (KAERI), white neutrons are generated based on the 100-MeV proton linear accelerator. Although the primary neutrons generated in the production target are expected to have kinetic energy more than a few keV, a considerable thermal neutron flux is expected because of neutron moderation in the accelerator tunnel. For the measurement of the thermal neutron flux in such a gamma-neutron mixed field, CVD diamond detectors, which were manufactured by CIVIDEC, are employed for being used a thermal-neutron flux monitor. The response of the detectors to thermal neutrons was experimentally derived by using a thermal-neutron irradiation facility in Korea Research Institute of Standard and Science (KRISS). And then the response of the diamond detectors to the white neutrons whose kinetic energy extends over many orders of magnitude from 100 MeV down to a few meV was investigated in the accelerator tunnel at KOMAC. Here, we present and discuss the results of the characterization study of the CVD diamond detectors as a thermal-neutron monitor for the accelerator-based white neutron source.

Acknowledgements: This work has been supported through KOMAC (Korea Multi-purpose Accelerator Complex) operation fund and the NRF grant (NRF-2018M2A2B3A02072238) funded by MSIT (Ministry of Science and ICT).

Keywords:

Thermal Neutron, White Neutron, KOMAC

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.14

Pure Crystal Growing and Research at Center for Underground Physics

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Abstract:

The Center for Underground Physics (CUP) at the Institute for Basic Science (IBS) has been conducting two major experiments. One is the COSINE experiment for dark matter study and another is the AMoRE experiment for neutrinoless double beta decay study. The COSINE is using NaI:Tl scintillation crystals and the AMoRE is using ^{100}Mo based scintillation crystals such as Li_2MoO_4 and $CaMoO_4$. Both experiments require ultra-pure crystals to minimize their internal backgrounds. We have been studying in growing pure crystals for both experiments. After the growths, we checked purities of grown crystals through ICP-MS and HPGe measurements. In this poster, we will present updated results of grown pure crystals and their properties.

Keywords:

NaI, Li2MoO4, CaMoO4, COSINE, AMoRE

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.15

The Study on Muon Therapy

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Abstract:

The muon is a subatomic particle that includes the muon- and the muon+ with the charge of -1 or 1. As the proton beam, the muon beam shows a Bragg peak when it interact with materials. Therefore, the muon can be considered as the candidate of radiotherapy as well as proton.
In this study, based on the Monte Carlo method, a water phantom is defined, which includes the target volume and three interesting volumes. Then, the interaction processes of proton beam, muon+ beam, and muon- beam in materials are simulated. Moreover, the dose deposition of proton beam, muon+ beam, and muon- beam in each volume are calculated. Through analyze the calculated results, it can be found that comparison to proton, the muon beam, especially muon- beam, has advantage to reduce the physical dose deposition in upstream volume of target.

Keywords:

Proton, Muon, Monte Carlo Method

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.16

Czochralski Growth and Characterization of Pr^{3+} Activated $Li_6Y(BO_3)_3$ Single Crystal

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Abstract:

Borate crystals are very much promising for different applications like thermal neutron imaging, light-emitting diodes (LEDs), plasma display panels (PDPs), medical imaging, lasers, scintillators, and thermoluminescence dosimetry. The $Li_6Y(BO_3)_3$ (LYBO) is an orthoborate compound, possesses monoclinic structure with an optical band gap (E_g) of 6.8 eV which allows different activators to be doped for efficient luminescence. In the present study, LYBO phosphors have been synthesized with Pr^{3+} rare-earth doping. The Pr^{3+} doping concentration has been optimized ranged from 0.1 to 2.5 mol% in order to find the highest luminosity. The 1.0 mol% Pr^{3+} doped phosphor has been found to have the highest X-ray luminescence with peak intensity at 612 nm. Single crystals have been grown in an argon atmosphere with 1mol% Pr^{3+} activated LYBO composition. The crystals have been cut and polished to characterize with X-ray and 266nm Laser excitation. The transmittance spectrum has been obtained from a 7mm thick piece of the grown crystal. The CIE chromaticity diagram is showing the combined emission light will be in the violet region. The scintillation property and decay time have been measured with a ^{241}Am alpha source.

Keywords:

Phosphors, Single Crystal, X-ray Luminescence, Decay time

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-nu.17

Study on the Improvement of Energy Resolution of Gamma-ray Spectrum through Electrical Noise Reduction of High Purity HPGe Detector

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Abstract:

In the gamma-ray energy spectrum study, nuclide analysis through energy analysis is very important. High-purity HPGe detectors, which are commonly used for gamma-ray energy measurements, are commonly used because of their high energy resolution and relatively high detection efficiency. However, in order to maintain a high energy resolution, the semiconductor detector has a problem in that it is difficult to maintain the original performance if the noise generated from the surrounding environment is not effectively blocked, and the effect of the expensive device is not achieved. Therefore, in this study, ground loop isolator (NEXT-001HDGL) was used to remove the electrical noise generated from the detector. In order to test the effect of improving energy resolution, HPGe detection device newly installed in the proton accelerator KOMAC was used. In the case of gamma-ray energy 2614 keV, the energy resolution was improved from 4.4 keV to 3.0 keV, and in the case of gamma-ray energy 1460 keV, the energy resolution was improved from 3.7 keV to 2.2 keV. This result is considered to be very useful for the gamma-ray spectrum study using the HPGe detection equipment of KOMAC.

Keywords:

Electrical noise, HPGe detector, gamma-ray spectroscopy, KOMAC

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-op.01

Elliptic polarization grating in PMMA doped with disperse orange 3

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Abstract:

We study the transmission polarization holograms in azo dye-doped material. The elliptic polarization grating was recorded in PMMA bulk doped with disperse orange 3 by two orthogonal linearly polarized waves (p-s) from He-Ne laser of 632.8 nm. The diffracted waves were analyzed by transmittance of the grating described by Jones matrix with Jacobi-Anger expansion. When the polarization of the probe wave is rotated by an angle, the polarizations of the diffracted waves of the order are rotated by an angle with respect to the probe wave. When probe wave is vertically polarized, the two diffracted waves are horizontally polarized. When the probe wave is left circularly polarized, the two diffracted waves have the same left circular polarization. The experimental results followed the square of the 0 order and 1 order Bessel function of the first kind. The diffraction efficiency of the order is approached to 34% (maximum value of the square of the 1 order Bessel function).

Keywords:

polarization hologram, elliptic polarizatio grating, disperse orange 3,

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-op.02

젤 물질을 첨가한 액정의 구동전압 및 반응속도 분석

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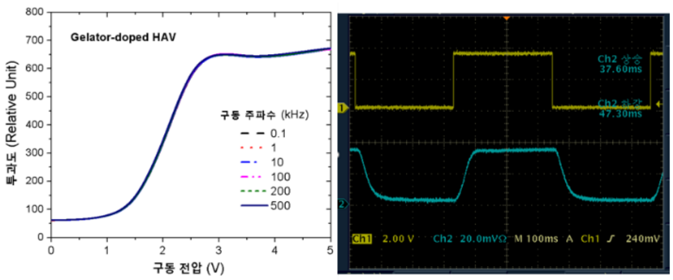
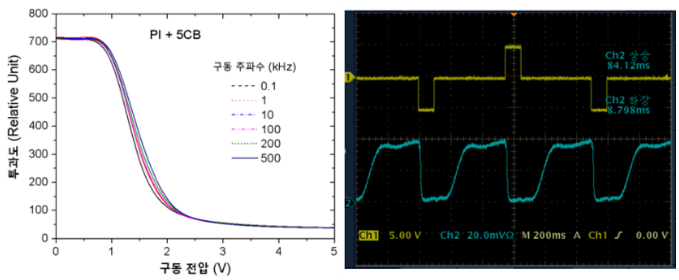
Abstract:

본 연구에서는 젤 물질(gelator)을 첨가한 Negative 액정(G+N LC)과 폴리이미드(polyimide) 배향막을 이용한 Positive 액정(PI+5CB LC)을 만들어 640 nm 파장에서의 구동전압(threshold voltage)와 응답속도(response speed)를 비교 측정한 결과를 소개한다.
액정의 저전압 구동 특성과 고속 전기광학적 특성은 공간광변조기, 액정 렌즈, 디스플레이, 광 셔터, 광 변조기 등의 응용에 매우 중요하다. 본 연구에서는 젤 물질로 12-hydroxystearic acid (12-HSA)을 첨가하고 Negative 액정으로는 HAV (HAV-634117, HCCH, China)를 사용하여 10 마이크론 간격의 ITO 유리셀에 삽입한 액정셀(G+N LC)을 구성하였다. 구동 전압 특성과 반응 속도를 실험적으로 측정하여 기존의 폴리이미드 배향막을 이용한 5CB 액정(PI+5CB LC)과 특성을 비교하였다.
제작된 G+N LC의 특성을 시준된 640 nm 파장의 레이저 다이오드 광원으로 사용하고 편광자로 쌍으로 빛을 차단 후 이들 사이에 놓인 액정에 100 Hz ~ 500 kHz 주파수의 사각파를 걸어준 경우, 구동 전압이 2.8 V 수준 이상으로 증가할 때 최대 투과도를 보였다($\Delta V_{10\text{-}90\%}$ = 1.86 V). 응답시간은 진폭이 5 V인 직교펄스 구동에 의해 rise time $t_{r(10\rightarrow 90\%)}$ 과 fall time $t_{f(90\rightarrow 10\%)}$ 이 각각 37.1±2.45 ms와 47.7±1.12 ms로 측정되었다. 반면에 PI+5CB LC의 경우에는 100 Hz ~ 500 kHz 주파수의 사각파인 경우 2.5 V 수준 이상으로 증가할 때 투과도의 변화가 최대가 되었다(($\Delta V_{90\text{-}10\%}$ = 1.10~1.13 V). 응답시간은 편광자 쌍 사이에 액정을 두어 투과 모드로 두고 진폭이 ±5.0 V로 상하로 진동하는 교대 펄스로 측정한 액정 투과도의 fall time과 rise time이 각각 85.26±1.11 ms와 8.91±0.18 ms로 측정되었다.



젤 첨가된 negative 액정의 전압 및 주파수 특성과
사각파에 대한 반응 속도 측정 결과



배향막을 이용한 positive 액정의 전압 및 주파수 특성과
사각파에 대한 반응 속도 측정 결과

Keywords:

액정, 수직배열

Relaxation of Higgs mass and dark matter

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Abstract:

We consider a new solution to the hierarchy problem in the SM by introducing a four-form coupling to the Higgs doublet.
The interplay between the hierarchy problem and the cosmological constant problem is addressed.
We propose the models with SM singlet scalars for reheating and dark matter production in this scenario.

Keywords:

four-form relaxation, Higgs, dark matter

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.02

Sommerfeld effects and dark matter in models with discrete symmetry

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Abstract:

We consider the Sommerfeld effects for dark matter in models with discrete symmetry. The spontaneous breakdown of a local U(1) symmetry in the dark sector leads to the discrete symmetry for ensuring the stability of dark matter. We discuss the Sommerfeld effects of light mediators in the dark sector on the self-scattering and annihilation of dark matter in these models.

Keywords:

Sommerfeld effects, Dark matter, Discrete symmetry

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.04

Study of reactor antineutrino detection efficiency with neutron captures on hydrogen at RENO

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Abstract:

The RENO has been taking data since August 2011 using two identical liquid scintillator detector. The detection efficiencies of near and far detectors are basically measured using control data samples. However, some of efficiencies are estimated by MC samples when a control data sample is not available. Two identical detectors provide powerful benefits to reduce a systematic error of a ratio measurement by cancelled common uncertainties. Nonetheless, there might be a slight difference between their detection efficiencies. The difference gets worse because of detector degradation such as decreased number of active PMTs and decreased attenuation length of liquid scintillator. In this presentation, we report their measured efficiencies for detecting reactor antineutrinos with neutron capture on hydrogen.

Keywords:

RENO, Neutrino, Hydrogen

Design and simulation of superconducting coplanar waveguides using Sonnet™ software for the Axion dark matter experiments at Center for Axion and Precision Physics Research

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Abstract:

The axion is a hypothetical particle arising from the Peccei-Quinn mechanism to resolve the Strong CP problem. And a light axion in the 1 – 100 μeV mass range is a compelling cold dark matter candidate. Such a light axion is weakly coupled as to be undetectable in conventional instruments. Combining a tunable microwave cavity coupled to a low-noise receiver, maintained at cryogenic temperature in the bore of a high-field magnet, we can achieve substantially improved sensitivity. In order to couple the cavity and a low-noise receiver whose noise level is about 1 – 2 photons, coplanar waveguide (CPW) resonators are readily used because only a single layer metallization step is typically necessary, making them robust and reproducible. Furthermore, high-quality factors are readily obtained when low-loss crystalline substrates are used. Prior to fabrication and measurement, prospective designs of the resonators need to be simulated using microwave simulation software packages. In this study, the CPW with f = 5 GHz is designed and fabricated which is matching with axion mass range that we are probing. CPWs have been designed and the simulations have been performed using Sonnet(TM) Software utilizing silicon, and silicon dioxide as dielectric substrates. We plan to present a detailed study of the CPW design.

Keywords:

axion

P1-pa.06

Study for Fabrication Process of Metallic Magnetic Calorimeter(MMC)

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Abstract:

MMC is a type of low temperature detector that precisely determines incident energy by measuring the change of magnetization due to the increase of the temperature of the metallic paramagnetic material in converting energy into heat in the mK temperature region. We fabricate 150 MMC devices with a size of 2 mm x 3 mm on a 3 inch Si wafer deposited with 300 nm thick Nb superconductor material. The MMC fabrication process mainly consists of the following 9 steps: 1) Fabrication of superconductor Nb meander, 2) Oxidized layer on Nb surface, 3) SiOx film coating, 4,5) Metal heater and lead on superconducting Nb structure, 6) Ag(Au):Er paramagnetic metal film deposition, 7) Gold seed layer for current lead and 8,9) Gold absorber and stems. The conditions of each processes have been optimized by measuring physical properties at room and low temperature and the morphological structures through SEM and AFM. The results are discussed in the presentation.

Keywords:

MMC, LowTemperature, Matalic magnetic calorimeter, Fabrication

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.07

Study of energy deconvolution algorithms at RENO

YOON Seok-Gyeong [1], YOO Jonghee *[1], YANG Byeongsu [1], JU Kiwon [1], YU Minsang [1], JANG Jeeseung [2], LIM Intaek [3], GWAK Piljun [4], KIM Jaeyool [4], MOON Dongho [4], SEO Junhu [4], SHIN Changdong [4], JOO Kyungkwang [4], JOHAAIB Atif [4], KIM Jonggun [5], SEO Jiwoong [5], YU Intae [5], JEON Sanghoon [5], JUNG Daeun [5], KWON Eunhyang [6], KIM Sang yong [6], KIM Soo-Bong [6], SEO Hyunkwan [6], LEE Dongha [6], LEE Hyungi [6], JANG Hanil [7], PARK Myoung Youl [8], CHOI Juneho [8], KIM Wooyoung [9]

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Abstract:

It is not simple to extract true values from measured observables by unfolding the detector resolution. For the appropriate comparison of energy spectra obtained from different detectors, it is necessary to eliminate energy resolution from the measured ones. We usually unfold the energy resolution of measured data using one of several algorithms based on a Monte Carlo simulation tuned for the detector effects. In most cases, an unfolding process produces an unphysical solution because of errors in the measured values. We have considered two main methods to solve this ill-posed problem: Singular Value Decomposition (SVD) and Iterative Bayesian Unfolding (IBU). General features of these two methods will be reviewed by examining how to choose proper constraints and regularization parameters. We will also present how to apply the two methods to obtain an unfolded reactor antineutrino spectrum.

Keywords:

deconvolution, unfolding, reactor antineutrino flux, SVD, IBU

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.08

Title: Analytical Study with Multiple Channels in AMoRE Experiments

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Abstract:

The advanced Mo-based rare-process experiment (AMoRE) is an underground cryogenic particle detection experiment to search for neutrinoless double beta(0vBB) decay of 100Mo. The experiment uses six 40Ca100MoO4 scintillating crystals composed of enriched 100Mo isotopes with total mass of 1.9 as the target material for simultaneous detection of phonon and scintillation signals with MMC readouts at millikelvin temperatures. As a pilot stage of the project, it has been carried out with 12 channels at Yangyang underground laboratory. We present a new analysis tool that can be applied in multiple channels.

Keywords:

AMoRE, neutrinoless double beta decay, scintillation, metallic magnetic calorimeter

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.09

Status of stabilization heatersfor the AMoRE double beta decay experiment

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Abstract:

AMoRE (Advanced Mo-based Rare process Experiment) is a large-scale project aiming at search for neutrinoless double-beta decay of100Mo. The project utilizes metal-magnetic calorimeters (MMC) for simultaneous measurement of phonon and scintillation signals from molybdenum-containing crystal scintillators at milli-Kelvin temperature. Because the heat capacity of the detector components and MMC sensitivity depends on temperature, signal amplitudes drift over a long time period as the base temperature varies. This effect makes worse the energy resolution of the detectors that is a crucial characteristic for a double beta decay experiment. A Joule heater was installed on a CaMoO4 scintillating crystal to inject periodically controlled amount of heat to the crystal. This makes it possible to produce reference signals that can be used for the gain stabilization. After installing the heater and off-line gain correction the energy resolution of the detector was improved. However, we have found that there is still a room to improve the stabilization system performance by advancement of the heater attachment method.

Keywords:

AMoRE, neutrinoless double-beta decay

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

An upgrade of muon veto detector in AMoRE-1

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Abstract:

The AMoRE searches for neutrinoless double beta decay of 100Mo using molybdenum-based crystals with cryogenic sensors in yangyang laboratory. The AMoRE is an extremely rare event-searching experiment that requires ultra-low background. One of main backgrounds of this experiment is cosmic muon induced events. By installing a muon veto detector outside the AMoRE crystal detectors, muon events coming from outside can be removed. But the muon veto detector in the AMoRE-pilot, the previous experiment of AMoRE-I, had a small gap between top and side counters. In order to cover this gap, we have upgraded the muon veto detector by adding 8 more plastic scintillator counters. With this upgrade, the AMoRE-1 is now surrounded by muon veto detectors in all directions. Construction and performance of the upgraded muon detectors will be presented.

Keywords:

AMoRE, neutrino-less double beta decay, Muon, PMT, Plastic scintillator

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.11

Super-Kamiokande Monte Carlo tuning with Korean light scattering measurement system

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Abstract:

In 2019, Super-Kamiokande was upgraded for dissolving gadolinium and its Monte Carlo (MC) simulation has been modified accordingly. Based on roughly a year of data taken by a Korean light scattering measurement system after the upgrade, we have measured probabilities for laser-light scattering and absorption by the water inside the detector. The measured results are used to tune the MC simulation and are essential for estimaing detection efficiency and reconstructing physics event. In this presentation, we will describe the Korean light scattering measurement system, measured results, and tunning the MC.

Keywords:

Superkamiokande, Gd, water cherenkov, neutrino

Development of Novel Silicon Photomultiplier Tube

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Abstract:

Precision photo-detectors are widely used in many industrial, technological and research fields. The most widely used photo-detector is photomultiplier tube (PMT) but now silicon photomultiplier (SiPM) is emerging and replacing conventional PMT in many research areas. We aim to develop the new kind of photo-detector with high gain that can be used in the future for the neutrino detection in Korean neutrino observatory. The idea is to replace the conventional dynode structure of PMT with silicon photomultiplier and use scintillation crystal on top of it. Light falls on photocathode and photo-electrons will be emitted and guided to the scintillator crystal by an electric field which is generated by anode at the high potential. Crystal absorbs photo-electrons and produces scintillation light, which can be in turn detected by SiPM. Developing a new photo-detector is a quite difficult and time taking process. Electrical simulation has been performed for the geometry optimization with various configurations and the simulation result will be presented. A demonstrator has been built to prove the principle of this new kind of photo-detector and the test result obtained with the demonstrator will be also presented.

Keywords:

Transit time spread, scintillator, photocathode, photo-detectors

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.13

Measurement of temperature-dependent responses of NaI(Tl) crystal detector for rare event searches

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Abstract:

NaI(Tl) detector has been widely used in many aspects including rare event searches. Especially high-light yield of recently developed NaI(Tl) crystals allow possibilities of a low-mass dark matter search in COSINE-100 as well as a neutrino-nucleus coherent scattering search in NEON. It is known that the light yield of NaI(Tl) crystal can be slightly increased in low temperatures around -35 ℃. We measure responses of the NaI(Tl) crystal at two different temperature environments of -35 ℃ and room temperature. In this presentation, an overall detector performance for rare event searches will be reported.

Keywords:

NaI(Tl) detector, low temperature

Development of a muon detector with extruded plastic scintillator and SiPM for AMoRE-II experiment.

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Abstract:

AMoRE-II (AMoRE phase-II) is next phase of the AMoRE searching for neutrino less double beta decay of 100Mo isotopes using ~200 kg of molybdenum containing cryogenic detectors. In order to maximize the sensitivity, AMoRE-II is aiming to run the detector at zero-background in various methods. One of the methods is to have the experiment to be carried in a deep underground free from the cosmic ray backgrounds. However, even in such a deep underground environment, there are still survived cosmic ray particles which can affect the measurement and should be excluded as much as possible. A muon veto counter is necessary to reject cosmic muons coming to the inner detector volume where the molybdate cryogenic detectors are located. We have studied on possibility of using an extruded plastic scintillator and wavelength shifting fiber together with SiPM as a muon veto detector. We are going to present construction and performance of the muon veto counter such as muon-gamma discrimination and muon detection efficiency.

Keywords:

AMoRE, muon, extruded scintillator, SiPM, WLS

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

Underground Rock Gamma Simulation for AMoRE

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Abstract:

AMoRE is an experiment to search neutrino-less double beta decay. The neutrino-less double beta decay phenomenon is a very rare process that we have to do an experiment at underground to control the cosmic muon background. Therefore, it is important to understand rock gammas occurring in the underground. If we simulate decays in the rock directly, system resources are consumed quite a lot. There are several ways to reduce consumption of system resources. This poster will present ways to reduce the system consumption and the simulation results.

Keywords:

Rock, Gamma, Simulation, Geant4, Underground, AMoRE, neutrino, neutrino-less double beta decay

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.16

A simulation study of neutron background in AMoRE-II

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Abstract:

The AMoRE-II (AMoRE phase-II) is the next phase of the AMoRE searching for the neutrino less double beta decay of 100Mo isotopes. In order to achieve the maximum sensitivity the AMoRE is aiming to run the detector at zero-background. One of dominant background sources are neutrons from external environment. This study is going to estimate the effects of neutrons on background rate with generated neutron energies from 1 to 10 MeV in a few different shield configurations using Geant4 simulation package. Details of the various shield configurations and their effects on neutron shielding will be presented.

Keywords:

AMoRE, neutrino-less double beta decay, Geant4, simulation, neutron background

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.18

Pulse Shape Discrimination using NEOS data with Deep learning

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Abstract:

In the NEOS experiment, pulse shape discrimination is used to distinguish between electron-recoil events and proton-recoil events using differences of their waveform shapes. Compared to the traditional way of discrimination by qtail-to-total qcharge ratio of the waveforms, a machine learning tool may utilize the whole waveform shape. Our goal is to improve the discrimination power to reduce the fast neutron background.

Keywords:

Pulse Shape Discrimination, Machine Learning

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.19

차세대 중성미자 검출기를 위한 물-기반 액체섬광검출용액 개발 연구

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Abstract:

차세대 중성미자 검출기는 대용량, 대규모를 필요로 한다. 기존의 기름-기반 액체섬광검출용액과 비교해서 물-기반 액체섬광검출용액은 여러가지 장단점을 가지고 있다. 현재 진행중인 물-기반 액체섬광검출용액 개발에 대한 상황 및 결과들에 대해 간단히 소개하고자 한다.

Keywords:

물-기반 액체섬광검출용액, 계면활성제, 기름-기반 액체섬광검출용액, 차세대 중성미자 검출기

2020 KPS Spring Meeting
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Study of Anti-Aging with a Polystyrene scintillator

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Abstract:

Polystyrene scintillator, very commonly used in the high energy particle physics experiments, is a kind of plastic that is aged by many reasons. The typical reasons of aging are the photon, the chemicals in polystyrene itself, the chemicals in laboratory, etc. It is hard to reduce the photon produced during the experiment. We can reduce the other chemicals in the scintillator by accurate manufacturing. In this study, we are focusing to study of aging by chemicals in the air and to reduce the aging by that chemicals. At the end of study, we will suggest the way of anti-aging of polystyrene scintillator.

Keywords:

Polysterene Scintillator, Anti-aging

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pa.21

Background Modeling for COSINE - 100

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Abstract:

The COSINE-100 is a direct dark matter search experiment that uses an array of scintillating NaI(Tl) crystals as a target/detector. The experiment started taking data in September 2016, and has been running stably. We have fitted the NaI(Tl) crystals' measured energy spectra for 1.7 years of data with a Monte Carlo simulation model that contains a variety of background components. Here, the modeling of background sources for the COSINE-100 WIMP search data will be presented.

Keywords:

COSINE - 100, Background, MonteCarlo Simulation, DarkMatter

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.01

Propagation of Nonlinear Structures in a Nonextensive Plasma: Effects of Ion Temperature, Electron Trapping, and Kinematic Viscosity

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Abstract:

A theoretical investigation has been made of compressive(rarefactive) monotonic double layers and solitary hole in an unmagnetized plasma which consists of warm viscous ions and nonextensive trapped electrons, taking into account effects of ion temperature, electron trapping, and kinematic viscosity. Using the usual reductive perturbation technique from a set of hydrodynamic equations, we have derived a Schamel-Korteweg-de Vries(K-dV)-Burgers equation for nonlinear structures. To solve the Schamel K-dV-Burgers equation, the tangent hyperbolic method is used. Analytic solutions for compressive(rarefactive) monotonic double layers and solitary hole are obtained. The effects of ion temperature, electron trapping, nonextensivity, and ion kinematic viscosity on the characteristics of nonlinear structures are discussed. These results are in qualitative agreement with simulation and experimental results. This simple model on nonlinear structures will provide us with an important view in space observations and simulation results of different kinds of plasmas.

Keywords:

Schamel-Korteweg-de Vries(K-dV)-Burgers equation, Reductive perturbation technique, Nonextensive plasma, Nonlinear structures

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.02

Mitigation of runaway electron by inverse Landau damping

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Abstract:

Runaway electrons (RE) of relativistic velocities can be generated during a disruption of magnetically confined plasma. Mitigation or prevention of RE is required for steady-state tokamak operation because the energetic electrons can cause severe damages on the plasma-facing components. This work probes a method to reduce the kinetic energy of RE via wave-particle interaction, namely inverse Landau damping. As expected, using a numerical Vlasov solver, it is confirmed that an electrostatic plasma wave with its phase velocity slightly slower than the RE drift velocity can take energy from the RE. This inverse damping involves the velocity space diffusion of the RE distribution function that leads to the decrease of total kinetic energy. We are now investing that the effects of multiple waves (with different amplitudes and phase velocities) on the mitigation of RE.

* This work was supported by the National Research Foundation of Korea under BK21+ program, Grant No. NRF-2017M1A7A1A03064231 and Grant No. NRF-2019M1A7A1A 03088456.

Keywords:

Runaway electron, Inverse Landau damping, Vlasov solver

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.03

Oscillation of charged particles in uniform cold plasmas

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Abstract:

20세기 중반, John Dawson은 1D cold plasma 내부에서의 입자 운동에 대한 솔루션을 얻었다. 이 솔루션 덕분에, plasma 내부에선 입자들이 진동한다는 것과 그 진동수가 ω_p라는 것이 확실히 증명될 수 있었다. 허나 이 솔루션은 Lagrangian description을 통해 유도되었으므로, plasma의 한 입자만을 설명하기엔 적합하지만, 전체 입자들의 밀도분포나 전류분포를 표현하기에는 다소 무리가 있다. 따라서 이 포스터에서는 Dawson의 솔루션을 Eulerian description으로 다시 유도해본다. 이렇게 얻어진 솔루션이 어떤 필드 분포를 만드는지 보이고, 이 분포의 진동에는 high-order harmonics($2\omega_p$,$3\omega_p$,...)가 포함되어 있음을 증명할 것이다. 또한, 1D cold plasma를 넘어 3D plasma에 대한 솔루션을 근사적으로 구하고, 그것의 특징과 물리적 의미를 논의해볼 예정이다. 그리고 마지막에는 particle-in-cell 시뮬레이션과 얻어진 솔루션들을 비교해봄으로써 솔루션의 타당성을 검증한다.

Keywords:

cold plasma, plasma frequancy, particle-in-cell

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.04

Computational Observations of Nonlinear Double Layers in Multispecies Plasma with Massive Positive/Negative Ions

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Abstract:

One dimensional particle simulations for nonlinear double layer are performed in a multispecies plasma with massive positive/negative ions. The nonlinear double layers we considered is a type of monotonic double layer and non-monotonic double layer in phase space.
We have first introduced an analytic solution of weak nonlinear double layers in multi-components plasma with negative ions. This solution is the analytic extension of the solitary hole and the monotonic double layer with a potential depression at the low potential side. This theory helps you to understand the simulation results.
In the computational procedure, potential properties in the plasma system including a various density of positive/negative ions are investigated. Physical characteristics and formation of nonlinear double layers are shown in figures. Particle simulations are performed with an axially bounded electrostatic particle-in-cell code XPDP1.

Keywords:

Nonlinear Double Layers, monotonic double layer, non-monotonic double layer, Particle simulation, XPDP1

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.05

방출광 측정에 기반한 메탄, 산소, 질소 혼합개스 화염의 회전온도 및 진동온도 측정 및 고찰

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Abstract:

화염은 전자, 이온, 중성종들이 혼합된, 약이온화된 플라즈마 상태로 볼 수 있으며, 플라즈마와 전기장 및 자기장의 상호작용을 이용하여 연소과정 안정화, 연소온도 한계 확장, 유해물질 발생 저감 등 다양한 방면에서 연구가 진행되고 있다. 최근 새롭게 주목받고 있는 화염 제어 방식은, 전자기장의 인가를 통해 화염의 발생 형상 및 전파속도를 변화시키는 것이다. 이러한 제어 방식은 연소 공간의 제어가 비접촉식으로 이루어진 다는 점에서 연소기관 수명 향상, 효율 증가, 부산물 생성 감소 등의 이점을 기대할 수 있다. 전자기장을 이용한 화염 제어에 대한 더 깊은 이해를 위해서는 화염을 구성하는 플라즈마의 물리적 특성과 그 변화를 이해하는 것이 필수적이다. 본 연구에서는 화염의 방출광을 분석하여 화염내 이원자분자(diatomic molecule)의 회전온도(rotational temperature) 및 진동온도(vibrational temperature)를 측정하고, 기체조성에 따라 달라지는 연소 상태 변화를 실험적으로 고찰하였다. 화염은 산화제인 산소와 연료인 메탄, 기체흐름을 제어하기 위한 질소 가스의 비율에 따라 세 가지 다른 형상을 보였으며, 각각에 대해 방출광 측정을 진행했다. 방출광 측정은 화염 내에서 측정 지점을 선정할 수 있도록 설계된 수광부와 소형 분광기로 구성된 광학계를 구성하여 얻었다. 본 발표에서는 측정된 방출광의 분석, 특징적으로 나타난 OH와 CH 이원자분자 방출광을 기반으로 한 회전온도와 진동온도의 측정결과를 토의한다. 본 연구결과는 추후 진행할, 전기장 인가 조건에 따른 화염 내 2차원 온도 분포 및 전기장과 화염 특성 간의 상관관계 규명을 위한 기반기술이 될 것이다.

Keywords:

화염, 방출광, 진동온도, 회전온도

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.06

The change of the solenoid frequency effect on the diocotron instability in AC magnetic fields

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Abstract:

Diocotron instabilities occur in non-neutral plasmas due to the velocity shear of the electron beam. The stability of this instability was analyzed in the previous study. The method of reducing the diocotron instability with rotating magnetic fields was discovered [1]. However, there is no analytical theory for the diocotron instability with rotating magnetic fields. In this study, using the numerical simulation, it is found that which range of the rotating magnetic fields' frequency is suitable for decreasing this instability with the proper density broadening. On the one hand, low frequencies make the electron density broad, on the other hand, high frequencies make this electron plasma unstable. The adequate frequencies ease these instabilities while radially enhanced motions repeatedly broaden and contract the electron density.

[1] Y. H. Jo, J. S. Kim, G. Stancari, M. Chung, and H. J. Lee, "Control of the diocotron instability of a hollow electron beam with periodic dipole magnets", Phys. Plasmas vol. 25, 011607 (2018).

Keywords:

Diocotron instability, rotating magnetic fields' frequency, numerical simulation

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

레이저 유도 형광법을 이용한 헬륨 플라즈마의 충돌 전이 연구

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Abstract:

헬륨 준안정 준위원자의 특성 연구는 주로 레이저 흡수 분광학(Laser Absorption Spectroscopy)과 레이저 유도 형광법(Laser Induced Fluorescence)을 이용하여 연구되고 있다. 본 연구에서는 헬륨 플라즈마의 충돌 전이에 대해 연구하기 위해 레이저 유도 형광 신호를 측정하였다. 레이저 광은 선폭이 1 MHz 이내인 ECDL(external cavity diode laser)을 이용하였으며, 플라즈마에 수직으로 레이저 광을 조사하고, notch filter를 이용하여 레이저 광을 제거하였다. 광원으로는 파장 396 nm, 1083 nm 2개의 광원을 이용하였다. 396 nm 파장의 광원은 $2^1S \rightarrow 4^1P$ 흡수전이, 1083 nm 파장의 광원은 $2^3S \rightarrow 3^3P$ 흡수전이를 유도하는데 사용되었다. 플라즈마 발생장치로는 유도결합 플라즈마(inductively coupled plasma) 발생장치를 사용하였으며, 압력 5mTorr ~ 50mTorr 전력 50W ~ 1300W 범위에서 동작하였다. 여러 플라즈마 동작 조건에 대해 레이저 유도 형광 신호를 측정하였으며, 측정된 스펙트럼을 이용하여 전이선 세기 변화를 분석하였다. 분석된 전이선 세기 변화를 통해 충돌 전이 특성에 대해 분석하였다.

Keywords:

inductively oupled plasma, spectroscopy, laser induced fluorescence, 23S meatastable state

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.08

대기압 코로나 및 표면유전장벽 방전 플라즈마에서 전기풍 발생조건 탐색 및 플라즈마 특성 분석

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Abstract:

대기압 약전리 플라즈마 내의 전자, 이온 등 하전입자가 중성기체 입자와의 충돌에 의해 운동량이 교환되면서 전기역학적 힘이 기체입자에 가해지며 이로 인해 발생하는 기체의 흐름을 전기풍(Electric wind)이라 한다. 이 현상은 대기 내의 약이온화된 기체에서도 나타나 여러 자연현상의 발생 원인으로 주목받아 왔으며, 현상 이해에 대한 연구와 함께 공간적 제약없이 전기에너지만으로 기체의 높은 유속을 발생시킬 수 있다는 점에서 응용 연구 또한 진행되고 있다. 본 연구에서는 코로나 및 표면유전장벽 방전 방식의 두 전기풍 발생원을 제작하고, 실험적으로 발생되는 전기풍의 유속을 측정하고 이를 최대화하기 위한 조건 탐색을 진행하였다. 플라즈마 발생을 위한 고전압 전원으로는 최대 20 kV, 100 kHz의 사인파 가변 교류전원을 사용하였으며, 실험 결과 두 방식의 발생원 모두 전극으로부터 2 cm 떨어진 위치에서 최대 유속이 약 1.4 m/s로 측정되었고 인가전압을 높이고 인가주파수를 낮출수록 전기풍의 유속이 높게 측정되었다. 또한 전기풍 유속 분포를 파악하기 위해 전극으로부터 수평 및 수직 방향의 위치에 따른 전기풍 유속 측정도 함께 진행하였다. 이와 함께 전기풍 및 플라즈마의 발생 원리를 파악하고 이에 대한 이해를 높이기 위해 발생원을 모사한 2차원 전산모델을 이용하여 실험과 유사한 조건에서 전산모사를 진행하였다. 전자 및 이온 밀도 및 특성과 전기장의 세기 등 플라즈마 및 전기역학적 힘과 관련된 변수들을 계산하였고, 이를 통해 전자와 이온이 전기풍 생성에 미치는 영향을 정량적으로 분석하였다. 이 연구를 통해 실험을 통한 전기풍 발생조건 탐색과 전산모사를 통한 플라즈마 특성 분석을 함께 진행되었으며, 개발된 2차원 전산모델은 전기풍 발생에 대한 이해를 넓히고 전기풍 발생 최적조건을 찾는 도구로 유용하게 이용될 것이다.

Keywords:

전기풍, 표면유전장벽 방전, 코로나 방전, 전산모사

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.09

100 W 이하 저전력 홀추력기의 방전모드 변화에 따른 이온빔 특성 연구

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Abstract:

홀추력기는 외부에서 인가한 자기장에 의해 자화된 전자를 방전이 일어나는 채널 내부에 구속하여 방전을 유지하고, 자화되지 않은 이온은 축방향으로 가속되어 분사되게 하여 추진력을 얻는 전기추력기의 일종으로, 인가전력 대비 추력과 비추력이 상대적으로 높아 여러 우주임무에 활용되고 있다. 최근 100 kg 이하의 초소형 위성의 수요 증가로 인해 100 W 이하의 저전력 홀추력기 기초연구 및 개발 중요성 역시 상승하고 있다. 일반적으로 저전력 홀추력기는 채널반경이 작아 채널부피 대비 표면적이 커서 채널벽으로의 입자 및 전력 손실을 야기하여 추력성능 및 수명감소 등의 난제를 수반하기 때문에, 자기장 등의 운전변수에 따른 방전특성 분석이 필수적이다. 본 연구에서는 100 W 이하 홀추력기의 양극유량 및 양극전압에 따른 플룸 플라즈마의 특성을 분석하였다. 개발된 홀추력기의 자기장은 채널벽으로의 입자손실을 줄이기 위해 영구자석과 전자석을 활용하여 자기력선이 채널벽과 바로 닿지 않고 양극 방향으로 오목하게 설계되었다. 홀추력기 방전은 제논유량 2.8 – 4.3 sccm, 양극전압 160 – 280 V 및 양극전력 30 – 70 W 범위에서 수행되었으며, 특히 제논유량 4.3 sccm, 양극전압 200 V에서 이온빔의 형상 변화와 함께 방전전류가 21% 감소하고 추력은 12% 증가하는 방전모드 변화가 관찰되었다. 레이저유도형광 진단의 결과, 모드변화 직후 이온가속 범위는 출구면 기준 축방향 40 mm로부터 10 mm 이내로 감소하였으며, 전위지연탐침 측정 결과 양극전압 200 – 260 V에서 모드변화 직후 이온에너지분포의 반치폭이 14 – 50% 감소하였다. 또한 코로나 모델을 활용한 Xe I 스펙트럼 분석의 결과, 출구면 앞단 10 mm에서 모드변화 직후 이온화율은 40 – 60% 감소하여, 홀추력기의 이온화영역이 모드변화 직후 채널밖에서 감소하고 채널내부로 집중되는 것으로 분석되었다. 본 발표에서는 채널밖 이온화영역 감소에 따른 보다 상세한 빔특성 변화에 대해 논의한다.

Keywords:

이온빔 진단, 저전력 홀추력기, 자기장 제어

P1-pl.10

A possible Thomson scattering system for both atmospheric and vacuum plasma conditions

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Abstract:

Thomson scattering (TS) is a well-known plasma diagnostic for measuring the electron temperature and density. The previous TS system uses Nd:YAG laser at 250 mJ with repetition rate of 20 Hz. When focusing the laser beam at atmospheric conditions, the laser ionizes air where recombination takes place releasing abundant amount of photons at 532 nm. This tends to saturate the captured image of the ICCD camera even when gain is not applied. Therefore, the previous TS system is suitable for only vacuum plasmas. To apply TS at atmospheric conditions require a diode pumped Nd:YAG laser with much lower energy ~ 5 mJ but at a higher repetition rate of ~ 10 kHz. A possible TS system of using these two lasers, one for vacuum the other for atmospheric plasma, while sharing pre-existing collection optics and spectrometer has been considered. The beam path is merged by a polarized beam splitter. This would greatly reduce the expense of having two separate systems. A calibration chamber is needed so that vacuum conditions could be reached, while Rayleigh and Raman scattering are conducted to obtain factors needed for absolute calibration of the electron density. The previous TS system uses triple-grating to eliminate stray-light. For the combined TS system, single grating will be used to enhance spectral resolution and optical transmission. This will increase chances of detecting stray-light. However, there are several methods that can be implemented inside the calibration chamber to keep stray-light to a minimum.

Keywords:

Plasma, Thomson scattering, Laser

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.11

A tendency of Electromagnetic field change in MHD Plasma Fluid Generator

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Abstract:

An electromagnetic field of Magnetohydrodynamic (MHD) plasma fluid generator was analyzed for the application of cogeneration system. The MHD generator system have a high efficiency compared to the other generator system due to high temperature plasma fluid. A residual heat is remained after the MHD generation, so it is generally combined with the steam generator. The magnetic and electric field that directly affects to the electric generation was analyzed for calculating the electric power. The velocity profile of generator was described, then magnetic flux density has been analyzed. The power condition was set to 10 kW in the condition of temperature of 3000 K, velocity of 10 m/s, and mean magnetic flux density of 5 T.

Keywords:

MHD, Generator, Electromagnetic

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.13

Two-dimensional particle-in-cell simulation for the effect of the hollow-cathode showerhead on capacitively RF plasmas

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Abstract:

The plasma property in a capacitively coupled deposition reactor with the hollow cathode showerhead has been investigated using a 2D PIC simulation with the variation of the hole size, the secondary electron emission coefficient, the background pressure, and the edge shape of the hole. A ghost fluid method is used to reduce field enhancement by reducing the sharpness of the edge of the hole because extreme corners directly affect heating. When the hole size is large enough, there are two electron density peaks located in the hollow cathode and in the outer bulk plasma. The former is caused by the enhanced secondary electron emission, and the latter is by the ionization near the substrate. The hole size and the side slopes were varied to compare the plasma density and secondary electron emissions. Regardless of the hole size, ion heating was strongly affected in a sharp edge while electron heating is not affected by the edge slope.

Keywords:

Particle-in-cell, Hollow cathode, Capacitively coupled plasma, Showerhead

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.14

Global modeling of N_2/Ar and N_2/He discharges in the remote plasma source

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Abstract:

An inductively coupled remote plasma source (RPS) is widely used in semiconductor processing to utilize radicals that have relatively low kinetic energy. In this study, conditions for the efficient production of nitrogen atoms were investigated for both nitrogen-argon and nitrogen-helium gas mixture. The dominant chemical reactions were investigated at the steady-state. The productivity of nitrogen atoms is mainly controlled by the RF coil power and the partial fraction of the injected nitrogen molecules. The most dominant reaction mechanism for nitrogen-argon plasmas is the increment of the reactions which increase the density of the nitrogen atom compared with that of the injected nitrogen molecule. In the case of nitrogen-helium plasmas, however, the most dominant reaction mechanism is the decrement of the reactions which decrease the density of the nitrogen atom compared with that of the injected nitrogen molecule. Furthermore, the effect of metal grids on the plasma density was added to the global model by making neutral gas species escape from the chamber while charged particles remain with the constant chamber pressure. The calculated charged particle densities are almost the same with or without the metal grids.

Keywords:

Global model, production of nitrogen atoms, metal grid effect, remote plasma source

Plasma parameters measurement by analyzing bremsstrahlung continuum radiation in a helium plasma jet at atmospheric pressure

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Abstract:

Bremsstrahlung continuum radiation is emitted when the electrons are deflected in the electric field of the ions or atoms. Plasma parameters can be figured out by analyzing bremsstrahlung continuum radiation. In our experiment, a helium atmospheric pressure plasma jet (APPJ) based on dielectric barrier discharge was constructed by using a quartz tube and two metal electrodes. Helium plasma was generated by applying an AC voltage to two electrodes at the frequency of 5kHz and the amplitude of 10kVp.p. Plasma spectra were measured at three different positions: the position between the two electrodes, the position from an electrode to the end of the quartz tube, and the position outside the quartz tube. Bremsstrahlung continuum radiation was observed in the helium plasma spectrum at the region between the two metal electrodes. An additional metal electrode was placed outside the quartz tube to enhance the plasma intensity. Comparing with the plasma spectra of the nonappearance of the additionnal metal electrode, measured bremsstrahlung continuum radiation spectra were different when the additional metal electrode was installed. Plasma parameters were determined by analyzing the spectra of the emitted bremsstrahlung continuum radiation.

Keywords:

Atmospheric pressure plasma jet, helium plasma, continuum radiation, bremsstrahlung

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.16

OH 분자의 스펙트럼을 이용한 헬륨 대기압 플라즈마 제트의 가스 온도 측정

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Abstract:

유전체 장벽 방전 원리를 이용하여 대기압 플라즈마 제트 장치를 구성하고 대기압 플라즈마를 발생 시킨 후 플라즈마의 가스 온도를 측정하였다. Quartz 튜브 속에 디지털 유량 조절기(Mass Flow Controller)를 사용하여 2LPM의 헬륨가스를 흘려보내 주고, 함수 발생기와 교류 증폭기를 사용하여 주파수 5kHz, 전압 10kVpp인 사인 파형의 교류전압을 전극에 가해주었다. 플라즈마 방출광을 두개의 렌즈와 광섬유로 수집하였고, 분해능이 0.05nm인 분광기를 사용하여 OH 분자의 분광 신호를 측정하였다. 측정된 OH 분자의 분광 신호에 대한 Boltzmann plot 방법을 이용하여 가스 온도를 구한 결과 ~315K을 얻었다. 또한, 각기 다른 주파수, 전압, 헬륨가스의 유량에 따른 가스 온도의 변화를 분석하였다.

Keywords:

헬륨 플라즈마, 대기압 플라즈마 제트 , OH

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.17

Status of KSTAR Thomson Scattering Diagnostic System in 2019 KSTAR campaign

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Abstract:

Thomson scattering diagnostic is most important diagnostic system to measure an electron temperature and electron density in high temperature plasma like as a nuclear fusion machine. As this reason the most nuclear fusion machine equipped the Thomson scattering system. KSTAR Thomson scattering diagnostic had been installed for the first time in 2010 [1]. Since after first installation KSTAR Thomson scattering system is upgrading every year. In 2019 KSTAR Thomson scattering system was upgraded; First, four optical-fibers were added thus total measuring points were 31 points. Second, the edge collection lens were re-installed to improve an f-number. Third, anti-vibration system for collection system were installed. For the optical-fiber, until the last year the optical-fiber bundles were installed horizontally but in 2019 vertically installed to increase the measuring points. Because the optical-fiber clamp which hold the optical-fibers have limit of size. The new edge collection lens f-number is 0.768 times smaller than the edge collection lens which made 2018 to collect more scattered light from the plasma edge region. During the Rayleigh calibration to calculate the electron density profile a stray light was dramatically increased in 2019. That reason was a two-color interferometer system and an ICRH system were newly installed in the KSTAR vacuum vessel. To decrease the error of electron density calculation the stray light was effectively eliminated by using a 5 Giga-Sampling Digitizer (5GS/s). In this research, I will explain status of Thomson scattering diagnostic and next upgrade plan.

Reference:

1. J. H. Lee *et al.*, Development of KSTAR Thomson scattering system, Review of Scientific Instruments 81, 10D528 (2010).

Keywords:

Thomson scattering, KSTAR, Tokamak, Diagnostic

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.18

토카막 플라즈마 내 불순물 수송계수 도출을 위한 인공신경망 학습데이터 생성 알고리즘 개발

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Abstract:

토카막 플라즈마 내에 존재하는 불순물은 노심 내에 축적되면 높은 방사냉각을 발생시킬 뿐만 아니라 연료이온의 농도를 희석시켜 감금성능에 치명적인 영향을 미친다. 따라서, 불순물 수송현상 분석을 통해 노심 내 불순물의 농도를 제어하는 것은 필수적이다. 본 연구에서는 KAIST Impurity Modeling (KIM) 코드[1]와 각종 플라즈마 진단 데이터를 기반으로 불순물 입자의 수송계수를 자동적으로 도출하기 위해 인공신경망을 이용한 코드를 개발하는 것을 목표로 한다. 이를 통해 높은 정확도를 가진 불순물 확산계수와 대류계수를 개선된 계산속도로 얻을 수 있으며 불순물 수송현상의 기작을 분석할 수 있다. 첫 단계로, 실제 KSTAR에서 측정된 H-mode상태의 전자 온도 및 밀도 분포의 피팅작업을 수행한다. 피팅은 경사하강법(gradient descent algorithm)을 이용하여 평균제곱오차가 주어진 오차한계에 도달할 때까지 피팅함수의 계수들을 최적화하는 방식을 사용한다[2]. 이후 피팅된 프로파일을 바탕으로 10% 표준편차를 가진 가우시안 분포의 난수 발생기를 통해 가상의 H-mode 플라즈마 변수 분포들을 대량으로 생성한다. 추후에 이 가상의 변수 분포들은 휴리스틱 방식으로 수송계수를 도출한 기존 코드에 비해 향상된 정확도와 계산시간을 갖는 순환-합성곱신경망(Conv-RNN) 학습에 사용될 것이다.

참고문헌:

[1] I. Song *et al.,* 27th IAEA Fusion Energy Conference, Gandhinagar, India (2018)
[2] E. Stenfanikova *et al.*, Rev. Sci. Instrum., **87**, 11E536 (2016)

Keywords:

인공신경망, 불순물 수송

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.19

KSTAR 진공자외선(VUV) 분광 진단 시스템을 활용한 불순물 모니터링을 위한 후처리 프레임워크 개발

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Abstract:

진공 자외선(VUV) 및 극진공 자외성(EUV) 분광계는 토카막 플라즈마 내의 불순물들이 방출하는 분광선 정보를 제공하므로 불순물 모니터링을 위한 중요한 진단계이다. 또한 이들 분광계는 디버터에서 플라즈마 내로 유입되는 불순물을 모니터링할 수 있어 토카막 장치 보호와 핵융합로의 안정적인 플라즈마 운전에 필수적이다. 그러나 플라즈마로부터 방출되는 중성자와 감마선, 그리고 장치의 기계적 진동으로 인해 이들 분광 진단계의 측정결과에 심각한 노이즈가 발생한다. 따라서 정확한 스펙트럼 분석을 위해서는 적절한 스펙트럼 데이터 후처리를 통해 신뢰도 높은 데이터 획득이 필요하다. 본 연구에서는 네트워크 기반의 분산 제어 기능을 제공하는 EPICS 프레임워크를 사용하여, 기개발된 KSTAR의 VUV 진단 시스템 운용 코드에 불순물 모니터링을 위한 프레임워크를 통합하여 개발하였다. 정확한 데이터 처리를 위해 in-situ 파장 보정 및 노이즈 제거 기능을 포함하여 이전에 개발된 후처리 알고리즘이 시스템에 적용되었다[1]. 노이즈 제거 알고리즘의 경우, 실시간 모니터링을 위해 스펙트럼과 시간 방향 모두에서 노이즈를 제거하기 위해 시간적으로 연속된 3개의 프레임으로 구성된 각 스펙트럼 데이터 세트에 노이즈 제거 필터를 적용하였다. 이 단계에서 처리된 스펙트럼을 개발된 GUI 프레임워크에 삽입하여 데이터의 가시성과 접근성을 향상시켰다.

참고문헌:

[1] H. Shin *et al.,* Fusion Eng. Des. **153** (2020) 111495

Keywords:

KSTAR, 진공자외선(VUV) 분광 진단, Tokamak plasma

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.20

제한된 시선의 분광계에서 토카막 플라즈마 비대칭 분포를 이용한 토모그래피 재구성 방법 개발

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Abstract:

토카막 플라즈마 내 불순물의 거동과 분포를 파악하는 것은 안정적인 플라즈마 운용에 필수적이다. 진공 자외선(VUV) 및 극진공 자외선(EUV) 분광계는 다양한 불순물 분포 측정에 중요한 진단계로 여러 토카막 장치에서 활발하게 이용되고 있으며, 공간분해능을 가진 경우 토모그래피 재구성을 통해 장치 내 불순물 분포를 얻을 수 있다. 하지만 대부분의 토카막의 경우 광학계 시선이 공간적으로 제한적이어서 기존의 재구성 방법으로 얻은 2차원 불순물 분포의 신뢰도는 현저히 낮은 편이다. 본 연구에서는 제한된 분광계 시선으로 인한 기존 토모그래피 재구성 한계를 극복하고 불순물의 폴로이달 2차원 분포를 얻어내는 새로운 재구성 기술을 개발하였다. 개발된 재구성 방법은 Philips-Tikhonov 알고리즘을 기반으로 토카막 플라즈마의 자기장 정보를 이용해 (Ψ, θ) 그리드를 생성하여 토로이달 회전에 의한 원심력 효과가 고려된 마하 넘버에 의해 이론적으로 예측된 플라즈마 불순물 분포를 가중치로 적용해 재구성의 신뢰도를 높였다. 본 재구성 방법은 여러 가상(synthetic) 불순물 분포들의 분광데이터를 이용하여 검증되었고, KSTAR에 설치된 이미징 극자외선(EUV) 분광계인 CAES[1]로부터 측정된 실제 분광데이터에 적용하여 탄소와 산소 불순물인 C V (4.03 nm), C VI (3.37 nm), O VIII (2×1.90 nm)의 확연한 폴로이달 비대칭 분포를 성공적으로 확인하였다. 본 연구에서 개발된 재구성 기술은 ITER를 포함한 차세대 핵융합 장치에서의 불순물 수송 연구에 유용하게 활용될 것으로 기대된다.

Keywords:

토모그래피, 플라즈마 비대칭 분포, 분광계

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.21

KSTAR H-mode 플라즈마에서 D2 연료개스 주입에 의한 디버터 플라즈마 분리현상 실험 및 전산해석

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Abstract:

ITER 및 DEMO와 같은 미래 핵융합 장치에서는 노심 플라즈마로부터 디버터 타겟으로 향하는 열속이 대면재료의 물질적 한계보다 훨씬 높을 것으로 예상되어, 불순물 개스나 D2 연료개스 주입을 통해 디버터와 플라즈마를 분리시키는 기법이 디버터 열속제어의 효과적인 방법 중 하나로 알려져 있다. KSTAR에서는 저성능 운전모드인 L-mode에서 디버터 플라즈마 분리현상이 성공적으로 달성되었고[1], 고성능 운전모드인 H-mode에서의 연구에 대한 필요성이 제기되어 왔다. 이에 본 연구에서는 2019 KSTAR 캠페인에서 D2 연료개스 주입을 통한 H-mode 디버터 플라즈마 분리현상 실험을 수행하고 경계 플라즈마 해석 코드인 SOLPS-ITER를 이용하여 전산모사를 진행하였다. 전자밀도 상승 실험에서 랑뮈어 탐침배열로 측정한 결과 양 디버터 타겟에서 부분적인 분리현상이 달성되었으며, L-mode에서 나타났던 외/내측 타겟 간의 독특한 비대칭성[1]이 H-mode에서도 재현되었다. 외측타겟에서의 최대 입자속이 High recycling 조건에서 나타나는 값에 비해 3배 가까이 감소한 반면, 내측타겟에서의 최대 입자속은 거의 감소하지 않았다. 부분 분리현상 달성 이후 곧이어 L-mode로 전이되었는데, 이는 다른 탄소 대면재 토카막에서 수행된 H-mode 밀도한계 연구에서 관찰되었던 것과 유사하다[2]. 실험결과를 바탕으로 전산모사를 진행한 결과, 전자밀도 증가에 따른 타겟 입자속 변화를 정성적으로 재현하였다. 실험과 같이 외측타겟에서의 최대 입자속 감소율이 내측타겟보다 더 크게 나타났다. 자기장 수직방향의 수송계수 분포를 조정하면 정성적 재현뿐만 아니라 정량적 재현까지 가능할 것으로 예상된다. 본 연구는 불순물 개스 주입 또는 3차원 자기장이 존재하는 복잡한 조건에서의 디버터 플라즈마 분리현상 연구에 기반을 제공할 것이며, SOLPS-ITER와 같은 전산코드에 사용되고 있는 경계 플라즈마 모델을 보완하고 검증하는데 기여할 것으로 예상된다.

참고문헌

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Keywords:

KSTAR, H-mode, 디버터, 디버터 플라즈마 분리현상, SOLPS

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.22

Measurement of Deuterium Transport Parameters in ITER-grade samples of Tungsten and SS316LN

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Abstract:

Transport of hydrogen and its isotopes (deuterium and tritium) in fusion materials is one of the key issues for nuclear fusion operation in relation to safety. In this study, we have performed deuterium permeation experiments for the ITER-grade samples of tungsten and 316LN in the temperature ranges of 650–850 °C and 350–850 °C, respectively. The samples were fabricated into disks [20 mm in diameter and 0.2 mm (tungsten) or 0.5 mm (SS316LN) in thickness], and transports parameters (permeability, diffusivity, and solubility) of deuterium in the samples were experimentally measured by using the time-dependent gas-phase technique. Detailed results are presented, and our results are also compared with those previously reported by other authors.

Keywords:

ITER-grade tungsten, ITER-grade SS316LM, Deuterium, transport

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

Development of Automated Postprocessing System for ECEI Data

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Abstract:

An automatic postprocessing code has been developed to increase the availability of the electron cyclotron emission imaging (ECEI) data on the KSTAR. The code removes the white noise and low intensity components of data in the spectral domain using the threshold filtering technique [1]. The 2D images constructed from the postprocessed data demonstrate that the quality of the automated filtering is as good as the quality of the conventional manual filtering. The code is now able to generate 2D ECEI images with the virtual frame rate of 100 Hz for typical 10 s long discharge within the inter-shot period (about 10 min). It is envisioned that the automatically generated ECEI images without need for manual selection of filtering parameters will enable fast analysis of MHD activities.
This work is supported by NRF of Korea under grant no. NRF-2019M1A7A1A03088456.

[1] K. J. Kim, Master's thesis "Adaptive postprocessing of high frame ratio image data based on threshold filtering in spectral domain"

Keywords:

KSTAR, ECEI, Threshold filtering, Automated Data Postprocessing

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.24

Effect of flow imbalance on the operational performance of the KSTAR PF1UL magnets

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Abstract:

: A cryogenic circuit for large scaled superconducting device like a tokamak is installed quite complex. In the KSTAR tokamak, the five cryogenic circuits are managed for cooling of each components (Toroidal Field magnets, Poloidal Field magnets, structures current leads, thermal shield, bus-lines) independently. The circuit for the Poloidal Field magnets branches into one hundred cooling channels. Five cryogenic valves are controlling the flow rates according to cooling channel length. The KSTAR PF1 upper and lower magnets have ten cooling channels parallel respectively. The pressure drop of the magnets is adjusted by cryogenic valve and is maintained by a supercritical helium circulator. The flow rate should be uniform among the cooling channels or magnets but the flow imbalance was observed during the flow test of magnet individually. The measured imbalance was around 10 % between KSTAR PF1 upper and lower. To investigate for effect of the flow imbalance on the magnet, the simple model of the PF1 upper and lower magnets has been developed using SUPER-MAGNET code. The maximum temperature trends are studied in details depending on the imbalance

Keywords:

KSTAR, flow imbalance, superconducting magnet, supercritical helium

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.25

Nonlinear MHD Study on the SPI induced Thermal Quench in KSTAR Hybrid Scenarios

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Abstract:

Shattered pellet injection (SPI) is the baseline concept for the disruption mitigation system (DMS) in ITER, in which a cryogenic pellet is shattered into the disrupting plasma to mitigate the consequences of a disruption [1, 2]. SPI has experimentally shown improved disruption mitigation performance compared with other DMS concepts, and numerical studies have pointed the convective 1/1 kink mode to be the main mechanism that determines the disruption mitigation properties such as core mixing, and toroidal peaking factor [3, 4]. Since many advanced scenarios target plasmas whose q profile is flat near the plasma core, possibly absent of $q=1$ surface, it is important to examine the disruption mitigation properties with those discharges before its actual exploration in ITER. The 3D nonlinear reduced MHD code JOREK is being used to investigate the disruption mitigation by SPI in KSTAR. While the whole disruption process comprises of Thermal Quench (TQ), Current Quench (CQ), and as well as the Runaway Electron generation, we will focus on the TQ mitigation as it can also give basic parameters for the following events with relatively easy means of investigation of MHD model.

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Keywords:

Shattered Pellet Injection, Nonlinear MHD, KSTAR, Hybrid scenario, Disruption

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.26

Design and Calibration of New Polychromators in KSTAR Thomson Scattering Diagnostic

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Abstract:

Thomson scattering (TS) is a standard diagnostic device for measuring the electron temperature and density in Tokamaks.
The KSTAR TS system had 27 polychromators in 2018(core area: 14ea, edge area: 13ea). In 2019, four more polychromators were installed to increase the spatial resolution of the TS signal.
To make a new polychromator, a polychromator case, relay lens, band-pass filter and avalanche photo diode (APD) are required [1]. Of these, the polychromator case was provided in NIFS, Japan.
To verify the characteristics of each part, the following methods were tested. TS diagnostic is very sensitive to measure a scattered signal because the signal is less than 50mV. For this reason, noise reduction in an APD is important. So, we measured the signal to noise ratio (S/N) during increase the driving voltage of APD and found the value of the break APD down voltage. And we used a tungsten lamp to check the wavelength and bandwidth of the band-pass filter, and to fix the position of each part inside the polychromator case. Finally, to verify the optimal spectral response of new polychromator, we used a tungsten lamp and monochromator system.
As a result, in the 2019 KSTAR campaign, TS system had 31 polychromators. 14 polychromators were installed to measure the core area and the other 17 polychroamtors were installed to measure the edge area.

Reference

[1] J.H.Lee et al., “Development of prototype polychromator system for KSTAR Thomson scattering diagnostic”, Journal of Instrumentation 10 C12012(2015).

Keywords:

KSTAR, polychromator, APD

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.27

Edge-localized RF bursts in the KSTAR H-mode pedestal collapse

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Abstract:

We have developed a new diagnostic system on the KSTAR tokamak to measure radio frequency (RF) modulations of the electron cyclotron emission (ECE) in the mm-wave range. The RF diagnostic system utilizes the mm-wave heterodyne detectors in the ECE imaging system on the KSTAR [1] and provides high-speed (20 GSa/s max.) measurement with broad (<8 GHz) frequency range. For the case of the edge transport barrier (pedestal) collapse, the RF measurements at two different toroidal positions ($\Delta\phi \sim 18.5°$) show that intense waves of similar spectral characters are observed only along a specific direction (approximately the magnetic field line). This observation supports that the onset of pedestal collapse occurs at a localized region in the edge [2-3] and generates RF waves propagating mostly parallel to the magnetic field line. The origin of the intense RF waves is under investigation such as the excitation of upper-hybrid waves under double plasma resonance (DPR) condition [4] or whistler waves in the process of magnetic reconnection [5]. This work is supported by R&D program of "KSTAR Experimental Collaboration and Fusion plasma research" (NFRI-EN2001-11) and the National Research Foundation of Korea under contract No. NRF-2019M1A7A1A03088456 and 2019R1F1A1057545.

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Keywords:

Magnetic reconnection, Pedestal collapse, RF burst, Whistler wave

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.28

Line integrated density measurement based on refractometer

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Abstract:

Frequency modulated continuous wave (FMCW) reflectometer has been widely used to measure the plasma density profile by launching linearly frequency modulated microwave into the plasma and measuring the group delay of the microwave reflected at the cutoff density. For a certain frequency range, the microwave just passes through the plasma and reflects back from the vacuum inner wall. By analyzing the phase information of the passing-through microwave, the line integrated density can be obtained. The reflectometer operated in this particular regime is called refractometer. In the case that the microwave frequency is much higher than the plasma frequency, the line integrated density is directly given by the group delay. For the frequency range slightly higher than the plasma frequency, the refractometry measurements are dependent not only on the line integrated density but also on the details of the plasma density profile and the magnetic field intensity. It is analytically shown that the group delay can be expanded as a Taylor series of squared inverse frequencies. The coefficients of the Taylor series correspond to the moments of line integrated density. Therefore the line integrated density can be obtained by polynomial fitting the group delay as a function of squared inverse frequencies even in the case that the microwave frequency is compatible with the plasma frequency. This is confirmed by simulating the response of the refractometer for the various density profiles. This method works without assumption of a particular shaped plasma. The experimental measurements are also compared with the interferometry measurements in the KSTAR tokamak.

Keywords:

refractometer, line integrated density

KSTAR H-mode 플라즈마에서의 Heat flux width 연구

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Abstract:

Heat flux width(λ_q)는 디버터에 가해지는 열속을 결정하는 주요한 변수이다. 본 연구에서는 KSTAR H-mode 플라즈마의 λ_q를 SOLPS-ITER 전산코드를 이용한 모델링으로 계산하고, 그 결과를 실제 실험 데이터로부터 추정된 λ_q 및 empirical scaling law의 경향과 비교하였다. KSTAR 실험 데이터로부터 추정된 λ_q는 디버터에서의 열속 분포에 대한 analytic fit function을 바탕으로 도출되었다. 확산계수는 ballooning 불안정성을 고려한 simple practical model을 기반으로 고정하였다. 또한, 디버터에서의 열속 분포도 SOLPS 모델링의 계산과 비교되었다. 후속연구로 디버터 분리현상 및 KSTAR의 new actively cooled 텅스텐 디버터에 대한 λ_q추정이 진행될 예정이다.

Keywords:

Heat flux width, SOLPS, KSTAR

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.30

SOLPS모델링을 통한 KSTAR Closed 형태 디버터 구조 효과 분석

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Abstract:

장기간 기동을 고려하는 차세대 토카막 장치 및 실증로를 달성하기 위해서는 기존의 디버터에 비해 열속 완화 효과가 월등하게 좋아야 한다. 이는 플라즈마 대면체로 고려중인 재질이 10MW/m^2 이하의 열속과 5eV 이하의 온도를 달성하지 못하면 sputtering이나 Erosion이 발생하여서 디버터 자체의 손상이 누적 될 뿐 아니라 노심으로의 불순물 유입으로 인한 노심플라즈마 품질 저하로 인하여 장기간 구동이 불가능해지기 때문이다. 해당 조건을 만족 시키기 위해 디버터 타겟 분리 현상이 경계플라즈마 분야에서 가장 유력한 후보로 거론되고 있다. 디버터 분리현상에 대한 물리적인 이해는 아직 진행중에 있지만, 많은 연구결과에 따르면 토카막 구동조건, 사이즈, 디버터 구조, 재질등 여러 조건에 영향을 받는다는 사실이 알려져 있고, 또한 디버터 타겟에서의 중성입자 밀도와 매우 높은 상관관계를 가진다는 것이 밝혀졌다. 우리는 이 연구에서 디버터 구조를 바꿈으로써 생기는 중성입자 거동의 변화와 디버터 분리현상의 상관관계에 대하여 논의해보고자 한다. 특히 미국 DIII-D의 SAS(Small Angle Slot)과 유사한 구조와 기존 KSTAR의 디버터 구조에 대한 직접적인 비교를 통하여 디버터 분리현상에 대한 분석을 진행하였다. 해당 구조변경은 KSTAR의 Central Outer Target에 적용하였으며, 모든 전산모사는 SOLPS-ITER 패키지를 통하여 진행되었다.

Keywords:

KSTAR, SAS(Small Angle Slot), Tokamak, SOLPS-ITER, Divertor detachment

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.31

Progress on the Development of 2D Plasma/Neutral Transport Simulation System from Core to Wall in KSTAR

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Abstract:

Plasma Wall Interaction (PWI) is important due to the affection of core plasma performance as well as the wall damage [1, 2]. The two-dimensional plasma transport simulation is needed to investigate the plasma transport from the complex geometry of the tokamak structure. The outstanding issues are the grid generation in that complex and open-field configuration near the wall, and the coupled simulation of core-edge-SOL (Scrape-Off Layer) region. In this work, we present progress of the development of two-dimensional plasma and neutral transport simulation system in the domain including the core, edge, SOL and the far SOL region near the wall. This simulation system consists of a 2D plasma transport solver C2 [3], a neutral particle transport solver GTNEUT [4], and a grid generator VEGA2.0 [5, 6]. The computational domain was modified to include the far SOL region by adding a conformal mapping based method [7] to the grid generator. In addition, by considering the cross-diffusion, the contribution of the heat flux from the misalignment of the magnetic field surface and the geometry near the wall is solved. Some KSTAR hybrid scenarios sustaining high performance without harmful MHD are reproduced for the validation of the simulation system by using the fitted transport coefficient with calculated coefficients from the experiment in the core and Braginskii's coefficients in the SOL region.

Keywords:

Tokamak plasma transport, KSTAR hybrid scenario, 2D transport

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P1-pl.32

Development of multi-species ion module for gKPSP code

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Abstract:

Impurity ions in tokamak plasma can play a major role in transport and stability. [1] To address the impact of impurities in tokamak transport, a number of linear and nonlinear simulation studies were performed previously. [2, 3] Recently, gyrokinetic global delta-f code gKPSP is extended to include the multi-species kinetic ion module. In this presentation, some of development status, such as multi-species collision and linear ITG stability, will be reported.
Also, a few of nonlinear simulation results to investigate nonlinear effect of impurities on ITG will be presented. Pure and impure cases with same linear growth rates are compared to isolate the nonlinear effect from the linear one, while cases with different linear growth rates are studied in [3]. Modest increase of heat flux is observed in impure case, which is consistent to the prediction of residual zonal flow level change due to the presence of impurity. [4]

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Keywords:

gyrokinetic, ITG, impurity

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.102

Enhanced Photocatalytic Activity of the Cu2O Photocathodes with Wavelength-Scale Particles

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Abstract:

The Cu_2O photocathodes were fabricated by oxidizing copper film by soaking them in a 4 M NaOH solution. The particle size of the Cu_2O photocathodes were controlled by reducing reaction space of copper films. A Cu_2O film was obtained from one-step heating (80°C for one hour) of a multilayered film of Cu/Au/Ti (1000/50/10 nm) on a glass substrate followed by naturally cooling under ambient conditions. To fabricate the Cu2O photocathodes with wavelength-scale particles, molding by a micro contact stamp during fabrication of the Cu_2O structure was carried out. The Cu_2O photocathodes with a relatively smaller particle size than that of the Cu_2O microfilm, could be obtained by confinement of the Cu_2O crystal growth within the molded space of the micro contact stamp. The X-ray diffraction (XRD) and micro-Raman spectroscopy were carried out to confirm the Cu_2O phases in the microfilm and the molded Cu_2O samples. To characterize the light absorption capabilities of the Cu_2O photocathodes, diffuse reflectance spectroscopy (DRS) was measured and analyzed by finite-difference time-domain (FDTD) simulations. In DRS measurements, the molded Cu_2O photocathode showed enhanced light absorption compared to the microfilm Cu_2O photocathode. The enhanced light absorption was characterized by FDTD simulations; the wavelength-scale particle size resulted in absorbance enhancement near the Cu_2O band gap, and the mirror effect of the Au film underneath the Cu_2O photocathodes strengthened the absorbance over the entire monitored wavelength region. Finally, photoelectrochemical (PEC) characterization proved that the photocurrent of the wavelength-scale Cu_2O particles (obtained with the molding procedure) increased by approximately 2 - 5 times in the cathodic process, and the onset potential decreased by approximately 0.3 eV compared to that of the Cu_2O microfilm. The enhanced light absorption and relatively large surface area, due to the wavelength-scale particle size of Cu_2O in the molded sample, would result in an enhancement of the photocatalytic activity of Cu_2O materials.

Keywords:

Cu2O, Photocatalyst, Photoelectrochemistry (PEC), Finite-difference time-domain (FDTD), Polydimethylsiloxane (PDMS)

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.103

Raman spectroscopy of hBN/2H-$MoTe_2$ heterostructure

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Abstract:

2D materials are one of the most attractive topics because of their distinct properties, such as bandgap controllability and high carrier mobility. Additionally, the electron-phonon coupling is one of the fundamental couplings to study the quantum effects insightfully. Recently, many researches on 2D-material-based heterostructures reveal the intrinsic interlayer interactions. For example, hBN/WS_2 heterosturcures show unusual peaks in the low frequency region whichrepresents the interlayer interactions due to cross-dimensional electron-phonon coupling [1]. In this work, we prepared 2D heterostructures based on 2H-$MoTe_2$ and hBN by the mechanical exfoliation method and dry transfer. We performed low-frequency Raman maesurements on hBN/$MoTe_2$ and $MoTe_2$/hBN samples to understand interactions in the heterostructure as well as to observe the relation between the number of layers and the Raman signals.
References
[1] Miao-Ling Lin *et al.*, Nature communications **10**, 2419(2019).

Keywords:

2H-MoTe2, hBN, heterostructures, Raman spectroscopy

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.104

P-type WSe2 field effect transistor using MoO3 hole injection contact layer

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Abstract:

Extraordinary electronic performance of transition metal dichalcogenides (TMD) led great interest in transistor research. In particular, development of low contact resistance of TMD field effect transistor (FET) is critical to realization of high-performance logic device. However, previous studies have shown that the Fermi level of metals is pinned within the band gap of TMD result in unexpected Schottky barrier at the contacts.
Here, we fabricated p-type Tungsten diselenide (WSe2) FET by insertion of Molybdenum trioxide (MoO3) at the WSe2/Metal interface. The electrical characteristic of WSe2 FET with MoO3 contact layer shows MoO3 interlayer is effective in hole inject to WSe2 and the low resistance contact is successfully formed. Moreover, the method of inserting MoO3 Oxide layer also has advantage in fabrication which can simplify the process and can be compatible with current semiconductor technology.
Based on the ambipolar property of WSe2 FET, unipolar behavior could be implemented relatively easily with proper contact material like using MoO3 for p-type in this study.

Keywords:

transition metal dichalcogenides, MoO3, WSe2, 2D materials

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.105

Interlayer interaction in WSe_2/$MoSe_2$ heterostructure

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Abstract:

Heterostructures based on hexagonal 2-dimensional transition metal dichalcogenides (TMDs) have distinct physical properties such as interlayer excitons and Moiré patterns owing to the interlayer interaction between different layers. Although TMD-based heterostructures have been intensively studied so far, the interlayer interaction is not fully understood yet.

We fabricated heterostructures of monolayer WSe_2 and $MoSe_2$ on SiO_2/Si substrates using the dry transfer method. We performed Raman spectroscopy on the heterostructure samples with the twist angle in the range of 0°~30°, which show interlayer vibrational modes in the low frequency region. We identified shear-like and breathing-like interlayer vibrational modes depending on the twist angle. Additionally, photoluminescence signals from the interlayer excitons were observed either at room temperature or at 10 K. We performed photoluminescence excitation (PLE) and reflectance spectroscopy on the heterostructures using a collimated broadband light combined with a wavelength selector as the excitation source. The feature of the A exciton and B exciton states of each monolayer were observed in the PLE spectra.

Keywords:

Raman spectroscopy, Heterostructure, MoSe2, WSe2, Interlayer exciton

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.106

Hybrid Sensors of Single-walled Carbon Nanotubes and Salmon DNA for NO_x gas detection

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Abstract:

The fabrication of practical gas sensors which can detect specific analyte gas molecules is essential in variety of fields ranging from daily life to industry. In such aspect, numerous materials have been studied and fabricated for the detection of various target gas molecules of interests. Among such materials, carbon nanotubes (CNTs) have been widely explored for gas sensing applications due to their high surface area which guarantees effective adsorption of target gas materials, their superb electric properties and room temperature stability. Furthermore, functionalization of CNTs with appropriate target materials allows to enhance sensor performances such as sensitivity and selectivity. Here, we functionalize single-walled carbon nanotubes (SWCNTs) with naturally obtained salmon DNA (SDNA) and then fabricate hybrid films on a Si/SiO_2 substrate for the detection of nitrogen oxides (NO_x) gas.

Keywords:

Single-walled carbon nanotube, salmon DNA, film, nitrogen oxides, gas sensor

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.107

Energy filtering effect of electron and phonon transfer in Al_2O_3 / ZnO super lattice film

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Abstract:

The range of applications for thermoelectric material in the form of thick or thin films is rapidly expanding. Significant material savings could be realized if elements within a module could be made very short while retaining the same length to cross-section ratio as conventional products. In particular, researchers are focusing on increasing energy efficiency through the anisotropic effect of superlattice thin films.
Directional anisotropy transport in particular in nanostructured superlattice films could be crucial to understanding their thermoelectric properties, including figure-of-merit (ZT). However, few experimental studies have considered anisotropic properties in superlattice films. Therefore, this study investigated electronic and phonon transport anisotropy for atomic layer deposition Al_2O_3 (AO)/ZnO superlattice films on SiO_2/Si substrates at 77-500 K using the four-point-probe 3-w method and in-house Seebeck measurement system as a first step toward understanding corresponding superlattice film properties. In-plane and out-of-plane ZT values for AO/ZnO superlattice films were determined as 0.00017-0.19 and 0.00035-0.44, respectively, at 77-500 K.

Keywords:

phonon transport, superlattice films, thermoelectric properties

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.109

Self-Selective Non-Volatile Ferroelectric Memory Realized with Graphene Field Effect Transistor

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Abstract:

We experimentally demonstrated a new concept of non-destructive read-out process using transconductance measurements for ferroelectric random-access memory (FeRAM) using a graphene layer as the channel material of bottom-gated field effect transistor. With a 200 nm thick PZT (Lead Zirconate Titanate) layer as the ferroelectric film, the transconductance of graphene channel is found to change depending on the direction of spontaneous polarization (SP) of the ferroelectric layer. The transconductance for upward SP is estimated to be ~25 μS and that for downward SP be ~4 μS when the operational characteristics of Graphene/Al_2O_3/PZT/Pt/Ti field effect transistor fabricated on a SiO_2/Si substrate are measured. Here, the Al_2O_3 and Pt/Ti layer act as gate insulator and gate electrode, respectively. From the 24-hour retention test, it is also confirmed that the transconductance stays well-distinguishable for the two opposite directions of SP in the ferroelectric layer. This indicates that the memory state specified by the SP direction can be read out reliably from transconductance measurements. With the proposed read-out method, it is possible to construct an array of ferroelectric memory cells in the form of cross-point structure where the transconductance of a crossing cell can be measured selectively without any additional selector. This type of FeRAM can be a plausible solution for fabricating high speed, ultra low power, long lifetime, and high density 3D stackable non-volatile memory.

Keywords:

Ferroelectric Memory, Self-Selective, Graphene, Non-Volatile Memory, Transconductance

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.111

Direct Growth of Graphene by Chemical Vapor Deposition with CH_4 and CO_2

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Abstract:

Graphene is a material that forms a two-dimensional planar structure in which carbon atoms have shared bonds, and has excellent mechanical properties like elasticity, and high thermal conductivity.Graphene, in particular, has higher charge mobility than silicon. Because of these superior characteristics, it has been consistently studied and developed to utilize it in various fields [1-2]. Chemical vapor deposition(CVD) is the widely used method for growing graphene because it can produce large area of transparent and conductive graphene [3]. However, CVD graphene has to go through the transfer process for the actual applications. This process causes damage to graphene. CVD graphene having thin thickness and large area may be damaged severely in the transfering process. In addition, graphene is contaminated by the polymer used in the transfer process. A method for overcoming this problem is direct growth of graphene with metal catalyst. This allows graphene to grow directly on the substrate from which the device is fabricated, eliminating the need for a transfer process. However, the method of directly growing graphene using a metal catalyst is not free for the substrate. In order to grow graphene directly, a metal such as copper or nickel should be deposited on the substrate. In addition, there are currently no generalized metal catalysts except copper or nickel. The direct growth method according to the gas reaction on the surface using carbon dioxide(CO_2), which is the subject of this study, is free to the substrate. The graphene growth using copper or nickel as a metal catalyst works through carburization of carbon atoms and crystal growth in the process of cooling the substrate. In contrast, the present study suggests a method of directly growing graphene on a SiO_2 substrate without metal catalyst, where graphene grows by reaction of gas atoms on the surface without carburizing. Therefore, it is important to remove the hydrogen group of methane gas that works as a carbon source. The oxygen atoms of CO_2 are responsible for removing the hydrogen of methane. The reaction of methane gas and carbon dioxide follows the formula below;

$CH_4 + CO_2 \rightarrow 2C + H_2O$.

Keywords:

Graphene, Direct growth, CVD

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.112

The domain switching properties in the polycrystalline Si-doped HfO_2: Explanation to the negative capacitance

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Abstract:

The negative capacitance (NC) effect has been investigated in that it enables the field-effect transistor (FET) to have low power consumption and steep subthreshold swing (sub-60 mV/decade). However, there are ongoing debates about the origin and feasibility of NC in ferroelectrics. In this study, we explained this issue based on the domain switching of the polycrystalline Si-doped HfO_2.
The typical measurement circuit for NC is composed of a ferroelectric capacitor and a serially-connected resistor. The voltage drop (as a signature of NC) is simulated using the extracted switching parameters based on the domain switching model. It was confirmed to be mainly influenced by the activation field depending on the annealing temperature. After then, we analyzed the activation field in terms of the phase formation and the migration of bulk lattice oxygen by using impedance spectroscopy. Additionally, we proved the effect of thermal energy on the distribution of local leakage current by using the conductive atomic force microscopy and the loss of oxygen vacancies in the interface by using electron energy loss spectroscopy. These results demonstrated that oxygen vacancies are the dominant factor affecting the domain switching. Finally, we discussed the requirement of ferroelectrics focusing on the switching properties for enhancing the duration of the NC voltage drop.

Keywords:

domain switching, negative capacitance, Si doped HfO2

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.113

Improved switching characteristics of Ta_2O_5/TiO_2 multi-layer resistive-switching-based synaptic devices for neuromorphic system

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Abstract:

As the manipulation of large amounts of data is demanded, the efficiency of von Neumann architectures is in question because of the bottleneck. To date, new devices and computing architectures have been studied to solve this problem and one of them is a neuromorphic system that imitates the human brain.

An artificial synaptic device is essential to construct high performance of neuromorphic systems. Resistive-switching-based device, working in nano-scale and low power, is one of the promising candidates for synaptic devices. In this study, we will discuss optimization and development of tantalum oxide-based thin film capacitors for artificial synaptic devices. Especially, it is focusing on the effect of multi-layer structure.

Because the resistive switching occurs by conductive filament, an abrupt switching is often observed. By overlaying the titanium oxide, it is improved to be gradual resistive switching. This property makes better linearity of conductance change as a function of pulses, and it affects in a positive way on synaptic device. We compared the electrical properties of a single layer and a Ta_2O_5/TiO_2 multi-layer, such as working voltage, endurance, multi-level cell (MLC) characteristic, on/off ratio, and retention.

Keywords:

neuromorphic system, synaptic device, tantalum oxide, resistive swtiching, multi-layer structure

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.114

Variation of exciton energies in MoS_2/WSe_2 heterostructure

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Abstract:

Recently, heterostructures of transition metal dichalcogenides (TMDs) have attracted much interest owing to their unique physical properties. One of the most interesting characteristics is the large exciton energy of TMDs. As the electronic band structures of TMD materials are highly dependent on the number of layers, the interlayer interaction between constituent layers in the heterostructure also affects the band structure [1]. Therefore, understanding the changes of exciton states is important to revealing the band structure of the TMD heterostructure. In this study, we fabricated MoS_2/WSe_2 heterostructures by the stamping methods using exfoliated monolayer MoS_2 and WSe_2. The photoluminescence and Raman measurements were carried out to determine the quality of interface in the heterostructures. Especially, the interlayer breathing mode from low-frequency Raman measurements confirmed the existence of interlayer interaction between the constituent layers [2]. Furthermore, using the second harmonic generation spectroscopy and reflectance difference contrast spectroscopy, we observed a shift of the exciton energy in the heterostructure compared to those in individual constituent layers.

[1] M. M. Ugeda *et al.*, Nat. Mater. **13**, 1091 (2014).
[2] C. H. Lui *et al.*, Phys. Rev. B **91**, 165403 (2015).

Keywords:

transition metal dichalcogenide(TMD), 2D heterostructure, Raman spectroscopy, second harmonic generation, reflectance difference contrast spectroscopy

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.115

Optoelectronic Memory Based on Two-dimensional materials

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Abstract:

Two dimensional thin layered materials have excellent electrical and optoelectrical properties due to their structural characteristics. Two-dimensional transition metal dichalcogenides (TMDC), one of the 2D materials, exhibit excellent photoreactivity due to their band gap and are promising materials for optoelectronic applications[1]. The 2D thin layered structure allow their integration into flexible and wearable circuits using the characteristics of the mechanical strength and structural flatness.[2]
Compared with large scale studies on 2D material-based photoconductors and photodiodes, non-volatile optoelectronic memories made from these materials are rarely studied. This time we will use the optical characteristics of 2D material devices to advance the field of nonvolatile memory.
For memory devices, switching ratios, retention times and data storage capacities are essential. We have made various heterojunction structures using 2D materials and attempted to improve the performance of memories. Among 2D materials, black phosphorous (BP) and boron nitride (BN) heterostructures are also known to exhibit excellent data storage properties. Therefore, we tried to confirm the memory characteristics by attaching it with BN and other TMDC materials such as tungsten diselenide (WSe_2). In this experiment, we used mechanical expoliation to obtain thin layers of 2D materials and attached them together to make device. In addition, we fabricated a double layer structure and sandwich structure to check the data storage capacity and storage retention time. The materials used in this experiment are BN and WSe_2, and the devices made of these materials were used to check the memory chracteristics by changing the program-erase phase by modulating backgate voltage and UV light.

Keywords:

2D materials, TMDC, optoelectronic memory, memory device

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.116

Investigation of ferroelectric and antiferroelectric properties in $Hf_{0.3}Zr_{0.7}O_2$ capacitors

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Abstract:

In 2011, ferroelectricity of Si-doped HfO_2 was first reported [1]. After that, a flurry of studies on the ferroelectricity in various HfO_2-based films (such as $(Hf,Zr)O_2$, La:HfO_2, and Gd:HfO_2) have been done and all they showed ferroelectricity. These HfO_2-based materials have many advantages; for example, they can be made extremely thin and have good Si-compatibility and relatively large bandgap. Particularly, compared to the other films, $Hf_xZr_{1-x}O_2$ (HZO) has a wide range of composition ratio (x = 0.2 ~ 0.8), which makes engineering process easier [2]. Furthermore, depending on the composition ratio, HZO can be ferroelectric or antiferroelectric. When Hf is richer than Zr, HZO shows ferroelectricity. Otherwise, it shows antiferroelectricity.

In this presentation, we report the effect of electrical cycles on the phase transition between antiferroelectric and ferroelectric phases and their thermal stabilities in TiN/$Hf_{0.3}Zr_{0.7}O_2$/TiN capacitors. The pristine state of our film is antiferroelectric, as expected. We observed it can be changed to ferroelectric depending on the electrical cycles. We measured temperature-dependent polarization-voltage hysteresis loops for antiferroelectric and ferroelectric states. For antiferroelectric phase, the temperature-dependent loop change is not much. We calculated the values of energy storage density and its efficiency for each state at different temperature. On the other hand, for ferroelectric phase, it changes into antiferroelectric phase again with increasing temperature. After cooling to room temperature, it returned ferroelectric phase, but with negative horizontal imprint. We also use piezoresponse force microscopy to study ferroelectric and antiferroelectric domain structure.

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[2] M. H. Park, Y. H. Lee, H. J. Kim, Y. J. Kim, T. H. Moon, K. D. Kim, J. Müller, A. Kersch, U. Schroeder, T. Mikolajick & C. S. Hwang (2015). Ferroelectricity and Antiferroelectricity of Doped Thin HfO_2-Based Films. *Adv. Mat.*, ***27***(11), 1811

Keywords:

HfO2, Ferroelectric, PFM

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.117

Investigation of temperature-dependent local conductance change in an epitaxial VO_2 film using conductive-atomic force microscopy

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Abstract:

Vanadium dioxide (VO_2) undergoes an intriguing metal-insulator transition (MIT) near room temperature (at about 340 K in bulk). VO_2 has attracted considerable interest in condensed matter physics due to the relatively low transition temperature and the sharp change in resistivity with simultaneous structural phase transition (Note that they sometimes do not occur simultaneously.). From a practical viewpoint, VO_2 has been studied for various potential applications such as thermal sensors, thermal switches, and memristive devices. However, in spite of many studies so far, the primary MIT mechanism is still under debate.
To get further insights into the MIT mechanism of VO_2, we focused on the direct observation of local conductance change during MIT at the nanoscale. As a model system, we chose an epitaxial VO_2 thin film grown on a c-plane sapphire (Al_2O_3) substrate. By using conductive-atomic force microscopy (c-AFM) combined with a heater, we were able to directly visualize the electronic phase transition across the MIT temperature. Interestingly, the ring patterns were observed in the spatially-resolved c-AFM images. In other words, the grain boundaries are more conductive than the center of the grain. Especially, such patterns were observed at the whole measured temperature range (from room temperature to 355 K). This implies that the insulating and metallic phases coexist in the film and such coexistence seems to be sustained at least for the temperature range that we measured. Other complementary experiments, including x-ray diffraction, temperature-dependent Raman spectroscopy, and current-voltage (I-V) spectroscopy, were also performed to explain our c-AFM results and those data will be discussed.

Keywords:

VO2, Metal-insulator transition, Conductive-AFM

2020 KPS Spring Meeting
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P2-ap.118

High response and low concentration H2 gas sensors with p-type NiO nanoplates

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Abstract:

수소 가스는 가연성 가스중 하나이며 재생이 가능하고 청정한 에너지원으로 각광받고 있다. 자연 에너지원과 대기 오염의 증가를 고려하여 많은 연구자들이 청정 에너지원을 위한 수소 생산 및 저장 작업에 적극적으로 연구하고 있으나, 가연성이 높아 가스 누출로 인한 화재 사고의 모니터링이 매우 중요하다. 따라서 선택성과 안정성이 우수한 고감도, 저농도 감지의 수소 센서 개발의 필요성이 대두되고 있다.
본 연구에서는 계면 활성제 및 주형이 없는 수열 합성방법을 사용하여 고품질의 나노 결정질 NiO 나노 플레이트를 합성 하였으며 NiO 나노 플레이트의 가스센서를 제작하고 수소에 대한 감지 특성을 측정 하였다. 평균 두께가 20 nm 이며 평균 직경이 100 nm 인 NiO의 나노 플레이트 형태는 Scanning electron microscopy (SEM) 및 transmission electron micosopy (TEM)에 의해 확인되었으며 NiO의 결정질은 HRTEM 및 SAED 측정을 통하여 연구되었다. X-ray diffecation 및 energy dispersive spectrometer (EDS)를 통하여 구조적 특성 및 원소 조성을 각각 분석 하였다. 구조 매개 변수에 대한 자세한 조사를 수행하였으며 NiO의 광학 특성은 UV-Visible 및 photoluminescence 스펙트럼에서 분석되었다. NiO 나노 플레이트는 수소 (H2) 가스에 대해 우수한 선택성을 가지며 반응 시간 180 초 동안 가장 낮은 수소가스의 반응은 2ppm의 조건에서 3%의 response로 측정되었고, 200도의 최적화 된 온도에서는 100ppm의 조건에서 90%의 response로 측정되었다. 센서의 안정성과 함께 다양한 작동 온도 및 가스 농도에 따른 H2 반응을 연구하였다

Keywords:

H2 gas sensor, NiO, Nanoplates

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.201

Optical Characteristics of SiO_2 Nanopillar Array Patterns on Si Wafers

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Abstract:

We fabricated SiO_2 nanopillar (NP) array patterns on the SiO_2/Si wafers and investigated their optical characteristics. The NP arrays were prepared by electron-beam lithography and dry etching of SiO_2/Si wafers. The period, height, and diameter of the cylindrical NP arrays were 500 nm, 50 nm, and 300 nm, respectively. T The flat region as well as the periodic NPs should contribute to the optical characteristics of the samples. For clear understanding, wafers with different SiO_2 thickness (100 and 320 nm) were used and their optical properties were compared. he reflection spectra in the visible region were measured using a home-made micro-reflectance set-up. Finite-difference time-domain simulations were also carried out to explain the experimental results. The influences of the NP arrays on the optical spectra and the electric field distributions at the surface will be discussed in the presentation.

Keywords:

antireflection, nanopillar, SiO2, Si

2020 KPS Spring Meeting
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P2-ap.202

Facile synthesis and UV blocking application of carbon dot derived from organic dye

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Abstract:

Carbon dots (CDs) have been paid attention due to their low toxicity, abundant resource, cheap price and high quantum yield. In order to optimize the luminescent properties of CDs, utilizing suitable carbon source is one of important factor because their structure and chemical component affect their structural and luminescent properties. Also, utilizing a wasted materials as a carbon source have environmental and economic benefits. Among a wasted materials, organic dye is nitrogen-rich carbon source, which is profitable to possess a high quantum yield and tunable bandgap structure. Considering with toxicity and chemical component of organic dye, their landfill or incineration occur soil and air pollution.

In this study, CDs derived from organic dye were synthesized by using a microwave irradiation method. Since rapid and direct microwave irradiation occurred, the CDs were synthesized with low energy consumption and facile process, which is favorable benefit to the mass production of the CDs. The structural, morphological and luminescent properties of the CDs were analyzed. As the CDs exhibits nitrogen-rich and various surface ligand, the CDs show excitation independent luminescence and broad absorption band in ranged from UV to blue region. Using these results, the CDs were applied sunscreen application by coating a CDs on the glass.

Keywords:

carbon dot

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.203

Polarization-dependent asymmetric fatigue behavior in epitaxial $BiFeO_3$ capacitors

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Abstract:

The degradation in switchable polarization of ferroelectric thin films due to electrical cycling (i.e. polarization fatigue) is a long-standing problem in ferroelectric nonvolatile memories. To clarify the microscopic fatigue mechanism, there are some reports using planar device to observe in-plane polarization of $BiFeO_3$ [1]. However it is essential to investigate directly the changes of domain switching process in real capacitors under electrical cycling. In this respect, modified-piezoresponse force microscopy (m-PFM) can be a powerful tool, since it allows us to measure domain nucleation and growth in real capacitor geometry [2]. For example, Yang *et al.* reported that time-dependent domain wall pinning is a primary mechanism of ferroelectric fatigue behavior in epitaxial $Pb(Zr,Ti)O_3$ capacitors based on the m-PFM results [2].
We present the m-PFM study results of epitaxial $BiFeO_3$ (BFO) capacitors. BFO is one of the extensively studied ferroelectric materials due to high polarization, lead-free material, and magnetoelectric orders. To realize BFO-based electronic devices, understanding and resolving the polarization fatigue in BFO capacitors are imperative. In spite of few remarkable studies on the fatigue in BFO [1,3], direct observation of domain dynamics in capacitor structure (i.e., how domains nucleate and grow in capacitors) during fatigue is still lacking. As a model system, we used epitaxial BFO films grown on $SrRuO_3/SrTiO_3$ with a 4° miscut, which have 4 polarization variants. By means of m-PFM, we measured domain nucleation and subsequent growth in BFO capacitors with Pt top electrodes as a function of electric cycling number. Under a positive bias, we observed spot-like domain switching and domain sideway growth is more inhibited compared to the negative bias case after fatigue. And we measured switching currents of the BFO capacitors. Saturated polarization value, P_S, is decreased faster under a positive switching pulse than negative switching pulse. We discuss the possible mechanism of the different fatigue behavior depending on the voltage polarity.

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Keywords:

BiFeO3, PFM, fatigue

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.204

Improvement in the threshold voltage of both MoS2 n-FET and MoTe2 p-FET by charge transfer induced by organic molecules

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Abstract:

We employed HAT-CN organic small molecules to shift threshold voltages of both n-MoS_2 FET and p-$MoTe_2$ FET toward 0 V. It is attributed to the charge transfer between HAT-CN organic molecules layer and TMD channel. TMD based FETs reported so far mostly have a large threshold voltage.

HAT-CN, which has a deep work function, is commonly used as a hole injection layer in OLED industry and research. When HAT-CN is deposited on MoS_2, electrons move from MoS_2 to HAT-CN so that MoS_2 is p-doped and V_{th} moves toward 0 V. Whereas, in case of $MoTe_2$, electrons move in the opposite direction. Such difference comes from MoO_3 formed on the surface of $MoTe_2$ by an air annealing process.

To demonstrate the applicable advantage of such effect, a complementary metal oxide semiconductor (CMOS) is built and HAT-CN is deposited on the channels of the CMOS. Because both n-FET and p-FET in the CMOS are shifted to enhancement mode, the performance of CMOS is greatly improved in aspects of voltage gain and power consumption.

Keywords:

MoTe2, Threshold voltage, CMOS, Transistor

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.205

Emission Wavelength and Decay Time Dependence of Nitrogen Capped Silicon Quantum Dots on Ligand properties

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Abstract:

Silicon quantum dot (Si-QD) can reproduce light emission from 600 nm to near-infrared ranges with microsecond scale decay time by controlling the size of QD. However, there is a limitation to show only the emission with the wavelength above 600nm. To overcome this problem, there have been much effort to obtain short emission wavelength under 600nm including green and blue light. As a solution, some researchers have tried ligand passivation on the Si-QDs` surface. Among surface functionalized Si-QDs, especially, nitrogen capped Si-QDs have been reported to show a broad range of visible wavelength and decay time in the nanosecond scale. However, there remain a study on the luminescence mechanism in the nitrogen capped Si-QDs. In this work, we fabricated surface functionalized Si-QDs with various amine-based ligands. These Si-QDs' luminescence properties were characterized by photoluminescence (PL) and time resolved photoluminescence (TRPL). From TRPL results, we observed the amine functionalized Si-QDs show various decay time with nanosecond scale as a kind of ligands. To elucidate the luminescence mechanism of surface functionalized Si-QDs, we investigated the correlation between the luminescence and ligand properties such as electronegativity and electric dipole. With this study, we suggest the origin of fast decay time and the enhanced luminescence of surface functionalized Si-QDs.

[Acknowledgement: NRF-2018R1A6A1A06024977, NRF-2015R1D1A1A01060381, UOS-BSIRDF2019]

Keywords:

silicon quantum dots, surface functionalization, luminescence mechanism

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.206

Switching kinetics in TiN/Zr-doped HfO_2/Al_2O_3/TiN structure with different dielectric layer thickness

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Abstract:

Hafnium oxide(HfO_2) has been regarded as a candidate for preexisting ferroelectric materials because it presents good ferroelectricity at a scale of nanometers. So, HfO_2 has been studied to apply to various ferroelectric-based devices including ferroelectric random-access memory(FeRAM), ferroelectric field effect transistor(FeFET), synaptic device, and so on. And in this regard, ferroelectric/ dielectric bilayer structure has been studied for diverse purposes. In FeRAM-based devices, the insertion of dielectric layer between metal electrode and ferroelectric layer can prohibit the carrier injection from the electrode to ferroelectrics, and further the dielectric layer can perform as a tunnel switch. Also this heterostructure is the main operation part of FeFET, and there are several studies with negative capacitance effect of this structure. So it is important to understand the effect of dielectric layer interposed in ferroelectric-based devices. In this study, TiN/$Hf_{0.5}Zr_{0.5}O_2$/Al_2O_3/TiN capacitors were prepared by atomic layer deposition method.
The electrical characteristics were examined under varying thickness of Al_2O_3 to investigate the effect of dielectric layer.

Keywords:

MFIM structure, Ferroelectric/dielectric bilayer, HfO2, AO/HZO

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2020-07-13 - 2020-07-15

P2-ap.207

Interlayer vibration modes in few-layer 1T′ and T_d $MoTe_2$ studied by Raman Spectroscopy

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Abstract:

Molybdenum ditelluride ($MoTe_2$) crystallizes in several phases, and a temperature-driven structural phase transition from monoclinic 1T′ to orthorhombic T_d phase accompanied by inversion symmetry breaking has been reported [1]. Since the T_d phase of $MoTe_2$ is known as a type-II Weyl semimetal which hosts exotic topological properties [2], comprehensive understanding of the transition is important. Although the interlayer shear mode at ~13 cm^{-1} as well as a peak splitting at ~130 cm^{-1} is regarded as an indicator of the transition in bulk $MoTe_2$ [1], the interlayer vibration modes in few-layer 1T′ and T_d $MoTe_2$ are not fully understood and require more extensive studies. The transition and the interlayer modes in each phase can be thoroughly investigated by using Raman spectroscopy which is sensitive to the symmetry of sample [3].

We prepared few-layer $MoTe_2$ samples by mechanical exfoliation from a single crystal 1T′ $MoTe_2$ and performed polarized Raman measurements for different thickness, from monolayer to bulk. At room temperature, we observed the emergence of T_d phase with the peak splitting at ~130 cm^{-1} as the thickness is reduced, but samples of the 1T′ phase still exist. In the T_d phase, a drastic change occurred in the interlayer modes, and especially, the interlayer shear modes were enhanced compared to the 1T′ phase of the same thickness. Based on the interlayer vibration modes in few-layer 1T′ and T_d $MoTe_2$, we extracted interlayer force constants using the linear chain model and noticed the strong in-plane anisotropy in both phases. Not only bulk, but also few-layer samples exhibit the temperature-induced phase transition, while the critical temperature depends on the thickness of sample.

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Keywords:

molybdenum ditelluride, MoTe2, phase transition, interlayer vibration modes, Raman spectroscopy

2020 KPS Spring Meeting
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P2-ap.208

The Flexoelectric Effect in Flexible Bioinspired Nanogenerators Based on Nematic M13 Bacteriophages

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Abstract:

We report the first attempt to estimate the flexoelectric effects in energy harvesting by using nematically aligned M13 bacteriophage based flexible bioinspired nanogenerators. The M13 bacteriophage has an intrinsic permanent polarization in an axial direction of the phage which can be considered as a promising biocompatible material. Flexoelectric effect is a property of dielectric materials whereby it exhibits a spontaneous electrical polarization when subject to strain gradient, a strain difference over a small distance gives a large strain gradient. In order to characterize the piezoelectric and the flexoelectric performance in nanogenerators, both pressing and bending experiments were performed. We found that both piezoelectricity and flexoelectricity has a linear relation with applied loads and that voltage output coefficients in the pressing and the bending experiments were ~0.96 pC/N, and ~1.28 pC/N, respectively. The output performance in bending experiments was enhanced by 34% compared to that in pressing experiment, consistent with our prediction that electric power output from the bending experiment should be greater than that in the pressing experiment due to the additional flexoelectric effect caused by a strain gradient. Based on the linear superposition assumption of piezoelectric and flexoelectric effects, we could macroscopically extract the flexoelectric performance in the M13 bacteriophage based flexible nanogenerator and determine the pure flexoelectric coefficient as ~ 0.32 pC/N.

Keywords:

Flexoelectricity, Piezoelectricity,Nanogenerator, M13 Bacteriophage

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.209

Fluorinated polymetric sulfur for high efficient triboelectric energy harvesting

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Abstract:

The halogenic elements have a larger electron affinity than any other group, allowing them to accommodate extra electrons for triboelectric energy harvesting. However, because halogenic elements are not homopolymerizable, carbon-based polymers (i.e. PTFE, PVDF) are often employed for structural use and mechanical integrity at the expense of reduced electron affinity, intrinsically sacrificing triboelectric energy harvesting. Herein, Fluorinated polymeric sulfur demonstrated 6-fold and 3-fold increase in triboelectric energy outputs in voltage and currents respectively in comparison with commercial PTFE film. Such high energy harvesting was achieved by high electron affinity of sulfur and by its hypervalency via expanded-octet which provided coordination of two additional bonds with halogens compared to carbon. This yellow chemistry-based molecular engineering paves a way for a new class of triboelectric materials toward low-cost, eco-friendly, and scalable energy harvesting applications.

Keywords:

Triboelectric energy harvesting , Electron affinity , Hypervalency, Yellow chemistry, Inverse vulcanization

P2-ap.210

NbS_2/n-MoS_2 van der Waals Schottky Junction for High Mobility Metal Semiconductor Field Effect Transistors

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Abstract:

Van der Waals (vdW) Schottky junction-based metal semiconductor field effect transistors (MESFETs) using high work function conducting NbS_2 transistion metal dichalcogenide (TMD) gate on MoS_2 TMD channel have been investigated. Since this Schottky effect FET contains low density traps at the vdW interface, little gate hysteresis and ideal subthreshold swing of 60~80 mV/dec are expected. Operational gate voltage appears as low as ~-1 V for all devices and it was also found that the device mobility is significantly dependent on the condition of source/drain (S/D) contact for n-channel MoS_2. The highest mobility in MESFET reaches to ~more than 800 cm^2/V s with graphene S/D contact, although the lowest was ~15 cm^2/Vs as obtained from Au/MoS_2 contact when the contact was not annealed at all. Our TMD-based MESFET with NbS_2/n-MoS_2 junction is regarded novel and promising in view of 2D device electronics, and the MESFET with graphene contact appears particularly advanced presenting all-2D structure and very high mobility.

Keywords:

vdW Schottky junction, MESFET , MoS2, NbS2, TMD

2020 KPS Spring Meeting
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P2-ap.211

Self arrangement and diffusion of semiconducting quantum dots in display devices

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Abstract:

The development of displays using quantum dots is actively underway, and the use of quantum dots in optoelectronics has also been actively carried out.[1,2] In this study, we observed the different self arrangement behavior of CdSe quantum dots depending on the substrate by grazing incidence x-ray scattering. The x-ray scattering measurements were performed at 9A beamline, PLS-II, Korea. Besides, we found that the in-plane ordering depending on either the mixture of small molecule or polymer hole-transporting materials, which makes the interlayer diffusion effect that could occur in the device fabrication process. The detailed morphology-efficiency results will be discussed in this presentation.

This research was supported by the National Research Foundation of Korea (No. NRF-2015R1A5A1009962) and Samsung Display.

Keywords:

Quantum dot, CdSe, grazing incidence small angle x ray scattering, GISAXS, Display

2020 KPS Spring Meeting
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P2-ap.213

Ultrathin LiF for Dramatic Contact Resistance Reduction in MoS_2 Field Effect Transistors

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Abstract:

The contact resistance(Rc) at source/drain is still important issue to be resolved. We employed ultrathin (~ 2 nm) lithium fluoride(LiF) as an interlayer between Source/Drain(S/D) and n-MoS_2 channel for reducing the contact resistance. LiF has been used as an electron injection layer between metal electrode and n-type organic active layer in OLED industry and research.

Here, three different electrodes of Au, Al, and indium-tin-oxide (ITO) are selected for measuring Rc and field effect mobilities. For measuring the Rc, we use the 4-bar method. As a result, Au/LiF contact system achieved small Rc (~ 0.5 kΩ-μm) and high mobility (~50 cm^2/V s), while without ultrathin LiF FET has large Rc (~50 kΩ-μm) and low mobilty (~20 cm^2/V s). And our MoS_2 FET with LiF layer well operates at least 0.1 mV of drain voltage, while normal MoS_2 FET without LiF works at more than 10 mV. The other metals of Al and ITO on MoS_2 respectively show much higher R_C of ~15 and 38 kΩ-μm under a V_{GS}-V_{th} (=70 V or n=4.9x10^{12} cm^{-2}) condition.

We fabricated fully transparent low operating FET using ITO/LiF contact system. This FET shows a decent mobility of 6.5 cm^2/V s operating at low voltages, switching a green organic light emitting diode (OLED).

Keywords:

MoS2, Contact resistance, Transistor, low voltage device

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.214

Analysis of Charge Diffusion in Al_2O_3 –Au interlayer structure

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Abstract:

Trapping behavior of carriers in nanostructure are of importance for nanodevice application. In this study, we investigated the diffusion behavior of trapped charges in Au nanocluster/Al_2O_3 structure depending on initial charge distribution. Injection of charges were conducted in two different shapes such as line and dot. The electric potential of the charged surface and the behavior of diffusion was measured by Scanning Kelvin Probe Microscopy (SKPM). Analyzing remained charges over time, we found that trapped electrons are exponentially decayed. However, the injected electrons with a line-shape in Au NCs are found to have a larger time constant than those with a dot-shape.

Keywords:

charge trap, charge retention, quantum tunneling, flash memory, nanoparticle

2020 KPS Spring Meeting
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P2-ap.215

SiO_x Memristive Barristor Network Inspired by the Human Vision for Neuromorphic Computing

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Abstract:

Memristor, which simply consists of a switching layer inserted between two electrodes, is one of the most strong candidates to become a device-platform for imitating the principal of biological neural network due to its nonlinear and dynamic electrical characteristics depending on the history of applied electrical programming [1]. In this study, we fabricated a vertical form of a controllable device using a SiO_x memristor in combination with graphene barristor at room temperature and extended the device into an artificial synapse of a 16 × 16 crossbar array for an artificial neural network [2]. The device can exhibit a high ON-OFF ratio (> 10^6) and excellent endurance cycles and retention time regardless the gate voltage, where the switching is attributed to the transition between two Si phases (amorphous Si and Si nanocrystal). Moreover, the electrostatic gating from a graphene barristor can greatly improve the switching performances of the SiO_x memristor in terms of the switching behavior and energy. Based on the switching and gate-tunability, the device successfully mimicked the unique synaptic functions of rod-to-rod bipolar synapse in human visual system such as binary state and threshold-shift. Using the controllable SET-probability in the SiO_x memristor synapse, we utilized as a probabilistic artificial synapse and investigated the recognition accuracy for the fashion images according to different SET-probability based on drop-connect learning algorithm. From this study, we rather think that the switching uncertainty in a filament-type binary memristor may be good for the mimicking of artificial probabilistic synapse. Taken all together, the designed SiO_x artificial synapse and its based network could provide an another route toward the learning, energy and time-efficient neuromorphic computing technology.

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Keywords:

Silicon oxide, Synaptic barristor, Probabilistic synapse, Drop-connect network, Neuromorphic computing

2020 KPS Spring Meeting
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P2-ap.216

Novel fluorescent label based on $GdVO_4:Bi^{3+}$, Eu^{3+} phosphors for latent fingerprint detection in forensic science

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Abstract:

Latent fingerprint detection is a prominent technique in forensic science and individual identification. Traditional developed metal or magnetic powder dusting method in fingerprint visualization suffers the drawbacks of low contrast due to non-fluorescence of the powders, low sensitivity aroused from the non-uniform size and high background interference because of the complex colors or the complicated substrate patterns, which may greatly impeded its widely application. To overcome those limitations, many researchers shifted their attentions to high efficiency luminescent materials with small particle size less than 100 nm.

Rare earth doped vanadates attract a considerable attention because of their integration of good thermal properties, chemical stability and high photoluminescence quantum yield. The orthovanadate $GdVO_4$ is an attractive host lattice for several lanthanide ions to produce efficient phosphors emitting a variety of colours because of the efficient resonant energy transfer from the host to the lanthanide ions. It is also interesting to study properties of co-doped vanadates systems, where energy transfer occurs between the transition or post-transition metal ions and lanthanide ions. The Bi^{3+} is a well-known ion used as excellent sensitizer upon the excitation of near-UV light for several lanthanide ions, which not only enhances the emission intensity, but also improves the broadness of the excitation spectrum.

Keywords:

GdVO4:Bi3+, Eu3+, fingerprint detection

2020 KPS Spring Meeting
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P2-ap.217

열처리 된 다공성 실리콘을 감지부로 이용한 정전식 센서의 진동수 응답과 습도감응 특성

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Abstract:

본 연구에서, 정전식 센서(electrostatic sensor)는 열처리 된 다공성 실리콘(porous silicon)을 감지부로서 이용하여 제작되었다. 그리고 다공성 실리콘의 열처리 조건에 따른 센서의 진동수 응답 변화와 습도에 대한 감응특성이 조사되었다. 이를 위해, 정전식 센서는 열처리 된 다공성 실리콘을 진동판으로, 두꺼운 알루미늄 판을 상대 평형 판으로 제작되었다. 또한 두 평행판 사이에는 다공성 실리콘의 초기 진동방향과 진폭을 제어하기 위한 또 하나의 알루미늄 판이 삽입되었다. 두 평행판에는 최대전압 8 V의 AC전압이 인가되었고 진동제어를 위한 알루미늄 판에는 100 V의 DC전압이 인가되었다. 실험결과 정전식 센서의 진동수 응답은 다공성 실리콘의 열처리 조건에 따라 변화됨을 확인하였다. 또한 10 ~ 80 %의 습도 환경에 센서가 노출되었을 때 다공성 실리콘의 공명진동수가 높은 진동수 쪽으로 이동됨이 관찰되었다. 열처리 된 다공성 실리콘을 이용한 정전식 센서를 최적화 한다면 높은 감응효율을 갖는 기체 센서로서 응용될 것으로 기대된다.

Keywords:

다공성실리콘, 진동수 응답 특성, 정전식 센서, 기체센서, 습도감응 특성

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P2-ap.218

Control of electronic structure via oxygen vacancies in Ta-based materials

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Abstract:

Neuromorphic computing using a two-terminal circuit such as phase change random access memories (PRAM), spin-based memories, resistive RAM (RRAM) has attracted considerable attention because of the benefit beyond using complementary metal-oxide-semiconductor (CMOS) neuromorphic circuits. Especially, resistive switching devices such as memristor and RRAM have used as non-volatile memory due to their low operation power, and high scalability. Among various insulator materials, tantalum pentoxide (Ta_2O_5)-based resistive switching devices have been extensively investigated due to high endurance and fast switching[1, 2]. In these devices, oxygen vacancies play essential roles in the electric functionality, which is based on the formation and rupture of conducting paths within the insulating matrix. However, there is still a lack of fundamental understanding of the electronic structure and local structure of the Ta-based device. Here, we show the local and electronic structures of tantalum pentoxide powder and oxygen-deficient tantalum pentoxide films which have different oxygen stoichiometry using x-ray diffraction (XRD), extended x-ray absorption fine structure (EXAFS), and resonant x-ray scattering spectroscopy (RIXS). Especially, using RIXS we verified that their bandgap was strongly correlated with the concentration of oxygen vacancies in Ta-based materials. Therefore, the correlation between the bandgap and configuration of oxygen vacancies provides the atomic-level design rule of the tantalum-based neuromorphic computing circuits.

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Keywords:

RRAM, Neuromorphic computing, RIXS, Tantalum pentoxide

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P2-ap.219

Electrical investigation of epitaxial C_{60} layer on black phosphorus

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Abstract:

Two-dimensional (2D) materials have been used as templates for fabrication of various heterostructures hosting inorganic nanostructures, organic molecules, and other 2D materials. Novel physical properties can emerge from the coherent interaction of components in various heterostructures. Among various 2D materials, black phosphorus (BP) can serve as a unique 2D template due to its anisotropic puckered atomic structure and its thickness-dependent direct band gap. We directly observe the strong epitaxial molecular assembly of C_{60} on BP using transmission electron microscopy. The atomic trenches of puckered BP surface induce the alignment of C_{60} molecules along the zigzag lattice of BP and well-ordered molecular crystals of C_{60} are obtained on BP. We also study the charge transfer and charge transport behavior across C_{60} and BP interface.

Keywords:

Black phosphorus, 2d device, C60

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.220

Reduced graphene oxide photodetector with excellent optoelectronic properties

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Abstract:

Graphene materials have a lot of advantages for optoelectronic applications due to a combination of broadband absorption, ultrahigh mobility and field effect tunability. However, the lack of a bandgap and the intrinsic low light absorption leads to poor optoelectronic properties. Reduced graphene oxide (rGO) is an important graphene derivative for applications in photonics and optoelectronics because of the bandgap created by chemical oxidation. However, the recent reports of rGO show a large bandgap, which causes the limit of the infrared photoresponse. Here we modulate the degree of oxidizing power for delicate bandgap tuning. That modulated rGO show enhanced photoresponse at a various range of wavelengths.

Keywords:

reduced graphene oxid, photodetector

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.221

Luminescence properties of $LaTaO_4$:Eu^{3+} phosphors for white LEDs applications

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Abstract:

The ABO_4 structure phosphor materials have been the subject of increased scientific interest, both for fundamental research and for a wide area of application such as biological class, medical diagnosis, clean energy, and light emitting devices such as the light emitting diode (LED), etc. Especially, various application fields demanded to issues of environmental degradation and energy consumption. The white light emitting diodes (WLEDs) are expected as up and coming candidate to substitute these traditional light devices and the next generation lighting source.

In this work, the luminescence properties of $LaTaO_4$:Eu^{3+} were investigated by solvothermal method. Their crystalline structures, surface morphologies and luminescent characteristics were investigated for the samples prepared at various annealing processes by using X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL), respectively. The purpose of this study is to compare the luminescence properties of Eu^{3+} ion doped $LaTaO_4$ phosphors which were synthesized at various experimental conditions such as Eu^{3+} ion concentrations and sintering temperatures. And those results suggested that $LaTaO_4$:Eu^{3+} as red emitting phosphors could be potential candidates for white LEDs.

Keywords:

LaTaO4:Eu3+, white LED

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.222

Wafer-scale fabrication of cyclo-phenylalanine peptide nanowire based triboelectric energy generator

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Abstract:

Recently, wearable devices are essential for internet of things (IOT) based technology. In this backgrounds, biocompatible devices are necessary for fully wearable systems. This study developed a wafer-scale fabrication method of cyclo-phenylalanine peptide (cyclo-FF) nanowire array by thermal evaporation. After then, triboelectric energy generators (TEG) was fabricated and the cyclo-FF nanowires were employed as triboelectric materials that stable and biocompatible. The output voltage and current of TEG were ~ 350 V and ~ 10 μA respectively with corona discharge surface treatment. Even though cyclo-FF were dipped into water and TBS buffer solution, it still worked like earlier devices. In conclusion, the cyclo-FF nanowire array were fabricated simply and employed as triboelectric materials of TEG which performed excellent output characteristics for future applications.

Keywords:

Peptide, Cyclo-phenylalanine, Self-assembly, Triboelectric, Nanowire

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.301

MoS_2 Monolayers on Plasmonic Au Nanotriangle and Nanohole Arrays

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Abstract:

We prepared MoS_2–Au hybrid nanostructures and studied their photoluminescence (PL) characteristics. Nanosphere lithography (NSL) technique has been widely used to fabricate plasmonic metal nanostructures, as one of the most popular bottom-up approaches. In particular, it is very easy to control the geometric configuration of plasmonic nanostructures, when an additional dry etching process is followed after the NSL patterning. In this work, we fabricated Au nanotriangle (NT) and nanohole (NH) arrays, using the NSL technique. NT arrays enable excitation of localized surface plasmon (LSP), which can produce strongly confined light near the Au NT. In the NH array, excitation of propagating surface plasmon polariton (SPP) as well as LSP can be expected. MoS_2 monolayers, grown by chemical vapor deposition technique, were transferred on the NT and NH arrays. Both of the Au nanostructure enhanced the PL intensity of the MoS_2 monolayers. Finite-difference time-domain simulation results clear difference in the electromagnetic field distribution in the NT and NH arrays. Hot spots near the NT were observed and strong field intensity in the middle of the NHs were seen. Compared with the NT arrays, the NH arrays have some advantages. For example, the NH arrays can be used as electrodes for device operation, while allowing light transmission through them. Therefore, the NSL-fabricated MoS_2-metal hybrid nanostructures could provide us opportunities to propose novel optoelectronic devices.

Keywords:

MoS2, photoluminescence, nanosphere lithography, surface plasmon

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.302

Domain structure of single layer ReS_2

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Abstract:

Rhenium disulfide (ReS_2), one of the transition metal dichalcogenides (TMDs), is a semiconducting material which has a direct band-gap from monolayer to bulk. ReS_2 has an anisotropic crystal structure (1T′, distorted tetragonal) unlike hexagonal MoS_2 and WS_2, because Re has one more electron, which makes a Re-chain, than Mo and W. Furthermore, opposite vertical orientations of ReS_2 are not equivalent. Due to the in-plane anisotropic structure, its physical properties such as electrical transport and optical response are anisotropic [1]. The direction of the Re-chain and the direction of the c-axis of ReS_2 can be determined by polarized Raman spectroscopy [2, 3].

We made a monolayer ReS_2 sample by mechanical exfoliation and analyzed the sample that has two domains in one flake by Raman spectroscopy. The polarized Raman spectra in each domain show opposite vertical orientations [3, 4]. The direction of the Re-chain in each domain is also determined by polarization dependence of the Raman mode at 212 cm^{-1} [2, 3]. The grain boundary between the two domains is observed by Raman mapping for two different polarization angles. Furthermore, the grain boundary can also be observed by angle-resolved polarized optical microscopy (ARPOM) [5]. We found that the directions of the grain boundaries are not exactly aligned along the Re-chain directions.

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Keywords:

ReS2, Rhenium disulfide, Raman spectroscopy, Grain boundary, Domain structure

Mechanical cleaning of 2D crystal using AFM

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Abstract:

Contamination of 2D crystals from a fabrication process poses serious limitation on fundamental studies and applications of 2D crystals. Surface residues on 2D crystals often induce uncontrolled doping as well as charge carrier scattering. Vertical hetereostructures produced by stacked 2D crystals also suffer from trapped residues between layers. Here we explore the possibility of using atomic force microscopy (AFM) to clean the surface residues of 2D crystals. We find that 2D crystals transferred by PMMA or PDMS supports are covered by residues. The contact-mode AFM is utilized and the efficiency of surface cleaning depending on scanning parameters is investigated in detail.

Keywords:

AFM, 2D crystal cleaning, Mechanical cleaning of 2D crystal

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.304

Raman enhancement in WS_2/ReS_2 heterostructure

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Abstract:

Transition-metal dichalcogenides (TMDs) are known as layered materials and have been studied actively because of their novel properties such as strong light-matter interactions [1]. Tungsten disulfide (WS_2) and Rhenium disulfide (ReS_2) are two types of layered materials showing different dependence on the polarization angle of the incident light. The interactions between the two monolayers of WS_2 and ReS_2 and the polarization dependence of the heterostructure are not understood fully.
We stacked a monolayer WS2 on another monolayer ReS2 to fabricate heterostructures using the dry-transfer method [2]. Atomic force microscopy (AFM) and low-frequency polarized Raman measurements are conducted to inspect the quality of the heterostructure. Then, we compared the polarization dependence of the Raman modes from the heterostructure to those of the monolayers of WS_2 and ReS_2. The interlayer vibration mode shows weak anisotropy which may be induced from anisotropy of ReS_2. Moreover, excitation energy-dependent Raman measurement is conducted and the enhancement of specific Raman modes is analyzed.

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Keywords:

transition-metal dichalcogenides, Raman spectroscopy, heterostructure

Characterization of GeSe Nanoflakes Grown by Physical Vapor Deposition

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Abstract:

GeSe possesses a puckered structure similar to black phosphorus and shows interesting in-plane anisotropic properties including electrical conductivity and photoelectricity. However, due to its relatively large interlayer interaction, the sample preparation of an ultrathin GeSe flake by mechanical exfoliation is challenging. Here we present a bottom-up synthesis of thin GeSe samples using physical vapor deposition(PVD). Synthesized GeSe nanoflakes are characterized using various characterization tools, including atomic force microscope, scanning electron microscope, and Raman spectroscopy. Field effect transistors with synthesized GeSe are fabricated and anisotropic electrical properties of GeSe are investigated.

Keywords:

Germanium selenide, physical vapor deposition

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.306

MagnetoPlasmonic reflectance sensor for measuring physical quantities

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Abstract:

Self-assembled magnetoplasmonic film (MagPlas film) was fabricated with Ag@Fe_3O_4 nanoparticles that have magnetic and plasmonic properties at the same time. These nanoparticles on film change color when samples such as proteins and polymer are placed on that surface. The collective oscillation motion of conductive electrons in silver nanoparticles results in a surface plasmon resonance (SPR) that causes the color change. When a substance(BSA, Polymer) is combined with particles that construct the film structure, color change happens because of the refractive index around the plasmon particle surface changed. Then, by measuring the spectrum changes of the reflected light the concentration of the substance can be determined. The color change in the film can be easily seen with the naked eye and the degree depends on the concentration. The higher the concentration of the sample on the film, the reflective peak shows redshifting. This MagPlas film has high sensitivity by the changes of physical conditions, such as temperature and humidity, as well as the target's concentration, and can further be applied as a measurement sensor for various physical quantities.

Keywords:

magnetoplasmonic, nanoparticles, sensor, surface plasmon resonance, colorometry

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.308

Fabrication of Nano/Micro Grating Structures by Scanning Probe Lithography

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Abstract:

Generation of diffraction gratings by top-down and bottom-up approaches based on scanning probe lithography is demonstrated. With regard to top-down fabrication, silicon nanostructured diffraction gratings are fabricated through one-dimensional (1D) dip-pen-nanolithography (DPN). Nanodot arrays (two-dimensional simple cubic lattice) of alkanethiol self-assembled monolayers (SAMs) are printed by 1D DPN on an Au-film-coated silicon substrate with lattice distances of 700, 1000, and 1200 nm. Silicon nanocircular pillars of length hundreds of nanometers are generated by sequential Au etching and reactive ion etching (RIE) of the 1D DPN printed sample. The performance of the silicon diffraction gratings as a microspectrometer is demonstrated through red, green, and blue color diffraction with white light incident at 45°. Moreover, arrays of zirconia nanoparticles (NPs) with an average diameter of visible wavelength (dia. ≈ 470 nm) on an Au substrate are generated via bottom-up fabrication of the diffraction gratings. Microarrays of hydrophilic alkanethiol SAMs are obtained by polymer pen lithography (PPL). Self assembly of zirconia NPs occurs after the passivation of hydrophobic alkanethiol SAMs of the PPL-printed sample. Fraunhofer diffraction with a square aperture is observed for the zirconia NP diffraction grating fabricated by the bottom-up approach.

Keywords:

diffraction grating, scanning probe lithography

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.309

Cyan emitting carbon dot powders by using facile solvothermal method

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Abstract:

Recently, carbon dots have been attracted attention in several fields such as optical device, bio imaging, photocatalysis, sensor, and solar cell because of their special property (stability, biocompatibility). However, these carbon dots have several disadvantages. One of several disadvantages is difficult to apply the application because most of carbon dots exists aqueous solution. The way for applying the application of aqueous carbon dot is to change aqueous solution to solid powder.

In this work, the carbon dots and carbon dot powders were synthesized by using facile solvothermal method. The prepared carbon dots and carbon dot powders have good optical property and photo and chemical stability. Therefore, we present the characterization with using the prepared carbon dots and carbon dot powders. The results show that the prepared carbon dots can be effectively applied to several applications.

Keywords:

carbon dot

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.310

General Mode Quartz Tuning Fork Atomic Force Microscopy for Acquisition of Full Tip-Sample Dynamics

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Abstract:

The rapid advancements in Scanning Probe Microscopy(SPM) have been focused on acquiring comprehensive and high-resolution information on diverse materials. Along with the wide spectrum of SPM techniques, General Mode Atomic Force Microscopy (G-mode AFM) is a dynamic force AFM technique developed to compensate the information compression in data processing procedures[1].

In this research, we devised General mode Quartz tuning fork-based AFM. By utilizing multiple harmonic response of a detection probe attached to Quartz tuning fork(QTF), complete information of the interaction between tip and the surface is attained. In contrast to conventional AFM where the scope is limited to single frequency response, general mode AFM enables detection of multi-harmonic response which is generated due to convolution of nonlinear interaction force applied to the probe within its oscillation cycle. While the response behavior in different harmonics can be analyzed for interpretation of mechanical properties of the given sample, direct analysis of spatial and/or feature variabilities can be made using multivariate analysis.

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.311

극저선량 이온빔 조사를 이용하여 제작된 단일 NV color center의 광학적 특성 연구

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Abstract:

NV color center는 상온에서 전자 스핀의 측정 및 변조가 가능하기 때문에 범용 양자컴퓨터의 큐비트로 활용될 수 있다. color center를 이용한 큐비트 구현을 위해서는 원하는 지점에 단일 color center를 만들 수 있어야 한다. 이러한 방법으로는 single ion implanter를 활용한 방법과 패터닝과 극저선량(~ 10^9 ions/cm^2) 이온빔 조사 방법 등이 사용되고 있다. single ion implanter를 이용하는 방법은 가장 확실한 방법이지만 현재 국내에는 장치가 도입되어 있지 않으며, 극저선량 이온빔 조사 설비 또한 갖추어져 있지 않다.

본 연구에서는 50 keV N 이온빔을 electronic grade diamond에 10^9 ions/cm^2 의 조사량으로 주입하였다. 극저선량 조사는 한국원자력연구원 양성자과학연구단에서 수행하였으며, 극저선속 구현 및 선량 측정에는 양성자과학연구단에서 독자적으로 개발한 시스템을 사용하였다. 질소 이온빔 조사 이후에는 추가 vacancy를 생성시키기 위하여 100 keV H 이온빔을 추가 조사하였다. 이후 고온 열처리 공정을 통하여 NV color center를 생성시켰다. 생성된 color center의 광학 특성은 PL측정으로 확인하였으며, micro PL mapping을 통하여 생성 밀도를 확인하였다.

Keywords:

이온주입, 극저선량, NV color center

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.312

Identification of Superconducting Quantum Circuit with 8 Qubits with Single Measurement Line

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Abstract:

Transmon qubit is a kind of superconducting circuit (SC). Charge and superconducting phase can define two-level system and we can handle the whole system as a qubit. Transmon qubit has a merit of its flexible design. We can design both 'Cooper pair box' and its Josephson junction, which define E_C and E_J that determine the qubit transition frequency and other various parameters (T_1, T_2, etc.). Moreover, well-designed high Q-factor cavities or resonators can implement not only the control and measurement of quantum systems, but also the coupling between distant qubits.

In this research, we want to realize both single qubit operations and two qubit operations with multi-qubit superconducting quantum system and single measurement line. Especially, implementation of two qubit gates requires cross-resonance effect, such that uses exact qubit transition frequencies. However, identification of energy diagram for multi-qubit system is not trivial, because it is difficult to classify bare 0-1 transition frequency of each qubits from their entangled states and second excited states. Therefore, as a first step, we'll construct a procedure for identifying single qubit – cavity system, and further inspection of 8 qubit chip follows.

Keywords:

Superconducting Quantum Circuit, Transmon qubit, Quantum Computation

2020 KPS Spring Meeting
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P2-ap.312

Raman spectroscopic study of relaxor phase evolution in lead free $(Bi_{0.5}Na_{0.5-x}K_x)TiO_3$ ceramics due to potassium ion substitution

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Abstract:

Piezoelectric materials are used in a variety of electric devices including nanogenerators, sensors, and actuators. $Pb(Zr,Ti)O_3$ (PZT), a representative piezoelectric material, has been widely used in the commercial field because of its excellent piezoelectric properties. However, due to the harmfulness of lead in PZT, research is being conducted to replace it. In particular, the large strain induced by an external electric field have recently been found in lead free $(Bi,Na)TiO_3$ (BNT)-based materials having a perovskite structure. Therefore, the study of the cause of large strain in BNT-based materials is important. Previous studies have shown that the cause of large strain is the formation of the ergodic phase of relaxor ferroelectrics due to the presence of polar nano-regions (PNRs). PNRs are caused by the lattice distortions of A- and/or B-site doping and defects such as oxygen and A- and/or B-site ion vacancies in the perovskite structure. However, the X-ray diffraction commonly used in structural analysis, can only reflect the average structure of large length. Therefore, Raman spectroscopy can be used to investigate the local characteristics. In this study, we fabricated $(Bi_{0.5}Na_{0.5-x}K_x)TiO_3$ (BNKT) ceramics of various compositions according to potassium (K) ion substitution. In particular, the normalized strain (S_{max}/E_{max}) value improved significantly from 51 pm/V (x = 0.05) to 336 pm/V (x = 0.10). In addition, polarization–electric field (P-E) hysteresis loops measurements showed the pinch-type hysteresis shape found in the ergodic phase of relaxor ferroelectrics. These results suggest that the ergodic phase of relaxor ferroelectrics is formed in the BNKT ceramics by the x composition ratio. Therefore, we analyzed the microstructure change near the composition of x = 0.10 using the Raman spectrum of BNKT ceramics. Based on these results, the effects of K ion substitution on the structure properties of BNKT ceramics will be discussed.

Keywords:

Relaxor ferroelectirc, BNKT, Raman spectroscopy, Polar nano-regions

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.313

Out-of-Plane Thermoelectric Characteristics of p-type $Bi_2Te_3/Bi_{0.5}Sb_{1.5}Te_3$ Superlattice Film

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Abstract:

Superlattice (SL) films in TE device applications have been attracting much attention because their low dimensionality and thermal conductivity can greatly improve the TE figure of merit, with the increase in the density of states (DOS) near the Fermi level and the enhanced scattering of the phonons in the interlayer of the SL films due to quantum confinement leading to increased thermopower that results in ZT enhancement in the SL films.[1−3] Up to date, most previous studies have only focused on the in-plane TE properties and have rarely studied the out-of-plane TE properties of the films such as the Seebeck coefficient, electrical conductivity, and thermal conductivity. This is because the measurement of the out-of-plane TE properties in very thin films is difficult, and no techniques are available for these measurements. In this study, we report the out-of-plane Seebeck coefficient, thermal conductivity, and electrical properties of both p-type bismuth antimony telluride ($Bi_{0.5}Sb_{1.5}Te_3$, p-BST) and p-type bismuth telluride/bismuth antimony telluride ($Bi_2Te_3/Bi_{0.5}Sb_{1.5}Te_3$, p-BT/BST) SL films in the temperature range of 77−500 K. Because of the synergistic combination of the SL structure and low interface resistance, an impressively high ZT of ~ 1.44 was achieved at 400 K for p-type BT/BST SL films. The low interfacial resistance of the BT/BST SL film was clearly explained by theoretical calculations of the electronic structure of the BT/BST materials.

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Keywords:

Superlattice, thermal conductivity, bismuth antimony telluride, bismuth telluride

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-ap.315

PbS 광전압 소자에서 광전류 과도현상(transient)의 입사광 세기 의존성

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Abstract:

Fluorine-doped Tin Oxide(FTO)는 높은 전도율과 투과율을 가지고 있어 가장 널리 쓰이는 투명 전도성 산화물 기판이다. FTO 기판을 사용하여 화학적으로 증착한 PbS 층과 전자 빔 증착 방법을 사용한 Ti 층을 이용해 광전압 소자를 제작하였으며 소자에서 나타나는 광전류 과도현상의 입사광 세기 의존성과 그 원인에 대하여 연구하였다. 수직 소자와 수평 소자를 제작하여 그 차이를 비교하였다. 수직 소자는 Ti/PbS 쇼트키 접합을 이용하기 위해 Ti/PbS/FTO 구조로 제작하였으며, 수평 소자는 7 mm 간격으로 분리된 두 개의 Ti 전극 위에 PbS를 증착하여 PbS/Ti 전극/glass 구조로 제작하였다. 광전류 스펙트럼은 실온에서 바이어스 전압을 인가하지 않은 상태로 측정하였다. 소자의 cutoff 파장은 PbS의 실온에서의 밴드갭에 해당하는 ~3.2 μm 인 것을 확인하였다.

Keywords:

Infrared Lead Sulfide Photocurrent Photovoltaic

P2-ap.316

Transparent Two-dimensional Layered Double Hydroxide for Unipolar Switching Memory Application

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Abstract:

Diverse forms of two-dimensional (2D) materials have been attracting a lot of attention as emerging materials for low-power and high-performance electronic or optoelectronic device applications1. Layered double hydroxide(LDH) is a kind of 2D layers consisting of a positively charged metal hydroxide layer and intercalated charge-balancing anions, expressed by $[M^{2+}{}_{1-x}M^{3+}{}_{x}\,(OH)_2]^{x+}\,(A^{n-})_{x/n}\cdot mH_2O$. In this study, we synthesized three LDH layers using three divalent cations such as Zn2+, Ni2+, and Co2+ and controlled each packing density, which all were confirmed by XRD and SEM analysis. We analyzed and performed the electrical properties for each LDH in a form of two-terminal vertical junction structures using Pt and FTO electrode. Interestingly, the densely-packed ZnAl-LDH based device exhibited only a unipolar switching behavior with 10^3 ON-OFF ratio and acceptable stability, while all others did not show any switching feature. Different morphologies of the LDH layers depending on the ion kinds and the packing density are mainly attributed to their electrical characteristics. A potential switching the densely-packed ZnAl-LDH can be suggested by space-charge-limited conduction (SCLC) transport and directional motion of ionic vacancy by the electric field. The mechanism was further examined by the electrical responses according to the thermal stimuli. Our result indicates the importance of 2D LDH stacking morphology for the implementation of the nonvolatile resistive switching device.

Keywords:

Layered Double Hydroxide, 2D materials, ReRAM, Unipolar switching behavior

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-as.04

The Camera System for the IceCube Upgrade

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Abstract:

The IceCube Neutrino Observatory is a cubic kilometre volume of neutrino detector located at the geographic South Pole of Antarctica. IceCube records the signatures of neutrinos by observing Cherenkov light emissions from the charged secondary particles produced in neutrino interactions. The detector consists of 86 strings with more than 5,000 single-PMT optical sensor modules. An upgrade to the detector (IceCube Upgrade) is scheduled to be constructed in 2022/2023, which will add seven new strings with novel multi-PMT optical sensor modules and calibration devices at the centre of current detector volume. Korea plays a major role in the upgrade, that includes the contribution of a novel camera-based calibration system to be installed within the new optical modules.
The camera system will study the properties of surrounding bulk ice and refrozen ice in the drill hole. The system can also measure the detector geometry including location, orientation, and tilt of the optical modules and cable positions. The result of these calibration measurements will lead to an improved optical model of the detector medium (the Antarctic ice) and is in turn expected to enhance the neutrino event reconstructions. The mass-production of the camera system (with more than 2,000 camera modules) has started following the successful development of the Korean camera system. A series of hardware tests had been established and were performed over the first batch of 150 camera modules. We will present the summary of test results from the first batch of the mass-produced camera system. The result of a simulation study demonstrating the functionality of the system will be given as well.

Keywords:

IceCube , IceCube Upgrade, Detector Calibration, Camera System

Geant4 Monte-Carlo simulation studies for the ISS-CREAM Instrument

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Abstract:

A simulation model was developed for generating hadronic and electromagnetic cascades initiated by protons, He, and heavy nuclei in the Cosmic Ray Energetics And Mass for the International Space Station(ISS-CREAM) instrument using Geant4 Monte-Carlo simulation toolkit. The ISS-CREAM instrument is configured with a suite of particle detectors including four layers of finely segmented silicon charge detector for particle identification, a calorimeter for energy measurements, and top and bottom plastic-scintillator-based counting detectors for e/p separation. The experiment configuration was modeled as realistic as possible, including dead materials, gaps and mechanical structures. Performance of the ISS-CREAM instrument was investigated using isotropically generated events for the ISS-CREAM geometry with particles incident from the upper hemisphere. This poster will present simulation results on the instrument performance.

Keywords:

ISS-CREAM, GEANT4

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-as.06

Generalized Uncertainty Principle with minimal momentum and White Dwarf

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Abstract:

It is well known that gravitational corrections on quantum physics could lead to the Generalized Uncertainty Principle(GUP). In large distances the curvature of space-time becomes important. Therefore there is a limit to describe precision wavelength and we can introduce Minimal Uncertainty in Momentum(MUM) which appears as an IR Aspects of Quantum mechanics. On the other hand, to probe the short distances, particles require very high energies, lead to distortion of space-time. Thus we can introduce Minimal Uncertainty in Position(MUP) which appears as a UV Aspects of Quantum mechanics. In this poster, we use the MUM-corrected Uncertainty Principle to solve some quantum-mechanics examples such as the infinite potential in one dimension, the harmonic oscillator in one dimension and finally, we roughly show that MUM-corrected GUP with a positive parameter removes the Chandrasekhar limit.

Keywords:

White Dwarf, Chandrasekhar limit, Minimal length, Uncertainty Principle

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-as.07

Phase-Space Analysis of Halos around Large-scale Filamentary Structures

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Abstract:

It has been studied that galaxies evolve following a typical trajectory on the phase space under the influence of deep gravitational potential of galaxy clusters. Similarly, the large-scale filaments could also affect the evolution of galaxies before falling into the clusters. In this study, using a dark matter-only cosmological simulation, N-Cluster Run, we explore the evolution of galaxies on the phase space driven by large-scale filaments. We find that galaxies around the filaments form a common trajectory on the phase space as well as cluster galaxies do. We also examine how these trajectories change depending on various physical parameters such as galaxy mass, initial distance of galaxies from large-scale filaments, and cluster mass.

Keywords:

galaxy halo, cosmological simulation, large scale structure, filament

2020 KPS Spring Meeting
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P2-at.01

Optimization of loading rate in a magneto-optical trap using artificial neural network

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Abstract:

We report the optimization of a process to load rubidium(85) atoms to a magneto-optical trap using a neural network. The neural network consists of 5 hidden layers and each layer has 64 neurons. We use the three parameters of trap and repump laser detunings and anti-Helmholtz coil current as input to the network. The loading stage of 1 s is divided into three intervals, and at the beginning of each interval, the three parameters are refreshed. In addition, we allow the duration of each interval to change while keeping the total loading time constant. We observe the number of trapped atoms was the same compared to the result of humans.

Keywords:

neural network, rubidium 85, magneto optical trap, machine learning, atomic physics

P2-at.02

7Li Stimulated Raman Sideband Cooling and Spectroscopy

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Abstract:

Cooling atoms to zero-point energy is essential to demonstrate the controlled NOT(C-NOT) gate that uses entanglement between internal spin and motional states. Atoms are trapped in a 1D optical lattice. We use the Raman sideband cooling (RSC) by applying counter-propagating Raman beams along the lattice axis to cool the longitudinal motion . We carry out RSC between the $|2S_{1/2}$, F=1, m_F=-1$\rangle$ and $|2S_{1/2}$, F=2, m_F=-1$\rangle$ states which will be the qubit states. As a result, the red sideband becomes smaller indicating cooling of the longitudinal motion. We will report details of RSC scheme to cool both longitudinal and transverse motions as well as our progress towards the C-NOT gate operation.

Keywords:

Stimulated Raman Sideband Cooling, Atomic Spectroscopy, Controlled NOT gate

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-at.03

Annihilation of vortex clusters in a strongly interacting Fermi gas

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Abstract:

Understanding the topological defects and its dynamics is important in characterizing the quantum turbulence of a many-body system. Here, we investigate the annihilation dynamics of vortex clusters in a strongly interacting Fermi gas. One of the main obstacles for establishing a clear picture of the annihilation dynamics of vortices is the small size of the vortex core. In the limit of a strongly interacting Fermi gas, the bulk sample size and the vortex core size may differ on the order of a thousand. Conventionally, the imaging limitation has been avoided by applying a time-of-flight(TOF) before imaging. We show that this problem can also be circumvented by employing a non-cycling transition for *in situ* optical imaging. The suggested *in situ* optical imaging scheme is used to identify the scattering and decay of vortex clusters across the BCS-BEC crossover, where the microscopic physics governing the superfluidity smoothly evolves from a Bardeen-Cooper-Schrieffer(BCS) superfluid of long-range Cooper pairs to a Bose-Einstein condensate(BEC) of tightly bound diatomic molecules.

Keywords:

Vortex dynamics, Strongly interacting Fermi gas

High-precision force detection via quantum enhanced metrology using squeezed-light-driven cavity optomechanics

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Abstract:

We analyze the sensitivity of a force detector based on the homodyne measurement as well as Mach-Zenhner interferometers involving the standard optomechanical cavity. The system is driven by a coherent superposition of a coherent light and a squeezed vacuum field, providing quantum correlation and coherence in the optical field in order to enhance the sensitivity beyond the standard quantum limit. We analytically find the optimum measurement strength, squeezing direction as well as squeezing strength at which the symmetrized power spectral density for the additional quantum noise is lower than the standard quantum limit.

Keywords:

quantum metrology, optomechanics, precision measurement

2020 KPS Spring Meeting
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P2-at.06

양자중력계용 외부공진기 다이오드 레이저의 주파수안정화

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Abstract:

양자중력계의 정확도 및 안정도는 사용된 라만레이저의 주파수안정도에 영향을 받는다. 본 연구팀에서는 $\Delta g/g=5\times10^{-11}$ (@ 1 d) 이하의 안정도를 갖는 고감도 양자중력계를 개발 중이다. 이를 위해서는 레이저의 상대 주파수안정도가 1×10^{-11} 이하여야만 한다. 라만레이저로 사용되는 외부공진기 다이오드 레이저의 주파수를 안정화하기 위해 MTS(Modulation Transfer Spectroscopy) 분광시스템을 구성하고 FPGA 기반의 디지털 서보회로를 이용하여 주파수를 안정화하였다. 주파수안정화된 두 외부공진기 다이오드 레이저의 맥놀이 주파수 측정으로 얻어진 레이저의 단기 및 장기 주파수안정도가 모두 1×10^{-11} 이하임을 확인하였다.

Keywords:

양자중력계, ECDL, MTS, 주파수안정화

2020 KPS Spring Meeting
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P2-at.07

Characterization of ^{87}Rb-^{129}Xe/^{131}Xe-N_2 atomic vapor cells via free induction decay measurements

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Abstract:

We analyzed characteristic parameters of ^{87}Rb-^{129}Xe/^{131}Xe-N_2 atomic vapor cells by using free induction decay measurements. In particular, two characteristic parameters such as the transverse relaxation times and magnetic fields of both ^{129}Xe and ^{131}Xe magnetic moments were investigated as a function of temperature of cell, wavelength and intensity of the optical pump beam. We discuss optimal conditions for atom spin gyroscopes based on our analysis.

Keywords:

Atom Spin Gyroscopes, Free Induction Decay, Xe

Stimulated emission of spin-correlated atom pairs from Bose-Einstein condensates

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Abstract:

We present the collective emission of matter wave jet in spinor Bose-Einstein condensates. The dynamical instability of initial spin configuration triggers spontaneous formation of atom pairs, (0, 0) <-> (1, -1), where these atoms can be amplified and leave the trapped condensate. The experiment is extended version of recent “Bose Firework” [1-3] to spin sector, where we observe a clear cross spin correlation. This results suggest the created pairs could be a macroscopic Einstein-Podolsky-Rosen (EPR) pairs [4]. Interfering the two spin states, we observe clear modulations on the coincidence probability and magnetization correlation, confirming the presence of entanglement. Moreover, we numerically studied the formation of the jet using the time dependent Bogoliubov equation in quasi-2D system to understand the microscopic mechanism of jet emission in spin sector and the technical limits for estimating entanglement depth [5].

[1] L.W. Clark *et al.*, Nature **551**, 356 (2017).
[2] H. Pu *et al.*, Phys.Rev.Lett. **121**, 243001 (2018).
[3] Z. Wu and H. Zhai. Phys. Rev. A **99**, 063624 (2019)
[4] H. Pu and P. Meystre. Phys.Rev.Lett. **85**, 3987 (2000).
[5] B. Lueke *et al.*, Phys.Rev.Lett. **112**, 155304 (2014).

Keywords:

Bose-Einstein Condensate, Entanglement, Spinor condensate, Matter-wave jet, Dynamic instability

2020 KPS Spring Meeting
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P2-at.09

Optical wave guiding and spectral characteristics of micro/nanofiber

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Abstract:

We present theoretical studies on the propagation properties of the guided optical wave and the spectral properties of entangled photons from spontaneous four-wave mixing in micro/nanofibers. We first perform numerical calculations for single-mode propagation, field distribution, fraction of power, and group-velocity-dispersions by solving Maxwell's equations with boundary conditions in cylindrical coordinates. Then, these obtained wave guiding properties of micro/nanofibers are applies to estimate the spectral properties such as central wavelength and bandwidths of the created photons via spontaneous four-wave mixing that can be tailored by controlling diameter and length of micro/nanofibers. This theorestical work provides useful guidlines to design micro/nanofiber based quantum sensing and quantum light source for quantum technologies.

Keywords:

spontaneous four-wave mixing, micro/nanofiber, optical wave guiding properties

2020 KPS Spring Meeting
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P2-at.10

Enhancing a sensitivity of target detection with N-photon entangled states

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Abstract:

We investigate a two-mode N-photon entangled state to probe a target in the presence of loss and thermal noise. The N-photon entangled state preserves the total photon number N when it is observed by photon number resolving detectors. The target is simply replaced by a beam splitter with a reflectivity. Using quantum Fisher information, we show optimal conditions of the N-photon entangled states to estimate the reflectivity of the beam splitter. We also present that the N-photon entangled states can beat the performances of a two-mode squeezed vacuum state and a separable coherent state.

Keywords:

N-photon entangled states, target detection, quantum Fisher information

2020 KPS Spring Meeting
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P2-at.11

Numerical simulation of entangled photon-pair generation via SPDC in periodically poled $KTiOPO_4$ crystal

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Abstract:

Spontaneous parametric down conversion (SPDC) in nonlinear crystals has been widely used for photon-pair generation. Recently there has been a great interest in periodically poled structures because of their efficient photon-pair generation rate. Experimental factors which can affect SPDC results include temperature, wavelength and bandwidth of pump beam, cutting angle and poling period of the crystal and the type of SPDC. In this research, we provide a numerical simulation of photon-pair generation properties via SPDC in periodically poled potassium titanyl phosphate ($KTiOPO_4$, ppKTP). Using 405nm pump, we got relationship between photon-pair propagation angle and wavelength (tuning curve) with respect to temperature and types of SPDC (type 2, type 0). Collinear, degenerate, and collinear-degenerate conditions are extracted from the tuning curve. We investigated spectral properties of SPDC and found the spectral region that SPDC occurs dominantly. Using 780nm pump, we got telecommunication band photon-pair around 1560nm and found a condition that makes each photon spectrally pure. This numerical result can help determining experimental setups for quantum standoff sensing research area.

Keywords:

Nonlinear crystal, Quantum sensing, Photon-pair generation

2020 KPS Spring Meeting
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P2-at.12

Computational ghost imaging with turbid media

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Abstract:

We present experimental results of computational ghost imaging in the presence of turbid media. Computational ghost imaging is a technique to image an object by using spatial light modulator(SLM) and a position-fixed bucket(single-pixel) detector, instead of multi-pixel detector which is used in a conventional imaging system. In our experimental setup, the SLM generates random binary spatial patterns in the illumination beam, and the bucket detector measures the intensity of the light back-scattered by the object. The image of the object can be reconstructed from the correlation between the random patterns and the intensities measured in the single pixel detector. We present that the image can be reconstructed even when there is turbid media before the bucket detector, while a conventional imaging system such as a charge-coupled device(CCD) camera cannot obtain the image in the same situation.

Keywords:

Quantum optics, Ghost imaging, Computational ghost imaging

2020 KPS Spring Meeting
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P2-at.13

광-마이크로파 양방향 변환을 위한 키텔모드 분석 연구

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Abstract:

상온에서 광-마이크로파의 양방향 변환을 위해 이트륨 철 가넷(Yttrium iron garnet, YIG)의 키텔모드 (Kittel Mode)를 활용하고자 한다. 강자성체의 스핀여기(Spin excitation)을 이용하는 것으로 키텔모드의 마그논 쌍극자 모멘트와 빛이 상호작용하여 양방향 변환이 구현될 수 있다. 마이크로파 공진기를 이용한 마이크로파 모드와 키텔 모드간의 강한 상호작용을 통하여 마이크로파는 페러데이 효과를 통해 광파로 변환되며, 광파는 역페러데이 효과를 통해 마이크로파로 변환 가능하다고 알려져 있다. 이를 위한 전 단계로 본 연구에서는 마이크로파 공진기가 없는 자유 공간에서 수행한 마이크로파에서 광파로의 변환 결과를 분석하고, 이어서 서로 수직 편광된 결맞은 2주파수 레이저와 케텔모드간의 상호작용을 통한 광파에서 마이크로파로의 변환 실험을 수행하고자 한다.

Keywords:

키텔모드, YIG, 광마이크로파 변환

A convex-roof measure of quantum non-Gaussianity based on quantum relative entropy

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Abstract:

We propose a convex-roof measure of quantum non-Gaussianity (QNG) based on quantum relative entropy [1]. Our QNG measure is faithful because it always gives a positive value whenever a state cannot be described as a Gaussian mixture. We prove that our measure satisfies properties as a proper measure of QNG including convexity, additivity, and monotonicity under Gaussian channels and conditional Gaussian operations. Furthermore, we illustrate how to explicitly evaluate QNG for a noisy single-photon state. We find that its QNG coincides with its non-Gaussianity if the single-photon fraction is large enough.

[1] J. Park, J. Lee, K. Baek, S.-W. Ji, and H. Nha, Phys. Rev. A **100**, 012333 (2019).

Keywords:

quantum non-Gaussianity, quantum relative entropy

P2-at.15

Low-cost High-performance Diamond Nitrogen-Vacancy Spin Ensemble Magnetometer

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Abstract:

Nitrogen-Vacancy (NV) center in diamond has attained more attention as a solid state magnetic field sensor. Functioning at room-temperature, NV diamond has sensitivities below pico-tesla. Such results, however, require specially-grown ^{12}C enriched diamonds or an additional device amplifying external fields. In the present work, we pursued the implementation of a low-cost yet high-performance NV diamond magnetometer. A high density NV centers were fabricated in an inexpensive Type 1b diamond crystal synthesized by HPHT method. With a high refractive-index half ball lens and an elliptic reflector, the photon collection efficiency can reach 10 %, which is nearly 3 fold as high as using the best objective lens. Balanced detection efficiently reduces residual intensity noises from pump laser, leading sensitivity noise floor close to the shot-noise limitation. Dual frequency microwave driving technique doubles the field sensitivity and significantly suppresses the temporal baseline drift due to laser-induced heating that hinders reliable long-term operation. Finally, we obtained a magnetic field sensitivity of 70 pT/Hz$^{1/2}$ with negligible drift and sensitivity degradation for several hours. We believe this work paves the way for realization of a practical NV diamond magnetometer.

Keywords:

Quantum Sensing, Diamond , Nitrogen Vacancy Center, Magnetometer

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-at.16

Stability of energy transfer in an opto-mechanical systems

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Abstract:

We theoretical demonstrated the stability conditions for wide range of parameters in opto-mechanical systems. Our system assumes two optical cavities, mediated by one mechanical oscillator in between the cavities. The perfect energy transfer was shown between the cavities. In addition, we showed the perfect non-reciprocality in the blue detuned systems. In particular, we showed the controllability for the perfect energy transfer by tuning the coupling phase.

Keywords:

Three-mode optomechanical system, stability, Perfect energy transfer, Non-reciprocal

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P2-at.17

Quantum Simulations of Light Propagation through a Two-Dimensional Lattice of Cold Atoms

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Abstract:

We simulate numerically the effects of position fluctuation in light propagation through two-dimensional (2D) lattices of cold atomic vapors. Light at the normal incidence has intensity approaching saturation limit, and atomic spacing in the lattice is small so that density llattice constant is smaller than the wave number of the incoming light. The collective optical responses are computed using the Monte Carlo sampling for atoms in the Mott-insulator state. Gaussian function is used to approximate the vibrational ground-state wave function in each site in the 2D lattice so that density distribution function is used to sample randomly the positions of atoms. Transmission spectra obtained by using a semiclassical approach are plotted as a function of detuning in various confinement strengths and compared with those from quantum-mechanical formalism.

Keywords:

2D Planar lattices; Dense Cold Atoms; Quantum Position Fluctuation;Quantum Numerical Simulation;Light Propagation

P2-at.18

Implementation of exterior complex scaling as an absorbing boundary condition of solids affected by intense laser pulses

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Abstract:

In solids, the biggest obstacle in calculating electron dynamics excited by laser pulses in the length gauge is the accurate implementation of the periodicity of the atomic potential of solids. Due to the drawback, the velocity gauge, which is easily able to implement the periodic property of the atom potential, is used mainly in the calculation of high-order harmonic generation resulting from the interaction of lasers and solids. Length gauge description is sometimes more helpful to provide a conceptual understanding of the underlying physics. For example, the three-step model is constructed entirely in the length gauge, in which a clear physical picture has emerged. In length gauge, the time-dependent Schrödinger's equation has been solved usually by introducing a mask function or an absorbing potential near spatial boundaries. As another alternative to the boundary condition, we propose an exterior complex scaling (ECS) method. The essence of the ECS is to automatically create the boundary condition so that the wave function vanishes as $r \to \infty$. The ECS method is validated as comparing against the same physical phenomena calculated in the velocity gauge.

Keywords:

length gauge, time-dependent Schrodinger equation, exterior complex scaling, solids, High harmonic generation

P2-bp.01

Multi-site multi-color fiber photometry to record neural activity in freely behaving animals

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Abstract:

Fiber photometry has been increasingly popular in neuroscience research in freely behaving animals. In combination with genetically encoded calcium indicators, neural activity can be measured in deep brain structures, which translate neural activity into an optical signal. We have been developing a multi-site multi-color fiber photometry system to monitor neural activities in several brain regions of a freely behaving animal. It provides the capability to measure multiple cellular events in action at the same time throughout the neural circuitry. Here, we present the operating principles of the multi-site multi-color fiber photometry system, some preliminary results, and future applications.

Keywords:

fiber photometry

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.03

Optimization of culture of PLCL osteoblasts through electrical stimulation

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Abstract:

Culture of osteoblasts (MG63) in tissue engineering is an important issue. PLCL materials are excellent in biocompatibility and biodegradability and provide favorable conditions for osteoblasts (MG63) culture. In this study, the beneficial conditions for culturing osteoblasts (MG63) were studied by incorporating CaP, a bone component, and Alendronate used as a therapeutic agent for osteoporosis into polymer PLCL. After analyzing material compatibility, electrical stimulation was added to efficiently promote osteoblast culture. The culture of osteoblasts (MG63) was analyzed by thinly coating the prepared PLCL polymer on the electrode substrate. The cell number and conductivity were observed and analyzed at different voltages and times. Through this experiment, we were able to confirm the effects of cell culture using materials and electrical stimulation.

Keywords:

fosteoblasts (MG63), PLCL, conductivity

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.04

Nano-radiosensitizer delivery to mouse brain tumor models by gamma rays

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Abstract:

HVGGSSV peptide was found to bind specifically to the tax-interacting protein-1 (TIP-1) receptor expressed in irradiated cancer cells. The purpose of this study was to improve tumor-specific delivery and bioavailability of nanoparticle-mediated radiosensitizers in mouse brain tumor models using gamma irradiation. chitoPEGAcHIS nanoparticle was conjugated to HVGGSSV peptide that could bind to tax-interaction protein 1 (TIP-1) as a radiation-inducible receptor. c-Jun N-terminal kinase (JNK) inhibitor, SP600125 was incorporated into this copolymer and then HVGGSSV-chitoPEGAcHIS-SP600125 nanoradiosensitizer was fabricated. Synergistic therapeutic effects of radiation treatment and HVSP-NP were investigated in Lewis lung carcinoma (LLC) cell-bearing mouse brain tumor models. HVGGSSV-chitoPEGAcHIS-SP600125 nanoradiosensitizer effectively reduced DNA damage repairs to irradiated LLC cells. Optical bioluminescence assay showed that radiation induced TIP-1 expression in mouse brain tumor and that the nanoradiosensitizer selectively targeted irradiated tumors. Radiation treatment with HVGGSSV-chitoPEGAcHIS-SP600125 nanoradiosensitizer induced greater apoptosis and significantly inhibited tumor growth compared to radiation alone. TIP-1 was identified as a radiation inducible receptor that binds the HVGGSSV peptide in mouse brain models. HVGGSSV-chitoPEGAcHIS-SP600125 nanoradiosensitizer was found to be able to selectively target irradiated tumors and significantly increase tumor growth delay in LLC-bearing mouse brain tumor models.

Keywords:

Nanoparticles, Brain tumor, JNK inhibitor, Gamma rays

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.06

Spontaneous Hinge-Bending Motions of Angiotensin I Converting Enzyme: Role in Activation and Inhibition

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Abstract:

The inhibition of human angiotensin I converting enzyme (ACE) has been regarded as a promising approach for the treatment of hypertension. Despite research attempts over many years, our understanding the mechanisms of activation and inhibition of ACE is still far from complete. Here, we present results of all atom molecular dynamics simulations of ACE with and without ligands. Two types of inhibitors, competitive and mixed non-competitive, were used to model the ligand bound forms. In the absence of a ligand the simulation showed spontaneous large hinge-bending motions of multiple conversions between the closed and open states of ACE, while the ligand bound forms were stable in the closed state. Our simulation results imply that the equilibrium between pre-existing backbone conformations shifts in the presence of a ligand. The hinge-bending motion of ACE is considered as an essential to the enzyme function. A mechanistic model of activation and the inhibition may provide valuable information for novel inhibitors of ACE.

Keywords:

spontaneous conformational change, MD simulation, hinge-bending motion, ACE, activation and inhibition mechanism

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.07

Focused clamping of a single neuronal SNARE complex by complexin under high mechanical tension

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Abstract:

Neuronal SNAREs (soluble N-ethylmaleimide–sensitive factor attachment protein receptors) catalyze the fusion of synaptic vesicles with presynaptic membranes through the formation of SNARE complexes. Complexin (Cpx) is the only presynaptic protein that tightly binds to the neuronal SNARE complex and therefore regulates synaptic vesicle fusion. However, it remains unclear how Cpx modulates the energy landscape involved in the SNARE complex assembly, especially when mechanical tension is loaded on the SNARE complex. Using magnetic tweezers, we studied how Cpx interacts with a single neuronal SNARE complex and found that the molecular effects of Cpx manifested only under high mechanical tensions above 13 pN. We found that Cpx mechanically stabilized the central four-helix bundle composed of the SNARE motifs. At the same time, Cpx prevented the zippering of SNARE complexes from reaching completion by inhibiting the assembly of the linker domains. These results suggest that Cpx generates a focused clamp for the neuronal SNARE complex in a linker-open conformation.
The last step of neurotransmitter release is the joining of Ca2+ sensor Synaptotagmin-1(Syt1). Syt1 is expected to cue Ca2+ triggering the release of neurotransmitters by interacting with intact lipid membranes. To reconstitute the synaptic terminal environment on magnetic tweezers, we cast synaptotagmin and artificial lipid membranes with SNARE complex.

Keywords:

SNARE, complexin, synaptotagmin, magnetic tweezer, single-molecule biophysics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.08

Constructing two-dimensional folding energy landscape of GPCR protein

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Abstract:

G-Protein Coupled Receptors (GPCRs) are the family of receptor proteins that control a variety of biological processes from light perception to innate immune response. Because proper folding of GPCR proteins to its native state is crucial to their appropriate localization and function, misfolding of GPCR proteins leads to huge accumulation of nonfunctional proteins, causing genetic diseases such as retinitis pigmentosa. In that sense, understanding and elucidating the energy landscape of GPCR along its molecular and functional extension is essential to tackle this misfolding problem. In the previous work, the direct folding process of human β2-adrenergic receptor (β2-AR) was observed by using magnetic tweezers at single-molecule level. Applying this method, we are observing the folding pathway of β2-AR at various force levels so that we can construct the folding landscape of β2-AR along extension space. Moreover, GPCR proteins show dynamic conformation change when they interact with ligands including agonist, inverse-agonist and antagonist or G-proteins. By introducing these ligands, we will construct two-dimensional free-energy landscape by introducing functional space perpendicular to the molecular extension.

Keywords:

GPCR, β2-AR, Protein folding, Folding Energy Landscape, Magnetic Tweezers

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.09

In-situ protein function monitoring at the single nucleus level

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Abstract:

Cellular heterogeneity is a natural characteristic of biological systems, which presents major challenges in current precision medicine and diagnostics. Single-cell analysis allows for studying cell-to-cell variation within a cell population. Conventional in-vitro methods for analyzing specific biological functions in tissues require to culture billions of cells and extract proteins from the cells. Here, we propose a platform for monitoring a mismatch recognition function in cells at the single nucleus level. Single nuclei are lysed at tens of a micron-size chamber where DNA substrates are immobilized for detecting mismatch repair using microfluidics. Mismatched nucleotides are detected by single-molecule FRET in real-time. This method is potentially useful to screen protein functions in cells with high spatiotemporal resolution at the single nucleus level.

Keywords:

Single-cell analysis, DNA mismatch repair

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.10

Combining MT and electrophysiology and its application to SNARE-mediated pore formation

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Abstract:

Neurotransmitter release achieved by synaptic vesicle fusion is a critical event that enables neurotransmission. SNARE proteins mediate this fusion properly. This process is studied by various techniques. Among them, MT technique contributed to measure the force and energy for SNARE complex formations. Also, the patch-clamp method is possible to detect the ionic current in live cells or patches of the cell membrane. Recently, based on the electrophysiology, the ionic current during the fusion event was measured in detail using nanodisc construct. We combined this electrophysiological technique with MT technique and aimed to measure the ionic current made by fusion events adjusting the force applied to a 'fusion construct'. Also, we may find the energy scales for pore formation by measuring the change in ionic current under the applied force.

Keywords:

magnetic tweezers, electrophysiology, SNARE proteins

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.11

Highly accurate sensing of endogenous miRNA

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Abstract:

MicroRNAs are short RNAs (~22nt) that regulate the gene expression at the post-transcriptional level. Many miRNAs are found to play a crucial role in cancer development, and thus they are emerging as promising diagnostic biomarkers. However, detection of miRNAs is difficult because their size is small and there are many highly homologous miRNAs which differ only in a single-nucleotide. Using Argonaute (Ago) enzyme and Point Accumulation for Imaging in Nanoscale Topography (PAINT), we develop a highly accurate single-molecule detection technique for the amplification-free counting of miRNAs.

Keywords:

miRNA, let-7, single-molecule

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.12

Fluctuation analysis of transcription in live mammalian cells

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Abstract:

Transcription is the initial step of gene expression, in which the genetic information in DNA is copied into RNA by RNA polymerase. In eukaryotic cells, RNA polymerase II (PolII) and its associated factors transcribe all protein coding genes and a number of noncoding RNA. Yet it is not well known how the complex transcriptional machinery control transcriptional dynamics through the initiation, elongation, and termination of RNA synthesis in mammalian cells. To address this question, we directly monitored the transcriptional output in live cells using a transgenic mouse that expresses fluorescently labeled Arc mRNA. By imaging transcription sites (TS) in live mouse embryonic fibroblasts (MEF) cultured from the mouse model, we collected the fluctuation data of the transcriptional events. By fitting the autocorrelation curve of fluorescence intensity fluctuation from the TS, we measured the initiation, elongation, and termination rates of Arc mRNA. We also simulated the transcription model using a simple computational method to determine the contribution of the three stages. This study will allow us to compare the simulation and the actual observations, which will shed a light on the complex regulation of mRNA synthesis in live mammalian cells.

Keywords:

transcription, stem-loop system, fluctuation analysis

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.13

The role of beta-actin mRNA localization in single dendritic spines studied by two-photon glutamate uncaging

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Abstract:

mRNA localization in neurons is required to synthesize proteins in dendrites and axons. Long-term potentiation (LTP) is an important form of synaptic plasticity underlying learning and memory. To investigate the physiological role of beta-actin mRNA localization in dendritic spines, we employed two-photon glutamate uncaging to stimulate single dendrite spines with or without beta-actin mRNA localization. Hippocampal neurons cultured from the MCP ´ MBS knock-in mice in which all endogenous beta-actin mRNAs are fluorescently labeled were used for live-cell imaging of beta-actin mRNA. The activity of all neurons was blocked by applying tetrodotoxin (TTX), which is an inhibitor of sodium channels. Two-photon uncaging of glutamate was carried out to stimulate only a single dendritic spine. The structural LTP was assessed by measuring the changes in the volume of dendritic spines. Our results suggest that localization of beta-actin mRNA has a strong correlation with structural LTP process. To visualize local translation of actin proteins from beta-actin mRNA around a single spine, we labeled newly synthesized actin proteins with fluorescent dyes using puromycylation-PLA (proximity ligation assay) technique after stimulation. This study sheds a light on the implication of beta-actin mRNA localization and local translation for LTP in neurons and their role in long-term memory formation.

Keywords:

beta actin mRNA, localization, long-term potentiation, synapse , translation

2020 KPS Spring Meeting
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Transcription of Arc mRNA induced by electrical burst stimulation

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Abstract:

Immediate early genes (IEGs) are genes that are rapidly induced by neural activity. The expression of IEGs such as Arc, c-fos, and Egr1 has been used to investigate the relation among external stimuli, neural activity, and memory formation. Inside cells, there exist signaling pathways where the chain reaction of enzymes leads to the gene expression and regulation. These pathways can be driven by external stimuli such as heat, chemicals, growth factors, and electrical stimulation. In this research, we investigated the effect of electrical stimulation on the expression of Arc in hippocampal neurons cultured from the Arc-PBS x PCP-GFP mice. Among various frequency range of brain waves, 4~8 Hz (5~10 Hz for rodents) is called theta frequency. The theta frequency wave is observed during rapid eye movement (REM) sleep and known to be involved in memory formation. Particularly, the theta burst stimulation (series of high-frequency bursts given at theta frequency) is known to induce long-term potentiation (long-lasting increase in synaptic responses). We focused on the effect of the burst stimulation and tested various time intervals between the bursts to find the optimal burst frequency for the induction of Arc transcription. Live-cell imaging of Arc-PBS x PCP-GFP neurons allowed us to observe real-time response of Arc transcription. We found that theta burst stimulation induced Arc transcription in ~45% of neurons, which were significantly higher than the percentage of neurons activated by other frequency ranges. These results will shed light on the relation between Arc transcription and LTP-inducing electrical stimulation.

Keywords:

immediate early gene, Arc, electrical stimulation, theta burst stimulation

Imaging activity-dependent transcription of endogenous Arc mRNA in live mouse brain

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Abstract:

During learning and memory formation, the immediate-early genes (IEGs) such as Arc, c-fos, and egr-1 are rapidly induced in the subset of neurons. Recent findings revealed that these IEG expressing neurons store the information that are needed for the memory recall. Since memories are theoretically thought to be distributed in specific neurons or 'engrams', IEG expression has been used as a marker for engram cells. However, little is known how the engram representing a specific memory changes over time. To investigate the dynamics of engrams in a live animal, we used a transgenic mouse in which endogenous Arc mRNAs are fluorescently labeled by the PP7-GFP system. By using in vivo two-photon imaging through hippocampal windows, we were able to find neurons transcribing Arc mRNA in a few minutes after behavioral experiments. We compared the engram patterns in the CA1 region of the hippocampus after contextual fear conditioning and fear memory recall. This longitudinal imaging of engrams will shed a light on the dynamic processes of encoding, consolidation, and retrieval of memory in vivo.

Keywords:

Arc, Memory trace, Engram

Discovering novel cancer-specific PPI complex through single-molecule Co-IP

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Abstract:

Protein-protein interactions (PPIs) mediate signaling complexes during cellular processes. Multi-protein supercomplexes have been reported in specific cancers such as lung/pancreas adenocarcinoma, lymphoma and breast cancer. Interestingly, targeting components of the supercomplexes in these cancers decreases cell proliferation and its survival. Most cancer cells dysregulate PPIs and rewire various signaling pathway to survive, raising the possibility of the presence of supercomplexes in other cancers. Phase separation is emerging concept, contributing formation of biomolecular condensates likes these aberrant PPI complexes. Considering this concept, promiscuous protein interactions by some chaperons and intrinsically disordered proteins (IDPs) may contribute to form aberrant PPI complexes. Here, we represent new method to find out novel cancer-specific supercomplex through screening common chaperons and IDPs involving known cancer specific PPI complexes. Single-molecule Co-IP combined with CRISPRi and mass spectrometer will help to figure out unknown supercomplex of specific cancer in a high-throughput manner. Finding novel cancer-specific supercomplex may give new therapeutic options for refractory types of cancer such as triple-negative breast cancer (TNBC) and multiple myeloma.

Keywords:

Single-molecule, Protein-protein interactions, Supercomplex, Chaperons, Intrinsically disordered proteins

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.17

Protein foci in live cells

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Abstract:

Cells respond to dynamic extracellular stimuli through the regulation of their protein abundance, which results from the control of pre-translation and post-translation. The events can often be observed in the form of "protein foci," a locally concentrated protein spot. In this poster, we presented the dynamics of protein foci in living cells. PCNA-associated factor (PAF15) physically interacts with PCNA during DNA replication for DNA translesion synthesis. Interestingly, our in-vitro experiments indicated that PAF15 inhibits PCNA loading onto DNA through the competition with RFC (PCNA loading factor). This observation raised a question of how PCNA can be loaded during the S phase at which PAF15 is most abundant in cells. To address the puzzle, we visualized PAF15 fused with GFPspark in living cells using fluorescence microscopy. PAF15 foci are extremely stable, but they are regulated by cell cycles and UV-C irradiation generating DNA translesion. The observation reveals a role of PAF15 foci for the interaction of PAF15 and PCNA during DNA replication.

Keywords:

PAF15, KIAA0101, PCNA-associated factor, Live Cell imaging

P2-bp.18

Translational control of a specific gene by light-induced liquid-liquid phase separation

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Abstract:

Many times, tight spatiotemporal control of gene expression is an underlying mechanism for introducing asymmetry to biological systems. For example, mRNA localization with regulated translation is known to be essential for the proper development of oocyte and consolidation of memory in the brain. However, there lacks a tool which recapitulates this nature's ability to precisely control the translation of a specific gene. Here, we implemented a technique to control the translation of a specific gene by light using a recently developed OptoDroplet system. Using this novel tool, we are trying to understand the differential roles of newly synthesized β-actin and Arc in sculpting synaptic strengths.

Keywords:

Gene expression, Phase separation, Optogenetics, translation, mRNA

P2-bp.19

RNA polymerase diffuse on DNA via the hopping mechanism after intrinsic termination

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Abstract:

Despite previous studies about intrinsic termination, it is uncovered what is the fate of RNA polymerase (RNAP) after termination. In our previous single molecule fluorescence study, RNAP dissociation is often followed by RNA transcript release in bacterial intrinsic termination. Moreover, remained RNAPs on DNA can diffuse one dimensionally in bi-direction, and these RNAPs can bind to nearby promoter on template DNA and initiate transcription again. In this study, we measure the diffusion coefficient of remained RNAPs under variable salt condition and we unveiled that diffusion of RNAPs after termination can be described as hopping. Furthermore, this hopping mode makes it possible that diffusion of RNAPs recognizes the promoter located on not only template DNA but non-template DNA.

Keywords:

Single Molecule FRET, PIFE, intrinsic terminator, E. coli RNAP

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2020-07-13 - 2020-07-15

P2-bp.20

Single-molecule imaging of translation initiation

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Abstract:

Translation is the process of converting genetic information into a specific amino acid chain. During the translation, a complex of eIF4E, eIF4G, and poly(A) binding protein (PABP) that are assembled at 5′ cap and 3′ end of messenger RNA (mRNA) results in a “closed-loop” of mRNA. However, the visualization of the “closed-loop” has not been achieved in real-time. We first characterized the binding kinetics of mNeonGreen-tagged PABP to poly(A) tail using single-molecule fluorescence microscopy. We then monitored 5′ cap-bound eIF4E labeled with mScarlet-I and mNeonGreen-PABP associated with 3′ poly(A) tail of mRNA in polysome extracts. The mRNA with PP7 stem-loops in the 3'UTR was tethered to the PEG-biotin-coated Quartz glass through the streptavidin-binding peptide (SBP) that contains PP7-coated proteins. We will present the single-molecule studies of the translation initiation complex on mRNA.

Keywords:

Translation initiation, singlemolecule, imaging, mRNA

P2-bp.21

Coexistence of two independent mechanisms of Rho-dependent transcription termination

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Abstract:

Factor-dependent transcription termination, comprising 20-50% of Escherichia coli termination sites1, is induced by a hexameric helicase Rho. Concerning the mechanisms of Rho-dependent termination, there exist two competing models. In a conventional model named as the catch-up pathway, Rho first binds to rut (rho-utilizing) site of RNA transcript, then catches up RNA polymerase (RNAP) waiting on a pausing site, and finally disassembles the transcription complex. In a model named as the pre-binding pathway, Rho makes a stable complex with RNA polymerase from the beginning, and induces the disassembly of the transcription complex through an allosteric mechanism upon its binding to the rut site. We report single-molecule fluorescence assay that monitors the Rho-dependent termination pathways of E. coli. Contrary to the conventional belief, we find that two pathways are not mutually exclusive, but coexist with a varying proportion in a terminator-dependent fashion. Interestingly, the pre-binding pathway becomes efficient with a good correlation with the pausing time at the termination site, a fact favorably used for the riboswitch-based termination regulation observed in the leader region of mgtA gene.

Keywords:

Rho-dependent termination, mgtA, rut, single-molecule assay, RNA genesis

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2020-07-13 - 2020-07-15

P2-bp.23

Single-molecule screening of mismatch recognition function of cells

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Abstract:

MutS homologs (MSH) are the fundamental component of DNA mismatch repair (MMR), which recognize mismatched nucleotides mainly generated during DNA replication. Therefore, the malfunction of MSH can cause various diseases such as Lynch syndrome, as well as sporadic colorectal, gastric, endometrial, ovarian, and upper urinary tract tumors. To monitor the MSH function in cells, we constructed a circular DNA that contains a mismatched nucleotide and a donor-acceptor pair for single-molecule FRET using CRISPR/Cas9 nickase. When MSH binds the mismatch, DNA is kinked by 60°, which results in a decrease in the distance between the donor-acceptor pair. We validated that mismatch recognition at this circular DNA increases FRET efficiency using purified human MSH proteins, and then monitored FRET changes in three types of human cell extracts. MMR proficient (HeLa) and MLH1 deficient cell extracts (HCT116) show the transition of low-FRET to high-FRET in real-time, but the FRET change does not occur in MSH2 deficient cell extracts (Hec59). We propose a single-molecule method to screen the function of MSH in cells.

Keywords:

single-molecule FRET, MutS homologs, human cell extracts

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.24

Single-molecule fluorescence imaging of DNA mismatch repair

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Abstract:

Human mismatch repair is activated by MutS homologs (MSH) and MutL homologs (MLH). MSH recognizes mismatched nucleotides and forms stable sliding clamps. MLH authorizes strand-specific endonuclease starting at a distant 3′- or 5′-DNA scission for which PCNA triggers MLH. However, the mechanism of 3′-MMR excision reaction has been poorly understood. To visualize 3′-MMR excision reaction, we developed a real-time single-molecule fluorescence imaging method to confirm the endonuclease activity by MLH. We showed that MLH endonuclease functions the elimination of DNA strand in the 3′-MMR excision reaction. Furthermore, we showed 3′-MMR and 5 ′-MMR excision reaction at the same time.

Keywords:

DNA mismatch repair, MLH1-PMS2 endonuclease, singlemolecule imaging

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P2-bp.25

The kinetic steps of hCHD7 comprise multiple substeps

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Abstract:

Chromodomain-helicase-DNA-binding (Chd) family proteins remodel chromatin by translocating nucleosomes along DNA, but the mechanism is not fully answered. In previous single-molecule FRET studies on yeast Chd1p, we revealed that yeast Chd1p uses single ATP to unwrap first and then translocate a nucleosome by 4 or 7 base pairs. Here, we examine whether another member of CHD family, CHD7(hCHD7), has the same remodeling mechanism as Chd1p. Our results show that hCHD7 has smaller fundamental step size than Chd1p as other chromatin remodelers such as SWI/SNF, ISWI, and INO80. Furthermore, domain-swapping study of Chd1p and hCHD7 suggests that whether domains of Chd1p may determine the fundamental remodeling step sizes.

Keywords:

smFRET, Chd, Nucleosome Remodeling, Chd1, Chd7

P2-bp.26

Bending of D-shaped heterogeneous ring DNAs: the Euler-Kirchhoff theory and a FRET experiment

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Abstract:

The worm-like chain (WLC) model is a basic theory that describes the bending of a semi-flexible polymer. Here, we study a heterogeneous WLC that consists of two parts: a rigid rod-like part and a semi-flexible part. Based on the Euler-Kirchhoff theory, we analytically obtain the energy-minimizing shape of the WLC at the zero-temperature limit and, further, the conformation at room temperature. We perform a Langevin dynamics simulation for the corresponding model DNA and numerically support our theory. As an application, we explore the FRET data for the bending of D-shaped ring DNAs [1] and find that the D-DNAs having the double-stranded part longer than 38 bp can be described by our theoretical model. For the D-DNAs shorter than this, we provide a clue explaining the discrepancy.

[1] C. Kim, O. Lee, J.-Y. Kim, W. Sung, & N. K. Lee, "Dynamic release of bending stress in short dsDNA by a kink and forks", ***Angew. Chem. Int. Ed.*** **31**, 8943-8947 (2015)

Keywords:

DNA, Worm-like chain, Short ds DNA

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-bp.28

Heterogeneity and non-Gaussianity in the active motion of intracellular particles in Acanthamoeba castellanii

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Abstract:

Here we investigate the dynamics of the intracellular particles of Acanthamoeba castellanii, of which pathogenicity depends on the activeness of those particles. In the previous study [1], by tracking intracellular particles in the drug-taken cells, the origin of the activeness of the intracellular particles was revealed to be related to the myosin II motors. Here we carry out an extensive theoretical investigation analyzing the particle trajectories in the corresponding drug-taken and normal cells and elucidate in detail how the active motion is altered in response to the change of the intracellular environment due to addition of the drugs. In addition to analyzing the response to the change of the intracellular condition, we also study statistical properties of the particles via a number of single-trajectory observables such as the van-Hove self-correlation function, time-averaged mean-squared displacements, non-Gaussian parameter, velocity autocorrelation function and diffusivity distribution. We find that the active, heterogeneous dynamics can be explained using diffusing-diffusivity model, superstatistical approach and fractional Brownian motion with timescale-varying Hurst exponent.

[1] J. F. Reverey, J.-H. Jeon, H. Bao, M. Leippe, R. Metzler, and C. Selhuber-Unkel, Superdiffusion Dominates Intracellular Particle Motion in the Supercrowded Cytoplasm of Pathogenic Acanthamoeba castellanii, Sci. Rep. 5, 11690 (2015).

Keywords:

Single particle tracking, Diffusing diffusivity, non-Gaussianity, Superstatistics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.101

Photoinduced topological phase transition and optical conductivity of black phosphorene

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Abstract:

We theoretically study the photoinduced topological phase transition of black phosphorene induced by laser light with moderate intensity, which can satisfy the experimentally realistic requirement to preserve the quality of the sample. By deriving the effective Floquet Hamiltonian in terms of pseudospin $S = 1/2$ degrees of freedom, we calculate the Chern number and the optical conductivity of the system with varying laser frequency Ω. As one can expect from the photon-assisted transport, the longitudinal optical conductivity has a threshold frequency at $\Omega=\Delta/\hbar$, with Δ being the band gap of black phosphorene. Unlike the longitudinal optical conductivity, the optical Hall conductivity sharply increases when $\hbar\Omega$ goes beyond one-half of the band gap $\Delta/2$. We also show that the Chern number changes from trivial to nontrivial upon increasing frequency Ω beyond $\hbar\Omega = \Delta/2$.

*This work is supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (NRF-2016R1D1A1B01013756).

Keywords:

Topological phase transition, Floquet, Black phosphorene

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.102

탄성 변형에 의한 그래핀 양자점의 공명터널링

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Abstract:

그래핀의 우수한 수송특성을 양자점 연구에 활용하기 위해, 그래핀에 양자점을 만들기 위한 많은 연구가 이루어지고 있다. 하지만 bandgap의 부재로 인해 그래핀에 양자점을 구현하는 것은 어렵다. 그래핀의 우수한 역학적 성질에 힘입어, 그래핀에 탄성변형을 인가하고 그로 인한 전기적 성질 및 수송특성을 제어하는 연구가 최근 촉망받고 있다. 특히, 탄성변형에 의한 준자기장(pseudo magnetic field, PMF)의 영향으로 그래핀의 디락 페르미온이 국소화될 수 있다는 점으로부터 양자점을 구현할 수 있는 후보로 탄성변형이 대두되었다.
본 이론 연구에서는, 원형 탄성변형을 가하여 그래핀에 양자점을 형성하고 그 특성을 탐구한다. 그래핀 나노리본 양자홀 전도도의 공명 터널링 현상으로부터, 탄성변형이 일어난 영역에서 강한 국소화 상태가 존재함을 확인한다. 탄성 변형에 의한 양자점의 국소화 상태가 밸리-섞임에 의한 미세구조를 가지며, 그 미세구조의 갈림이 탄성변형에 의존하여 변한다는 것을 보인다. 따라서, 탄성변형에 의해 그래핀에 양자점을 인가함은 물론, 탄성변형을 조절함으로써 양자점의 양자상태를 조절할 수 있음을 밝힌다.

Keywords:

그래핀양자점, 탄성변형, 밸리섞임, 공명터널링

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.103

The low-energy electron band structure of a two-dimensional Dirac nodal-line semimetal: Cu_2Si grown on Si(111)

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Abstract:

Cu_2Si exhibits two Dirac nodal-lines, stemming from the crossing of one electron-pocket with two hole-pockets, that are protected by mirror reflectionsymmetry. When it is placed on Si(111), the hole-pockets and their satellite bands due to the quasi-5┐5 periodicity are clearly observed, whereas the electron-pocket is observed with very weak spectral intensity. Interestingly, close to the Fermi energy, the hole-pockets exhibit almost linear energy-momentum dispersion, when their spectral width is also linearly proportional to energy. These findings indicate that Cu2Si on Si(111) can host the Dirac nodal-line fermions, of which low-energy excitations might depart from those of the conventional Fermi liquid.

Keywords:

dirac nodal line, Cu2Si

2020 KPS Spring Meeting
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P2-co.104

Optimal Device Parameters for Multi-Layered WSe_2 Field-Effect Transistors

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Abstract:

TMDCs(Transition metal dichalcogenides)는 우수한 기계적, 화학적 그리고 열적 특성을 가지고 있을 뿐만 아니라, 그래핀과 다르게 넓은 밴드 갭을 가지고 있어 전자 및 광학 소자응용에 큰 기대를 받고 있다. TMDCs를 응용한 반도체 소자에는 전극으로 사용되는 금속과 반도체 물질 간 TMDC-금속 접합 구조가 필수적으로 들어가며, 접합면 공정 과정에서 발생하는 화학적, 물리적 불순물과, TMDC 내부에 생성되는 결함 구조에 의한 페르미준위 고정현상으로 TMDC 반도체 본연의 전기적 성질 구현이 어렵다는 문제점이 지속적으로 제기되어 왔다.

우리는 본 연구에서 TMDC-금속 접합면에 형성되는 쇼트키장벽의 높이와 너비에 따른 다중막 WSe_2 전이효과트랜지스터 성능을 정밀 분석하여 최적의 전기적 성질을 보유한 WSe_2 트랜지스터를 구현하고자 했다. 일함수값이 다른 플라티늄, 티타늄, 스칸디늄 전극을 사용하여 WSe_2-금속 접합구조의 쇼트키장벽 높이를 효율적으로 조절, 고성능 p-형, 양극성, 그리고 n-형 WSe_2 전이효과 트랜지스터를 구현할 수 있었다. 더불어, 쇼트키장벽 너비는 WSe_2-금속 접합면과 전이효과에 의해 전자수송현상이 발생하는 박막 간 거리에 의해 직접적으로 결정된다는 것을 확인할 수 있었고, WSe_2 박막 두께를 단일막 수준으로 조절한 고성능 전자소자를 제작하여 쇼트키장벽 너비 변화에 따른 다중막 WSe_2 전자수송 성질과 트랜지스터 특성을 정밀 분석하였다.

Keywords:

WSe2, FET, Metal Contact, Transport

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P2-co.106

2차원 전자계를 이용한 테슬라 밸브 구현 연구

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Abstract:

테슬라 밸브는 니콜라 테슬라에 의해 고안된 밸브로 별도의 조작없이 구조의 기하학적인 특이성을 이용하여 액체를 한 방향으로만 흐르게 할 수 있다. 본 실험에서는 GaAs/AlGaAs 이종접합 2차원 전자 가스층(2DEG) 을 활용하여, 테슬라 밸브와 유사한 구조를 활용하여 페르미 가스인 전자를 제어할 수 있는지를 확인하였다.
전도채널의 폭(1um ~ 20um)을 가진 다양한 기학학적 구조의 소자를 제작하여 ,이들의 I/V 특성과 온도에 대한 변화를 측정하였으며, 이를 통해 테슬라 밸브의 정류장치로서의 활용 가능성에 대해 연구하였다.

Keywords:

tesla valve, 2D electron gas

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P2-co.107

Structural analysis of an HCP-phase PdH nanoparticle using atomic electron tomography

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Abstract:

Palladium has been actively studied for a long time as one of the useful catalysts, hydrogen storage media, and hydrogen-permeable membrane materials. The discovery of Pd's hydrogen storage and hydrogen permeation mechanisms is of great importance for future generation fuel cells, and their hydrogen storage capacity and catalytic functions are closely related to the atomic structure.
In a graphene liquid cell geometry with a hydrogen-rich environment, a new structural form of Pd nanoparticles can be synthesized by controlling electron beam illumination. Through atomic electron tomography using scanning transmission electron microscopy (STEM) tilt-series images, we identified 3D coordinates of individual atoms in such a Pd nanoparticle and found that it exhibits an unprecedented HCP structure. Furthermore, we confirmed through domain analysis based on HCP fitting that the Pd nanoparticle has multiple domains rather than forming a single crystal.
From local lattice fitting, a 3D local lattice constant map and 3D local unit cell volume map of the whole nanoparticle were obtained, and by comparing the density functional theory (DFT) calculation result with the local unit cell volume, a 3D hydrogen concentration map was also determined.
These findings can explain the atomic scale relationship between structure and synthesis mechanism in full 3D details, which will be essential in the development of materials with enhancing hydrogen storage capacity and catalytic function.

Keywords:

Palladium nanoparticle, atomic electron tomography, structural domain, hydrogen storage, catalysts

Investigation about effects of depositing capping $SrTiO_3$ on $LaAlO_3/SrTiO_3$

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Abstract:

The two-dimensional electron gas at $LaAlO_3$(LAO)/$SrTiO_3$(STO) is well known to exhibit ferromagnetism and superconductivity. However, the effects of depositing capping STO on LAO/STO was not investigated. We fabricated vertical Josephson junction by depositing Aluminum on (STO)/(LAO)/(STO) to investigated how to change the interface characteristics. We found that STO/LAO/STO has phase transition to superconductivity at T= 200 mK. Below Tc, the peak of the Andreev reflection contributed by aluminium and oxide interface, was observed. As a result of investigating the superconducting energy gap from the peak, temperature dependence of the energy gap did not follow BCS theory unlike LAO/STO. Additionally, above Tc, the Andreev reflection between Aluminum and oxide interface contributed by ferromagnet was observed.

Keywords:

Josephson jucntion, Oxide interface

2020 KPS Spring Meeting
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P2-co.109

Chiroptical metasurface

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Abstract:

The chiroptical properties of metasurfaces are promising research field due to its potential applicability for flat optics. However, obtaining tunable optical properties is still challenging. Herein, we fabricated the chiral surface pattern by using a Polydimethylsiloxane (PDMS) transferred from the grating with gold sputtering (**au-gPDMS**). The Au-gPDMS has circular dichroism (CD) spectrum according to surface asymmetry, curvature, and direction of curvature. As a result, it was confirmed that curvature had the greatest effect on chirality. These results will open the novel method to approach tunable metasurfaces

Keywords:

metasurface,chirality,curvature, tunable

2020 KPS Spring Meeting
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P2-co.110

NMR 측정 데이터의 분석 알고리즘 개발

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Abstract:

물질 표면의 금속적 성질을 보이는 위상부도체는 핵-전자간의 초미세 상호작용에 의한 스핀-격자 완화(spin-lattice relaxation) 특성을 지닌다. 또한 원자핵과 전자 간 상호 작용에 의한 자기장 때문에 공명점 이동을 보이며, 이것을 Knight Shift 라고 부른다. 초미세 상호작용에 의한 핵자기공명(Nuclear Magnetic Resonance) 스펙트럼은 선폭이 매우 넓어 분석이 까다롭다. 게다가, 지연시간 변화에 따라 얻어진 스핀-격자 완화 데이터 분석도 넓은 선폭으로 인해 주의가 필요하다. 실제 NMR 측정 데이터는 온도의 변수로 해서 측정을 수행하므로 한 시료 당 수백 개의 NMR 공명 스펙트럼이 만들어 진다. 따라서 본 연구에서는 C++ 프로그램을 기반으로 하는 ROOT 데이터 분석 방법을 사용하여 NMR 측정 데이터를 분석하는 알고리즘을 개발하였다. 알고리즘 개발 전에는 각각의 공명 그래프를 한 개씩 분석해야하기 때문에 많은 시간이 소요될 뿐만 아니라 분석오류가 발생하였다. 본 연구에서 개발한 알고리즘을 NMR 측정 데이터에 적용한 결과를 서술하겠다.

Keywords:

NMR, C++, ROOT, 데이터 분석

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P2-co.111

Surface Wettability Change of Hydrophobic Polymers by Low Dose Irradiation of High-Energy Alpha Particles

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Abstract:

When materials are irradiated with high-energy charged particles, nuclear reactions can happen. Because of their high linear energy transfer (LET) characteristic, nuclear reactions occur near the surface of irradiated materials. Therefore, surface properties of materials, for example, wettability, can be changed by irradiation-induced nuclear reactions.
If functional groups such as amine (-NH_2), carboxyl (-COOH), or hydroxyl (-OH) groups, which represents hydrophilicity, are produced on hydrophobic surfaces, they can be changed to hydrophilic surfaces. Nitrogen and oxygen atoms, consisting of those functional groups, can be produced directly by nuclear reactions of carbon nuclei such as $^{12}C(\alpha, p)^{15}N$ and $^{13}C(\alpha, n)^{16}O$. In addition, they can be produced by $^{13}C(\alpha, p)^{16}N$ and $^{12}C(\alpha, n)^{15}O$ reactions and following β+ decay of ^{15}O and ^{16}N.
In this research, we performed high-energy alpha particle irradiation experiments with polymeric materials such as polytetrafluoroethylene (PTFE), polyethylene (PE), and polystyrene (PS), which are originally hydrophobic and have many carbon atoms in their chemical structure. Surfaces of those hydrophobic materials were successfully converted to hydrophilic surfaces after the very low-dose irradiation of high-energy alpha particles.

Keywords:

alpha particle, irradiation, hydrophobic, hydrophilic, polymer

P2-co.112

NMR spectroscopy for the massive 3D Dirac electron system

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Abstract:

Nuclear magnetic resonance (NMR) spectroscopy is one of the most promising tools to investigate the electronic structure at the Fermi level. Topological insulators are characterized by insulating band gaps in the bulk and a gapless surface state which is Dirac-like cone as a result of spin-orbit coupling and time-reversal symmetry. Here, we study the nuclear magnetic relaxation rate and Knight shift in the presence of the orbital interactions for three-dimensional (3D) Dirac electron systems. The increasing surface-to-volume ratios of the topological insulator $Bi_{0.5}Sb_{1.5}Te_3$ may affect the electronic structures at the Fermi level where the contribution of the gapless surface state increases, thus successfully being probed by the NMR spectroscopy.

(This work was supported by the National Research Foundation of Korea (NRF) grant (No. NRF-2018R1D1A1B07047259) and the KOMAC operation fund of KAERI by Ministry of Science ICT and Future Planning of Korean Government.)

Keywords:

nuclear magnetic resonance spectroscopy, topological insulators, Dirac electron system

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P2-co.113

1.7 MV 탄뎀가속기를 이용한 ERD (Elastic Recoil Detection) 시스템 개발 및 박막 내 수소 분포 측정 실험

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Abstract:

반도체를 비롯한 다양한 물질 연구 분야에서 박막 내 성분 분석 특별히 강조할 필요가 없을만큼 매우 중요하게 인식되고 있다. 박막의 두께가 얇아지고소자의 크기가 작아짐에 따라 이러한 물질을 구성하고 있는 주성분뿐만 아니라 박막제조 과정에서 의도와는 무관하게 유입되거나 존재하게 되는 불순물들의 농도와 불순물에 의한 영향 등이 중요해지고 그에 대한 관심 또한 커지고 있다. 이러한 불순물 중 대표적인 원소 중 하나인 수소이다. 본 연구에서는 1.7 MV 탄뎀가속기를 기반으로 한 ERD (Elastic Recoil Detection) 분석장치의 개발과 이를 이용한 박막 내 수소의 농도 분포 측정 결과에 대해 발표한다. ERD 장치는 한국원자력연구원 양성자과학연구단에서 운영 중인 1.7 MV 탄뎀가속기의 빔라인 중 하나에 설치된 RBS 챔버 내에 설치되어 있다. 실험에 이용된 He 이온의 에너지는 2.9 MeV 였으며 표적이온의 되튐각도는 30도로 하고 정확한 분석을 위해 Chares Evans @ Associates에서 제작한 50 keV 수소이온이 2E+15/cm2 조사된 시료에 대해 분석을 실시하였다. 실리콘 웨이퍼 내 조사깊이는 약 500 nm 이며, 입사각을 고려하여 계산한 헬륨이온의 최대 이동 거리는 1.94 um에 해당하고 이동 중 잃어버리는 에너지는 0.374 MeV 이고 수소이온의 중심위치에 도달할 때 헬륨이온의 에너지는 2.525 MeV가 된다. 되튀어 나오는 수소이온만이 검출기 내로 입사할 수 있도록 검출기 앞에 14 um 두께의 Mylar 필름을 설치하여 최대 2.9 MeV의 He 이온이 정지될 수 있도록 하였다. 추가로 ERD 시스템을 이용하여 실리콘 웨이퍼 표면의 자연산화막 내의 수소 분포와 PS 고분자 시료 내의 수소 분포도 함께 측정하였다.

Keywords:

1.7 MV 탄뎀가속기, ERD (Elastic Recoil Detection), 이온빔 분석, 수소

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.114

Progress in spatially-resolved tunneling spectroscopy of Andreev bound state in Josephson junction

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Abstract:

A Josephson junction consists of a non-superconducting insert sandwiched by two superconductors. Josephson junctions allow the supercurrent by forming a bound state of correlated electron-like and hole-like quasiparticles, which is called Andreev bound states (ABS)[1]. For topological Josephson junctions, ABS contains invaluable information about the topological materials in-between two superconductors [3]. Usually, ABS has been studied indirectly by measuring critical current [2], which lacks spatial information. Here, we report on the progress of spatially-resolved measurement on Andreev bound states. We fabricated local tunneling contacts at the side of graphene and measured the superconducting gap of Aluminum (Al) and niobium nitride (NbN). In addition, we observed the energy gap between Landau levels, which are formed in a perpendicular external magnetic field. We will discuss the measurement on ABS of Josephson junction mediated by quantum Hall edge state under a strong magnetic field. We expect this novel technique opens new avenues for probing exotic properties of topological materials.

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3. Fornieri, A., et al., *Evidence of topological superconductivity in planar Josephson junctions.* Nature, 2019. **569**(7754): p. 89-92.

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.115

Structural Evolution of Ga doped PtNi Fuel-Cell Nanocatalysts during Load Cycles at 3D Atomic Scale

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Abstract:

Recent studies showed that doping of transition metals on the surface of bimetallic electrochemical catalysts enhances both their oxygen reduction reaction (ORR) activity and the stability of the nanocatalysts. However, it has not been well understood how the doping can increase both the performance and stability. Understanding the distribution of atoms on the surface can be directly linked to the stability of the catalyst. In this regard, atomic electron tomography (AET) can be an essential tool to reveal the full 3D atomic structure of nanocatalysts, shedding light on the development of catalyst with much higher efficiency. In this study, we conducted AET experiments on Ga doped PtNi nanoparticles to understand the relation between the structural stability during load cycles and the chemical arrangements at their surfaces. We obtained the 3D atomic position of individual atoms and chemical species of nanoparticle at different load cycles without assuming crystallinity. Moreover, we calculated the full 3D strain tensor which is related to the stability of the surface atoms. Determination of atomic structure evolution during the load cycles will provide a general understanding of the degradation mechanism of nanocatalysts as well as the relationship between stability of nanocatalysts and surface atomic arrangements.

Keywords:

Ga doped PtNi, polymer electrolyte membrane fuel cell (PEMFC), nanocatalyst, atomic electron tomography (AET), 3D strain tensor

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2020-07-13 - 2020-07-15

P2-co.116

Ammonia borane을 이용한 h-BN(hexagonal boron nitride)의 성장과 defect states의 광학적 특성

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Abstract:

본 발표에서는 h-BN을 이용한 단광자 방출로 유망한 defect states에 대한 것을 다룬다. 이차원 물질인 h-BN은 5.9eV정도의 큰 에너지 bandgap을 갖지만 defect states에 의한 가시광 방출이 가능하며 단일 결점에 의한 단일 광자를 방출한다고 알려져 있다. 이를 위하여 h-BN을 직접 성장한다. 광자 기반 양자 정보 기술은 single photon emitter 을 필요로 한다. 대표적으로 SPDC(Spontaneous parametric down conversion) 를 이용하는 방법이 있으나 이는 통계적인 방출이다 . 반면 , h-BN 을 이용하면 PL 을 통해 필요할 때 single photon 을 방출할 수 있어 많은 연구가 진행되고 있다 본 연구에서는 h-BN 의 single photon emitter 특성을 연구하기 위하여 , h-BN 의 성장, 결정 특성, 광학적 특성 및 single photon emitter로서의 가능성을 연구 하였다.

Keywords:

ammonia borane, hexagonal boron nitride, photoluminescence, single photon emitter, Native defect states, C-based defect states

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P2-co.117

Towards high-accuracy measurements of thethermoelectric effect in suspended Bi_2Se_3 epifilms grown by molecular beam epitaxy on GaAs(111)A

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Abstract:

Bi_2Se_3 is well known as an efficient thermoelectric (TE) material. TE effect measurements are experimentally challenging to measure with high-accuracy due to environmental extrinsic effects. We report growth optimization of Bi_2Se_3 thin films and thermoelectric study of suspended Bi_2Se_3 beam structures. The Bi_2Se_3 thin films were grown on GaAs(111)A substrates by molecular beam epitaxy (MBE) and confirmed by (00n) series peaks of x-ray diffraction (XRD) that the material was grown along the c-axis of GaAs(111)A. Optimizing the desorption process of GaAs(111)A surface and growth conditions of GaAs buffer layers leads to low RMS roughness and less-defective structural aspects. Using the optimizied Bi_2Se_3 epifilms, we realize suspended beam structures with minimal heat dissipation to GaAs substrate and the environment, minimizing extrinsic effects. The beam structures are fabricated by selective wet etching, and at ends of the beam, platinum heaters and voltage leads are patterned to measure the thermoelectric effect. Nanomachining technique enables to calculate the dimensionless figure of merit (ZT) of Bi_2Se_3 with minimal environmental factors.

Keywords:

Thermoelectric effect, Bismuth selenide, Molecular beam epitaxy

2020 KPS Spring Meeting
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P2-co.119

Quantitative analysis of the chiral plasmonic structure with nanoparticles.

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Abstract:

Three-dimensional (3D) chiral nanostructure, has variant total optical loss spectroscopies under left- and righthanded circularly polarized (LCP and RCP) incident light. In order to control the chiroptical properties of chiral plasmonic nanomaterials, research on fundamental properties related to the correlation between chirality and optical activity has recently received attention. In particular, the chiroptical effect can be strongly enhanced thanks to plasmonic effects from the chiral nanostructure on nearby molecules. Various chiral nanostructures have been introduced including chiral nanoantennas, metamaterials, colloidal nanoparticles, and many others. However, for tailoring chiral plasmonic devices, the understanding of the resulting chiroptical response when coupling chiral and achiral structures together is crucial and has not been completely understood to date. Researchers presented a thorough experimental and simulational study to understand the intriguing chiral–achiral coupling scheme, but the cases were limited to their experimental cases so it wasn't enough as a basic study of chiral plasmonics. In this study, we built a basic system of chiral plasmonic nanostructure with spherical nanoparticles and studied quantitative chiroptical response which related to the position of the basic nanoparticles using the finite element method (FEM) simulation. Quantitative analysis in this study will be the basis to understand chiral plasmonic nanostructures to develop precisely controllable chiroptical devices.

Keywords:

Chirality, Plasmonics, Nanostructures, Circular dichroism, Finite element method

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P2-co.120

Preparation of clean layered materials with various thicknesses for surface-sensitive techniques using a glove box and a suitcase

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Abstract:

Reducing the dimensions of materials often leads to unexpected electronic states. In particular, transition metal dichalcogenides (TMDs) show the various physical properties, such as tunable charge density waves (CDW) [1-3], metastable superconductivity [4], controllable magnetic domains of itinerant ferromagnets [5], and so on, because of their enhanced electronic correlations or significant quantum size effects. Providing direct observation, scanning tunneling microscopy (STM) has contributed to understanding of surface structures and local electronic states. However, the degradation on the surface has precluded the experiment of versatile materials. Here, we present a straightforward technique of locally measuring surface-sensitive crystals by using a standard glove box and a compact suitcase. The combination succeeds in both protecting one of the air-sensitive ferromagnetic metals, Fe_3GeTe_2, and obtaining the atom-resolved images for the various thick flakes. The simple and straightforward method opens up opportunities for thickness effects on structural and electronic states of surface-sensitive van der Waals materials.

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Keywords:

Transition metal dichalcogenides (TMDs), Scanning tunneling microscopy (STM), Thickness-dependent, Surface protection

Doping of $MoTe_2$ using different gas under DUV light illumination

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Abstract:

TMDCs(Transition metal dichalcogenides)는 전기적, 광학적 우수한 특성을 가지고 있다. TMDCs는 큰 밴드 갭을 가지고 있기 때문에 이를 이용한 반도체 소자 연구가 활발하게 진행되고 있다. 이 실험에서는 반도체 공정 과정에서 소자특성 조절을 위해 반드시 필요한 doping을 control하려고 한다.

우리는 이 연구에서 O_2를 채워 넣고 Deep ultavilolet light (DUV, 220 nm, 11 mW/cm^2)를 쬐어주는 과정(DUV+O_2)과 N_2를 채워 넣고 DUV를 쬐어주는 과정(DUV+N_2)을 이용하는 doping 공정을 $MoTe_2$ 조각에 적용하였다. $MoTe_2$ 의 ohmic contact은 majority carrier type에 따라 Cr/Au electrode와 Al electrode를 사용하였다. 더 나아가 DUV+O_2 공정을 이용하여 P-type으로 만든 $MoTe_2$를 DUV+N_2 공정을 이용하여 다시 N-type으로 바꿀 수 있는 것을 확인하였다. Ambipolar 특성을 가지고 있는 $MoTe_2$의 경우, 20 min DUV+O_2 공정을 통해 P-type으로 만들 수 있었고, 20min DUV+N_2 공정으로 N-type을 만들 수 있다. 한편, N-type으로 만든 $MoTe_2$를 다시 P-type으로 만들 수 있었다. 또한 $MoTe_2$의 두께에 따라 도핑이 되는 시간이 다르게 관찰되어 두 변수간의 상관 관계를 알 수 있었다.

결론적으로 이 실험에서 $MoTe_2$를 매우 간단한 공정을 통하여 N-type과 P-type으로 만들 수 있을 뿐만 아니라 두께에 따라서 도핑을 해야하는 최소 시간이 필요함을 알 수 있었다. 이와 같이 도핑 공정을 이용하면 단일 물질 TMDCs로 p-n 접합을 만들 수 있다.

Keywords:

TMDCs, Doping

2020 KPS Spring Meeting
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P2-co.122

Towards realizing topological chiral 1D channel in high-quality bilayer graphene

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Abstract:

Topological valley-chiral 1D states has been realized in the AB/BA tilt defect boundary in bilayer graphene (BLG) [1-3]. However, the quality of BLG in the previous experimental studies has been largely limited by chemical impurities introduced during fabrication. Here, we present our progress on achieving high quality of BLG device embedding AB/BA tilt boundaries by covering graphene with atomically flat hBN crystals. Initially, the location of AB/BA boundary in pristine BLG is identified by using near field scanning optical microscope (NSOM), and then we covered the hBN on it. In this case, however, we found that the AB/BA boundary could be moved by the stress exerted on BLG during covering the hBN crystal. To overcome this problem, we confirmed that NSOM could still locate the AB/BA boundary with top hBN thinner than ~5 nm.

We performed transport measurement with dual gate operation and showed that the resistance saturates close to 4e^2/h when AB/BA boundary is involved. We will also discuss possible application of 1D chiral channel as a highly efficient Cooper pair splitter by contacting to the s-wave superconductors, by exploiting valley chiral nature of 1D channel [4].

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Keywords:

Topological boundary channel, Nanoplasmonics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.123

Observation of reduced adhesion over metals using nanoscale laser-induced periodic surface structures

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Abstract:

Adhesion between materials plays a key role in the field of tribology, which exhibits highly sensitive behavior to inhomogeneous environments. It is widely accepted that large adhesion forces are one of the main causes of failure in commercialization of microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) during manufacturing or final testing processes due to stiction between mechanical parts. In this work, we use atomic force microscopy (AFM) to demonstrate a multilevel approach using nanoscale laser-induced periodic surface structures to reduce surface adhesion. We find an appreciable reduction in adhesion over laser-induced periodic surface structures produced on metallic substrates as compared to non-patterned areas, which may find useful applications in fail-safe mechanical devices.

Keywords:

Tribology, Laser-induced periodic structures, Adhesion, Atomic force microscopy

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.124

High-field THz control over Berry's curvature of type-II Weyl semimetal WTe_2

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Abstract:

WTe_2, a transition-metal dichalcogenide (TMD) material, has recently attracted interest with its rich topological phases. The few-layer WTe_2 shows type-II Weyl semimetal phase, while the monolayer WTe_2 shows 2D topological insulator phase. The high-intensity quasi-DC and THz electric field were demonstrated to be inducing rather interesting nonlinear modulations on the topological properties of the material. Applying high-field on the material result in a nonlinear Hall current perpendicular to the field direction. Several reports demonstrated such a nonlinear Hall effect by Berry's curvature dipoles, with a time-reversal symmetric system[1-3]. Coherent excitation of the material with high-field THz induces shear structural modulation, resulting in the symmetry and thus topological changes in the material[4]. In our study, we utilize a high-field THz beam as a AC electric field and a source of coherent excitation. By utilizing a THz-range probe, we would like to directly observe possible interesting phenomena such as photoinduced topological phase transition and quantum rectification[5].

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Keywords:

high-field THz, topological insulator, Weyl semimetal

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.125

제일 원리를 통한 α-붕소 표면 위의 질소 원자와 분자 흡착 연구

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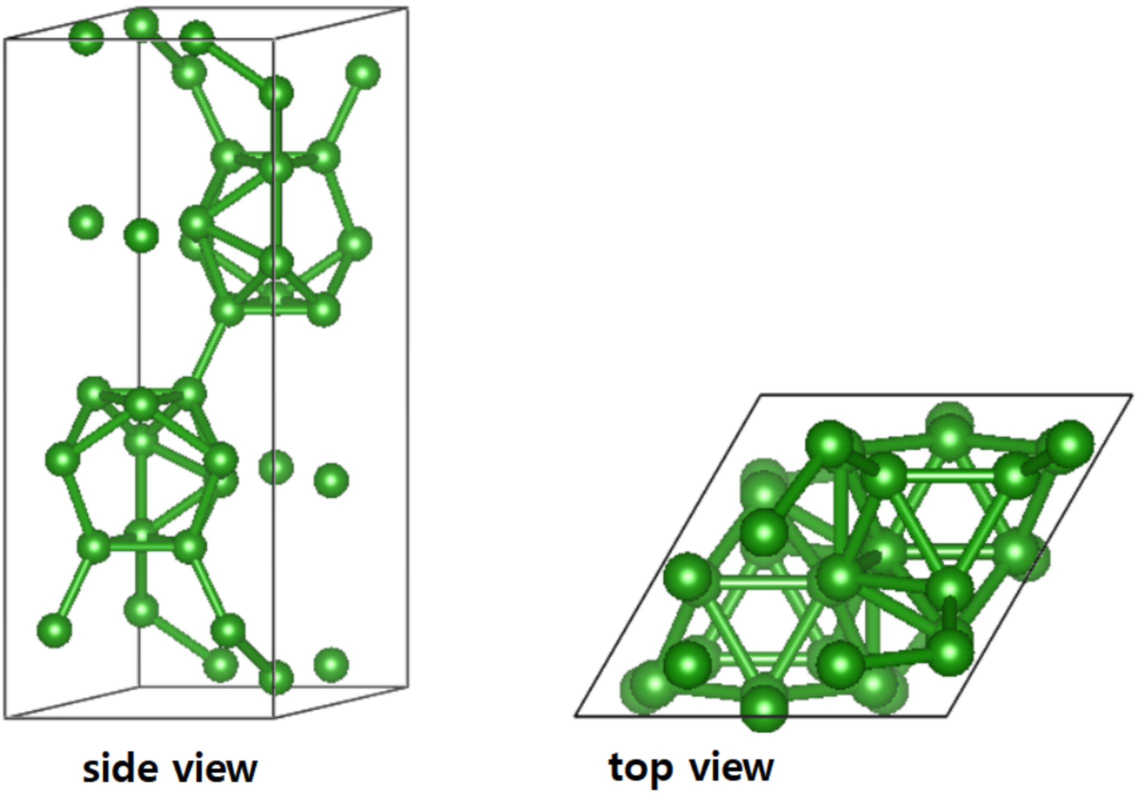
Abstract:

질화 붕소 나노 튜브(BNNT)는 물리적 화학적으로 매우 안정한 절연체이기 때문에 최근 많은 관심을 받고 있는 나노 신소재이다. BNNT는 h-BN이나 붕소를 이용하여 고압의 질소 분위기에서 레이저를 이용하는 방법 등으로 합성할 수 있다. 이 연구에서는 BNNT의 합성의 초기 과정을 알아내기 위하여 붕소 표면 위에 질소 원자와 분자의 흡착을 제일 원리 방법으로 조사하였다. 붕소 표면은 붕소 결정 중 안정적인 α-rhombohedral boron(12)을 (001) 방향으로 사용했다.(그림참조) 붕소 표면에서 재구성이 일어남을 확인할 수 있었는데 기존 표면보다 0.89 eV 만큼 더 안정적임을 확인할 수 있었다. 이 표면에서 질소 원자의 안정된 흡착 위치는 총 15개로 이중 가장 높은 흡착에너지는 2.14 eV 이었다. 질소 원자는 표면의 붕소 삼각형의 중심에 자리 잡으면서 세 개의 붕소와 결합하고 붕소 삼각형을 변형시켰다. 질소 분자의 흡착에너지는 분자의 방향에 따라서 0.24 eV~ 0.49 eV 임을 확인하였다. NEB(Nudged Elastic Band) 방법으로 질소 분자가 붕소 표면에서 질소 원자 2개로 분해도는 에너지 장벽을 계산한 결과 1.65 eV 로 매우 높게 나왔다. 하지만 분자 형태로 붕소 표면에 흡착되는 것보다 원자 두 개 로 각각 흡착되는 것이 에너지적으로 안정하므로 분해될 가능성이 있을 것으로 추측된다.



(그림)

Keywords:

Boron surface, Nitrogen, Adsorption, ab initio method

P2-co.126

First-principles Study of Graphene/Y_2C van der Waals Heterostructures

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Abstract:

Due to the characteristics of Dirac cone in the reciprocal space, graphene has received enormous attention from the world's scientific communities. Moreover, as two-dimensional (2D) material, graphene has the benefit of making heterostructures by stacking with other materials. On the other hand, the 2D electrides such as Y_2C and Ca_2N have an uncommon electric charge distribution called the electron cloud, which is composed of anionic electrons located between two electride layers. The anionic electrons are very loosely bound, causing them to act as an electron gas. In the viewpoint of future devices applications, it is important to investigate the electronic properties of graphene/electride van der Waals heterostructure by focusing on unique properties of graphene and electrides.
In this study, we have performed density functional theory calculations to calculate the electronic structure of graphene/Y_2C heterostructures built by sandwiching graphene between Y_2C electride layers. Especially, we focus on the change in charge distribution occurring in electron cloud of graphene/Y_2C heterostructures. The orbital projected band structure, partial density of states, charge density difference, and band alignment are investigated for analysis.

Keywords:

graphene, electride, Y2C, anionic electron, van der Waals heterostructure

P2-co.127

Low-Energy Inverse Photoemission Spectroscopy and Ultraviolet Photoemission Spectroscopy of C_{60} on CuPc

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Abstract:

Electronic structures such as LUMO and HOMO levels and transport gap (E_{Tr}) of organic semiconductors determine the charge carrier injection barrier, the study of this is an important key to understanding the behavior of charge carriers. HOMO levels can be measured by ultraviolet photoemission spectroscopy (UPS). However, LUMO cannot be measured using a UPS. LUMO can be measured by Inverse Photoemission Spectroscopy (IPES). IPES is the reverse process of Photoemission spectroscopy (PES) and is a useful and powerful tool for measuring empty molecular orbitals. The electron injection process allows you to directly measure the transport level of organic materials. Low energy IPES is especially useful if you do not want to damage the outside and measure the electronic structure. and this research system is an in-situ system, it prevents distortion caused by contamination. In this study, the electronic structures of CuPc and C60 were measured. This material has exciton binding energy, but the actual E_{Tr} can be measured using IPES technology. Later we will measure other organic and inorganic materials and analyze their electronic structure at their interfaces and surfaces.

Keywords:

Inverse Photoemission Spectroscopy, IPES, LEIPS, UPS, C60

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2020-07-13 - 2020-07-15

P2-co.128

Electric field dependence of electronic structure in p-n junctions with 2D van der Waals heterostructures

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Abstract:

The p-n junction has become an essential component in modern electronics and optoelectronics. It is created by contacting two different types of doped semiconductors, which makes the depletion of free charge carriers at the interface of the junction. In conventional p-n junctions, three-dimensional semiconductor materials have been used for making p-n junctions, so there have been some limitations in reducing the size of a p-n junction. Nowadays, many scientists have paid attention to two-dimensional van der Waals (2D vdW) p-n junctions because they are only one unit cell thick and have the superior efficiency of electron-hole separation. In this study, we investigate the electronic structure of p-n junctions with 2D vdW heterostructures using density functional theory calculations. Especially, we focus on the change in the electronic structure at the interfaces of doped 2D semiconductors when electric fields are applied. Details in electronic structure are analyzed in terms of orbital projected band structure and partial charge density.

Keywords:

p-n junction, 2D material, van der Waals heterostructures, DFT calculations

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2020-07-13 - 2020-07-15

P2-co.201

Optical Properties of a Two-Dimensional GeTe Layer

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Abstract:

Using the first principles calculations, we explored the optical properties of the two-dimensional α-GeTe structure. The 2D monolayer α-GeTe had an indirect band gap of 1.79 eV, and that indirect band gap was still observed in the bilayer although the band gap had decreased to 0.61 eV. We found that the optical band gap was much larger than the electrical band gap, which was due to the indirect band gap feature of the 2D α-GeTe system. In both systems, we found a very large refractive index in the visible range. Particularly, the bilayer system had a refractive index larger than 2.5 for blue light. Furthermore, the bilayer structure was found to have a larger reflectivity at ultraviolet frequencies. Consequently, we propose that the bilayer α-GeTe film can be utilized for potential optical device applications.

Keywords:

Optical property, 2D α-GeTe

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P2-co.203

Boron-, Nitrogen-, Aluminum-, and Phosphorus-Doped Graphite Electrodes for Non-Lithium Ion Batteries.

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Abstract:

Intercalation of Li^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Zn^{2+}, and Al^{3+} ions into B-, N-, Al-, and P-doped graphite has been studied using density functional theory calculations. While the intercalation of Li^+, K^+, and Ca^{2+} ions into graphite is thermodynamically favorable, that of Na^+, Mg^{2+}, Zn^{2+}, and Al^{3+} ions into graphite is unfavorable. When doped in the form of graphitic structure, B, Al, and P dopants significantly stabilize the ion-intercalated graphite compounds. As a result, Na^+ ions that are unable to intercalate into graphite can intercalate into B-, Al-, and P-doped graphite. The electron transfer from B, Al, and P dopants to host C atoms reinforces the ion–graphene electrostatic interaction, enhancing the thermodynamic driving force for ion intercalation. The catalytic activity of the dopant to promote the ion intercalation increases in the order of N < B < P < Al, which is associated with the electronegativity of the dopant.

Keywords:

Doped graphite, Intercalation, Batteries, Electrode, Density functional theory

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P2-co.204

First-Principles-Derived Effective Mass Approximation with Adaptive Mesh Refinement for the Quantum Nanostructures with Defect

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Abstract:

Semiconducting quantum nanostructures have opened up new opportunities for light-emitting devices due to their excellent properties including tunable bandgap coming from the quantum confinement effect [1]. To simulate the optical properties of the quantum nanostructures of realistic sizes, the effective mass approximation (EMA) can be adopted with the low computational cost although it often fails to produce accurate and reliable results compared to first-principles calculations. Thus, we recently developed a first-principles-derived EMA calculation method that extracts parameters for EMA from DFT calculations to accurately predict the optical properties of quantum nanostructures [2]. For that method, the EMA simulator was developed based on our grid-based Object-Oriented Real-Space Electronic structure (OORE) framework [3]. However, if abruptly varying regions (such as the region near a point defect) are present in the simulation cell, the whole grid should be dense enough to get accurate results and that costs enormous memory and calculation time. To solve that problem, the Adaptive Mesh Refinement (AMR) method is implemented to the EMA code which uses dense grid points only for the drastically varying regions. Then the EMA code with the AMR method is applied to CdSe nanoplatelets with substitutional Cu defect to predict the difference of optical properties with respect to pristine cases. Our work will contribute to the design of advanced optoelectronic devices quantum nanostructures.

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Keywords:

quantum dots, quantum nanoplatelets, effective mass approximation, adaptive mesh refinement, defect

P2-co.205

Full-bands Continuum Model Study of Nearly Flat Bands in Rhombohedral Tetralayer Graphene on hBN (4LG/BN)

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Abstract:

We investigated rhombohedral tetralayer graphene on hexagonal boron nitride (4LG/BN) within the full-bands continuum model. The interlayer interaction between the 4LG and hBN sheets is implemented through the effective moiré superlattice potential theory. Here, we show that the 4LG/BN in the 0° orientation of the hBN sheet has a well-isolated valence band near the charge neutrality point (CNP) even in the absence of an applied electric field. The isolated valence band has a bandwidth of W ~ 3 meV which is an order of magnitude smaller when compared to the on-site Coulomb repulsion energy estimate $U \approx 25$ meV corresponding to a moire length of $L_M \sim 15$ nm satisfying the relation U/W>>1. Further, we explored the evolution of low energy bands in the presence of an applied vertical electric field that leads to interlayer potential differences that we represent through Δ. For the 60° orientation of the hBN sheet to the aligned graphene layer of 4LG/BN, the conduction band is isolated with a very small bandwidth W~1 meV for Δ=0, while a small electric field $\Delta = -3$ meV isolates both valence and conduction flat bands. Our calculations show that it is possible to achieve isolation of either valence, conduction or both bands depending on the specific value of Δ. The localization of these isolated flat bands is confirmed by the real space representation of the local density of states (LDOS) at AB and BA stacking positions between graphene and hBN for zero field, but the flat band states are spread to AA sites in the presence of vertical electric fields. Our calculations improve to provide a guide about the wave functions expected in 4LG/BN that can be probed through scanning tunneling experiments. The inherently isolated flat bands in 4LG/BN makes of it an interesting candidate material for finding correlation phenomena such as Mott insulating phases, and for signatures of superconductivity as explored in the case of tBG, tDBG and TLG/BN.

Keywords:

Rhombohedral Tetralayer Graphene on hBN, Nearly Flat Bands, Effective Moire Potential

2020 KPS Spring Meeting
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P2-co.206

Rashba-type splitting in two dimensional Tl_2S/Bi(111) heterostructure

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Abstract:

Enormous research efforts have been focused on two-dimensional (2D) layered materials because 2D materials not only show many intriguing properties which are not found in their bulk counterparts, but also have various potential applications in optoelectronics, photonics, valleytronics, photovoltaics, and spintronics. Very recently, thallium dichalcogenide (Tl_2S) has attracted great attention because of their unique structure type (anti-$CdCl_2$), where the chalcogen atom (S) layer sandwiched between two metal atom (Tl) layers. Therefore, these materials are so called metal-shrouded 2D materials. On the other hand, bismuth (Bi) also attracts a great deal of attention for another reason. Note that Bi is a main building block element in the various TI compounds due to having a strong spin-orbit coupling. In addition, 2D ultrathin Bi(111) films are not only theoretically predicted to be elemental 2D topological insulator (TI) materials, but also experimentally synthesized and characterized. In this study, in order to understand the emerging fundamental properties of the heterostructure consisting of two different 2D materials, we investigate the electronic band structure of Tl_2S/Bi(111) heterostructure using the first-principles calculations. As a result, we find the Rashba-type splitting at the Γ-point of Tl_2S/Bi(111) heterostructure, accompanied by the Rashba spin topology. Detailed discussion on the electronic origin of Rashba-type splitting in 2D Tl_2S/Bi(111) heterostructure will be given.

Keywords:

Tl2S, Bismuth, Rashba splitting, 2D materials, Heterostructure

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-co.207

Role of Atomic Behavior and Local Structure Characteristics Between Phase Transition Process in Ag- and In- Doped Sb Rich SbTe Material as Phase Change Memory : First Principle Study

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Abstract:

Because of its fast phase transition speed (ps scale) and low power consumption during phase transition between its crystalline and amorphous phases than Ge-Sb-Te based group 1 phase change materials (PCMs), Sb-rich SbTe based materials with a small quantity of dopants (Ag, In, Ti, Sc and so on ...) have been widely investigated for progressive PCM. Especially, it turned out that Ag and In doped Sb-rich SbTe or AIST is as good as or even better than $Ge_2Sb_2Te_5$-based PCM in various phase transition properties, but, its local atomic configuration and the roles of respective Ag, In, Sb and Te atoms has been much less investigated. To reveal its local structural characteristics and the role of each atom during the phase transition of AIST, we perform molecular dynamics (MD) simulations using ab initio density functional theory. We select $AgInSb_{18}Te_4$ as an exemplary model composition of AIST and identify its crystalline phase by considering various atomic configurations and evaluating their total energies. To explore its amorphous phase, we expanded the model composition to construct a 2×2×2 supercell forming $Ag_8In_8Sb_{144}Te_{32}$ and perform MD simulation which mimics an experimental melt-quenching process. We investigate the structural properties by evaluating radial distribution functions, angle distribution functions, solid angle distributions of its crystalline and amorphous phases and compare them with experimental results obtained from XPS analysis. Finally, we discuss the roles of the In atom played not only in the phase transition process but also in retaining or stabilizing the amorphous phase.

Keywords:

PCRAM, PCM, Phase Transition

2020 KPS Spring Meeting
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P2-co.208

First-principles study of defects in GeS

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Abstract:

Two dimensional (2D) materials have recently attracted great attention in the fields of electronic devices due to their unique electrical and optical properties. Among 2D materials, graphene, black phosphorus (BP), and transition metal dichalcogenides (TMDs) have been actively studied in various ways. Along with such attention, GeS has also received attention as it has a similar structure with BP. Furthermore, it is worthwhile to note that point defects in 2D materials play a fundamental role in variation of their material properties because they can be donor or acceptor.

To understand the effect of defects on electronic properties of GeS, we have investigated the atomic and electronic structure of pristine and defective GeS using density function theory calculations. We study the formation of defects in the S sites such as vacancy and substitutional atom (Se or Te). Here, we focus on the change in electronic properties depending on the concentration and type of defect. Details are analyzed in terms of the orbital projected band structure, partial density of states, and charge density difference.

Keywords:

First-principles, GeS, vacancy, substitutional atom

2020 KPS Spring Meeting
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P2-co.209

A computational study of heteroepitaxial growth of GaN on the graphene/Al_2O_3 substrate

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Abstract:

Recently, two-dimensional (2D) materials have been actively studied in various research fields. Among 2D materials, graphene has excellent mechanical, electrical, and optical properties due to the unique electronic structure. Therefore, the study of graphene based heterostructures has been increasingly popular in both academia and industry. In this study, we have investigated the heteroepitaxial growth of GaN on the graphene/Al_2O_3 substrate using density functional theory calculations. Here, we focus on the roles of both graphene and Al_2O_3, forming the graphene/Al_2O_3 substrate on which GaN grows via the remote heteroepitaxy. Especially, we clarify how the heteroepitaxy of GaN on the substrate is made possible through graphene. In addition, it is confirmed that Al_2O_3 affects the GaN growth regardless of the in-plane crystal orientation of graphene.

Keywords:

Density functional theory, Graphene, Al2O3, GaN, Heteroepitaxial growth

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P2-co.210

Structural Identification of Charge Density Wave Phases of Monolayer 1T-VSe_2

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Abstract:

Since the discovery of graphene, transition metal dichalcogenides (TMDCs), which are two-dimensional layered materials, have attracted researchers due to their peculiar phenomena, including superconductivity, metal-insulator transition, and charge density wave (CDW) order [1-4]. TMDCs are made up of transition metal atoms (M: *e.g.*, Mo, W and V) and group- VI chalcogen atoms (X: *e.g.*, S, Se, and Te) with a formula unit of MX_2. By reducing the dimension of TMDCs, they show remarkable change of their physical properties such as indirect to direct band gap transition, quantum spin Hall effect, and CDW enhancement [5-7]. Monolayer (ML) 1T-VSe_2 has been investigated by many researchers due to recent observations of change in CDW order compared with that in bulk. Bulk 1T-VSe_2 has been known to show the $4 \times 4 \times 3$ CDW phase with a transition temperature of 110K [4, 8]. Differently from bulk, the ML 1T-VSe_2 was reported to show a CDW phase of $\sqrt{7} \times \sqrt{3}$ periodicity, whose possibility was supported theoretically [9, 10]. However, G. Duvjir *et al.* and P. K. J. Wong *et al.* reported the emergence of CDW of $2 \times \sqrt{3}$ and $\sqrt{7} \times \sqrt{3}$ superstructures with a full gap in ML 1T-VSe_2 [11, 12]. The atomic structure of these CDW phases and the mechanism of CDW transition are still veiled. In this work, we will present the results of first-principles calculations on the ML 1T-VSe_2. We performed density functional theory calculations based using Vienna *ab initio* simulation package. All calculations were performed using Perdew-Burke-Ernzerhof generalized gradient approximation for the electronic exchange-correlation interaction and the projector-augmented-wave potentials to describe the electron-ion interaction. In order to calculate the phonon dispersion relation, we employed PHONOPY. We will address the lattice instability due to unstable phonon modes, the resultant structural modification, and the electronic structure of CDW phases. Finally, we will compare the simulated scanning tunneling microscope (STM) images with the available experimental STM images.

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Keywords:
Density functional theory, Transition metal dichacogenides, Charge density wave, VSe2

2020 KPS Spring Meeting
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P2-co.211

First-principles calculation of O3-$NaRhO_2$ and its single oxide layer

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Abstract:

The *O*3-type layered sodium transition metal oxides (e.g., $NaCoO_2$, $NaTiO_2$) have been intensively investigated due to their unique properties such as good electrochemical activities, superconductivity, a large electronic conductivity, and a large Seebeck coefficient [1-3]. In this work, we have studied an *O3*-type oxide including the 4*d* transition metal Rhodium (*O*3-$NaRhO_2$) where the spin-orbit coupling might play an important role in the emergence of physical properties. Using first-principle calculation with the Hubbard-*U* method including the spin-orbit coupling, we examined the magnetic and the electronic properties of *O*3-$NaRhO_2$ and its single oxide layer.

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Keywords:

2020 KPS Spring Meeting
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P2-co.212

First-principles Prediction of Novel Two-Dimensional 1T-TiO_2

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Abstract:

Two-dimensional transition metal oxides have been attracted attention for many applications for photoelectrode, photovoltaic, gas sensor, batteries, and supercapacitors [1-4]. Recently, it has been reported that titanium dioxide (TiO_2) can crystalize in the anatase- and lepidocrocite-type nanosheet [2,5], although the bulk structure of the material is rutile, anatase and brookite. In this work, we theoretically predict 2D 1*T*-TiO_2 and compare to the other TiO_2 nanosheet and bulk structures. In addition, impact of the strain on the electronic properties of 2D 1*T*-TiO_2 is also examined since 2D structure has a benefit that more stretchable than bulk structure due to its geometric advantages.

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Keywords:

first-principles calculations, TiO2, strain

P2-co.213

Quantum walk using 3D aluminum cavity and superconducting qubit coupling system

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Abstract:

Quantum walk is a basic qubit algorithm for simulating a quantum system. Due to the high Q factor of the 3D superconductor cavity, quantum state of qubit has a long lifetime. It is sufficient time to operate many quantum gates [1]. Cavity-qubit coupling system is suitable for studying the quantum walk due to its many positon states [2]. We have a research plan for Quantum walk and cavity-qubit system is in course of preparation. Cavity is made of aluminum, which is a kind of superconductor, and superconducting qubits will be fabricated through Al e-beam evaporation. Additional qubit is under consideration for simulating new model using interaction between qubits and cavity mode.
[1] Hanhee Paik, R. J. Schoelkopf, etc. 2011
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Keywords:

Quntum Computer, Quantum walk, Superconducting qubit

2020 KPS Spring Meeting
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P2-co.214

Deep learning filter of tomographic 3D reconstruction in atomic electron tomography

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Abstract:

Tomography is a widespread technique in many fields not only in medical science but also in physics, chemistry, and material science. Recently, atomic electron tomography has been implemented to resolve individual atoms in materials at unprecedented 3D details [1, 2]. Atomic-scale resolution in all 3 dimensions is indispensable to obtain the atomic structure with a picometer scale. However, due to electron beam damage and missing wedge problem resulting from specimen geometry, only part of full angular range can be experimentally measurable. As a result, the 3D reconstructions often suffer from undesirable artifacts including elongations along the missing wedge direction, which limits the achievable resolution. Here, we present a 3D reconstruction filter based on deep learning to reduce the reconstruction artifacts caused by data imperfection. Our neural network architecture is based on 3D-Unet, which can be trained using simulated 3D reconstructions created with similar missing data structures [3]. Deep learning, figuring out a correlation between distorted 3D reconstruction images and atomic structures, enables us to alleviate this problem from inherently limited information. The trained deep learning model allows extracting Gaussian distributions of individual atoms from distorted 3D reconstructions images. Our deep learning filter could be directly applied to a 3D reconstruction volume to facilitate the identification of 3D atomic coordinates and chemical species in much-enhanced precision.

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Keywords:

Atomic electron tomography, 3D reconstruction, Deep learning, 3D-Unet

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P2-co.302

Strain chirality of chiral gold nanoparticle by Bragg coherent X-ray diffraction imaging

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Abstract:

Extending the chirality from molecules to nanomaterials is bringing many new opportunities. Recently, chiral nanomaterials have paid attention to applications in photonics, biochemistry, medicine, and catalysis. Chirality is related to a structure without S_n symmetry elements, such as a mirror plane and inversion symmetry. Because of this handedness, chiral nanoparticles have applications in photonics such as holography and meta-lens, etc. The chirality of the nanoparticles is developed at high-Miller-index facet, which has adsorption selectivity for growth precursor, e.g., peptide [1,2]. In this study, we observed the strain in chiral gold nanoparticle and its relation between the surface structure of high-Miller-index facet. To determine the strain distribution at the facets in the chiral gap, Bragg coherent X-ray diffraction Imaging [3,4] was employed. The measurements were performed at P10 at PETRA III, 34-ID-C, APS, and 9c, PLS-II. Strain field from the reconstructed result shows that there are intense strained regions at the starting point of the chiral gap and related to chirality development and high-index facet of the chiral gold nanocrystal.

This research was supported by the National Research Foundation of Korea (Nos. NRF-2015R1A5A100996 and 2016R1A6B2A02005468).

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Keywords:

Bragg Coherent X-ray Imaging, Chiral gold nanoparticle

P2-co.303

Direct Observation of Laser Triggered Interlayer Modulation of Bi2Se3 by X-ray Free Electron Laser Ultrafast Diffraction

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Abstract:

As a 3D topological insulator and 2D van der Waals material1-3, bismuth selenide has great potential for applications as quantum computing devices and optoelectronics due to its unique spin-polarized surface states and controllable of the unique surface photocurrent by inducing polarized photons4-7. In that connection, it is important to understand light-lattice interaction in ultrafast time scale, since it generates strains to the devices. Here, we report the ultrafast photon induced lattice dynamics of Bi2Se3 thin films in sub-picosecond time scale. In order to determine the structural changes, time-resolved ultrafast x-ray diffraction by using x-ray free electron lasers is employed as a measure of the direct observation of the lattice dynamics in real-time. In the beginning, Bi2Se3 shows carrier concentration sensitive contraction. The dynamics turn into lattice vibrational modes containing in hundreds of picoseconds. The lattice contraction is analyzed by density functional theory and the Lifshitz model

Keywords:

XFEL

2020 KPS Spring Meeting
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P2-co.304

이종접합계면에서의 국소화를 이용한 자성의 전류제어에 대한 연구

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Abstract:

우리는 TMR 구조(Tunnel Magnetoresistance)인 [$SrRuO_3$/$CaMnO_3$/$SrRuO_3$] 와 [$SrRuO_3$/$Pr_{0.5}Ca_{0.5}MnO_3$/$SrRuO_3$]를 이용하여, 전류를 통해 자성을 제어할 수 있는 새로운 매커니즘을 발견하였다. 이 구조의 magnetic coercive field는 전류의 세기에 따라서 큰 변화를 보였고, 이로서 전류로 자성의 hysteresis를 바꿀 수 있음을 발견하였다. 이런 현상의 원인으로 anti-ferromagnetic 층의 embedded ferromagnetic이 밀접한 관련이 있음을 magnetoconductance를 통하여 확인하였다. Hikami Larkin 이론을 이용한 분석결과, AFM 층에서의 spin에 의한 scattering이 저온에서의 trilayer의 전기적, 자기적 특성에 크게 기여하며, 전류의 세기에 의존함을 확인하였다. 이는 Embedded FM과 전류와의 상호작용에 의해 AFM 층의 spin configuration을 변화시킬 수 있음을 의미한다. 또한, 강한 전류는 AFM층의 고정된 spin을 느슨하게 만들어 pinning 현상을 감소시켜 coercive field가 감소하는 현상을 가져올 수 있다.

Keywords:

TMR, Current Controlled Magnetization, MR

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P2-co.305

Synchrotron X-ray induced dewetting process of metal thin films

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Abstract:

Metal nano-particles are of interest in many areas since they exhibit outstanding properties compared to bulk materials. Many photo-induced syntheses using lights such as visible and ultraviolet lasers have been demonstrated, where typically a chemical route with precursors has been employed. In addition, laser induced dewetting process of metal thin films has been significantly investigated to obtain the isolated nanoparticles on substrates. In this study, we demonstrated X-ray induced dewetting process of metal thin films using synchrotron white X-rays. Experiments were carried out at the 4B beamline of the Pohang Light Source-II in Korea. We found that 7-nm-thick Au thin films are vividly transformed into Au nano-particles through the spinodal decomposition mechanism, while Au films thicker than 15 nm showed a hole-generation transition mechanism. This is attributed to a thickness effect of the detwetting process. In this talk, details of the experimental results and analysis will be presented.

Keywords:

Synchrotron X-rays, Dewetting process, Metal thin films

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P2-co.306

Characterization of Non-Stoichiometric Ga_2O_{3-x} Thin Films Grown by Radio-Frequency Powder Sputtering

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Abstract:

We report the synthesis and characterization of non-stoichiometric Ga_2O_{3-x} thin films on sapphire (0001) substrates by radio-frequency powder sputtering. The chemical and electronic states of the non-stochiometric Ga_2O_{3-x} thin films were investigated. By sputtering in an Ar atmosphere, the as-grown thin films become non-stoichiometric $Ga_2O_{2.7}$. This is due to the difference in sputtering yield between Ga and O species of the Ga_2O_3 target. The electronic state of the thin films consists of ~85% Ga^{3+} and ~15% Ga^{1+}, corresponding to Ga_2O_3 and Ga_2O, respectively. The films have the electrical characteristic of a semiconductor, with an electrical conductivity of approximately 1×10^{-4} $S{\cdot}cm^{-1}$.

Keywords:

Non-stoichiometric gallium oxide thin film, Semiconductor, X-ray photoelectron spectroscopy, Electrical conductivity, Powder sputtering

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2020-07-13 - 2020-07-15

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Ionic transport in SnO_2 thin films by oxygen vacancy doping

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Abstract:

The ionic transport of thin film oxide heterostructures can be enhanced by oxygen vacancy doping, which can control the electrical conduction behavior and switch the device properties in the oxide thin film. The concentration of oxygen vacancies are usually controlled by diffusion through either the film/substrate interface or the film surface.

We investigated the effect of oxygen vacancy doping on the electrical conductivity of SnO_2 thin film on Y_2O_3-stabilized ZrO_2 (YSZ) and SnO_2/sapphire(0001) heterostructures. By performing the gate measurement on SnO_2/YSZ samples at temperatures of 400 and 500 ^{o}C, we observed that the increase in oxygen vacancies doped from the ionic YSZ substrates leading to the enhancement of electrical conductivity in SnO_2 thin films. In addition, annealing of SnO_2/sapphire(0001) samples in hydrogen reduction atmosphere at temperatures 300~600 ^{o}C induces the dissociation of the oxygen atoms on the surfaces of SnO_2 thin films, which also enhance the electrical conductivity. This is attributed to the formation of the electron accumulation layer on the film surfaces. This work will be extended to the investigation of dynamics of the ionic transport in the thin film oxide heterostructures.

Keywords:

Ionic transport, Oxygen vacancy, Oxide thin film, Electrical conductivity

2020 KPS Spring Meeting
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Photoluminescence changes of graphene quantum dots in liquid crystal with phase transition

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Abstract:

IIn the water with graphene quantum dots (GQDs), the photoluminescence (PL) does not change the intensity over time. However, liquid crystal (LC) and GQDs mixture decreased the PL intensity after a certain time. In addition, there was difference in the time dependent decreasing between nematic and Isotropic phase. In the case of nematic phase, the intensity of PL reduces the exponential function. In this paper, we will explain this phenomenon in two experiments.

Keywords:

네마틱 액정 (nematic Liquid Crystals), Graphene quantum dot (GQD), Photoluminescence (PL)

2020 KPS Spring Meeting
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RIXS experiment near Ir L_3 edge about IrO_2 thin film on TiO_2 for resolving the energy conversion mechanism

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Abstract:

Rutile-type iridium dioxide (IrO_2) has been in the spotlight as a spin-orbital entanglement system. For instance, spin-orbital related phenomena in IrO_2 were emerged, e.g., Dirac nodal lines crossing Fermi level, and large spin Hall effect[1-3]. On the other hand, IrO_2 is a good model system having high activity of energy conversion process. Despite tremendous efforts and researches, the physical origin of high activity in IrO_2 electrocatalysts for the energy conversion was not completely resolved[4-6]. The catalytic effect of IrO_2 in the energy conversion is governed by the energy exchange between orbital bonding. Particularly, H-O bonding strength could be correlated with 5d electronic structure of Ir. Due to lack of direct experimental evidence, our understanding of the hidden link between 5d electronic structure and catalytic activity is still poor. For instance, the dipole transition between d electronic states is forbidden by selection rule and this reaction evolves under the water.

We propose resonant inelastic x-ray scattering (RIXS) to resolve this problem. RIXS directly measure the intra dipole transition in d electronic states and doesn't require special sample preparation[7]. Using RIXS measurements, we successfully observed the IrO_2 electronic structure, specifically orbital states, of IrO_2/TiO_2(100) and IrO_2/TiO_2(001) thin films. We also verified that specific orbital states of IrO_2 thin films could affect the catalytic activity. It can provide important clues on functional link between electronic structures and energy conversion of 5d materials

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Keywords:

RIXS, IrO2

2020 KPS Spring Meeting
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고분해능 이미지 획득을 위한 Ptychography 및 Bragg CDI 연산 프로그램

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Abstract:

고분해능 이미지 처리 기법인 Ptychography와 3차원 이미지 처리 기법인 Bragg CDI 알고리듬을 빔라인 이용자들이 쉽게 사용할 수 있도록 경 엑스선(hard X-ray) 빔라인과 연 엑스선(soft X-ray) 빔라인 모두에 적용할 수 있는 Ptychography 연산 프로그램과 경 엑스선 빔라인용 Bragg CDI 연산 프로그램을 개발하였다. 다중코어와 GPU를 활용한 병렬연산을 도입하여 데이터 획득 후 수분 이내에 고분해능 이미지를 손쉽게 확인할 수 있도록 구현하였다. 이 연산 프로그램의 이용자 인터페이스를 소개하고 이를 적용한 사례에 대해서 논의될 것이다.

Keywords:

Ptychography, Bragg CDI

Prospect study of heavy vector boson production via VBF process at the HL-LHC

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Abstract:

The HL-LHC will run at $\sqrt{s}$ = 14 TeV and be expected to deliver an integrated luminosity of up to 3 ab^{-1}. This environment will significantly improve the sensitivity of all the rare processes. The observation of new heavy gauge bosons W' via the VBF process may also be possible in the HL-LHC era. In this study, we investigate whether VBF W' can be observed in the HL-LHC era or not, using MC simulation. The heavy vector triplet (HVT) model is used in the context of a simplified phenomenological approach to probe generic parameter space. The VBF mechanism gives a promising signature with two hadronic jets in the forward and backward region of the detector. Its special topology facilitates the search for beyond the Standard Model effects. The 95% CL expected exclusion bounds are derived in the simplified model parameter space for 3ab^{-1}.

Keywords:

VBF, W', HL-LHC, BSM, HVT model

2020 KPS Spring Meeting
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P2-pa.02

Search for Z′ bosons decaying into tau pairs in bottom fermion fusion process

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Abstract:

Anomalies in the B-meson decays reported by the b physics experiment could be explained by a heavy neutral gauge boson, Z′, with flavor changing bs coupling and a nonuniversal coupling to leptons. In this study, we investigate the Z′ decaying to tau tau in association with at least one b-jet.

Keywords:

Z', BSM, BFF

2020 KPS Spring Meeting
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P2-pa.03

Study on Muon Simulation in Neutrino Detector Using Liquid Scintillation

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Abstract:

전 세계적으로 중성미자 실험이 활발하게 진행되어 왔고 또한 새로운 실험이 진행될 예정이다. 중성미자 검출 실험에서 일반적으로 액체섬광검출용액이 유용하게 사용되고 있다. 지상 중성미자 실험에서는 뮤온 신호를 포함한 배경사건이 많이 발생하기 때문에 이를 이해하는 것은 매우 중요하다. 이 포스터에서는 액체섬광검출용액을 사용한 중성미자 검출기에서 뮤온 신호관련 몬테카를로 시뮬레이션 결과를 정리하였다.

Keywords:

Muon simulation

2020 KPS Spring Meeting
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P2-pa.04

Study on jet energy resolution with dual-readout calorimeter

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Abstract:

The dual-readout calorimeter is the novel technology of the calorimeter and has been included in the conceptual design report of both FCC-ee and CEPC projects. The Dual-REAdout Method (DREAM) calorimeter accomplishes the high precision energy measurement for hadrons and jets by measuring the electromagnetic shower fraction of hadron showers and correcting their energy event-by-event. Jet events have been generated with Pythia8 and used to investigate the jet energy resolution of the 4π dual-readout calorimeter. With the generated jet events, Geant4 simulation of the 4π dual- readout calorimeter has been performed. For this study, the anti-kt algorithm played an important role to reconstruct jets on the basis of the measured energy with the calorimeter. In this presentation, we introduce the jet energy resolution of 4π dual- readout calorimeter and its procedure.

Keywords:

Dual-readout, Calorimeter, 4π projective geometr, Shower, Jet

P2-pa.05

Feasibility study on reconstruction of B0 -> 4muons at BelleⅡ experiment.

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Abstract:

Abstract
높은 Luminosity를 가지고 있는 BelleⅡ 실험의 가속기는 중간자가 경입자로 붕괴되는 Rare decay channel들을 분석 할 수 있다. Monte carlo simulation을 이용하여 공명입자인 Y(4S)가 생성된 후 중간자가 4개의 뮤온으로 붕괴되는 채널을 분석 하였다.

Keywords:

Belle, Belle2

2020 KPS Spring Meeting
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P2-pa.06

Particle discrimination for the dual-readout calorimeter

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Abstract:

In high energy physics, incident particles to calorimeter are measured as showers. As the showers are complicated, deep learning is an ideal solution to optimise particle discrimination as it can be directly trained on complex raw data. The dual-readout calorimeter measures both Cerenkov and scintillating signals which can be used to discriminate between different hadrons, electrons and photons. These signals are mapped as images that are natural for convolutional neural networks to be trained on. The performance of particle discrimination using deep learning on the dual-readout calorimeter is presented.

Keywords:

Dual-readout, Deep learning, Jet discrimination, Particle discrimination

Study on the position resolution of the dual-readout calorimeter

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Abstract:

The dual-readout calorimeter is a versatile detector that provides high precision position measurements of incident particles as well as good energy resolutions for electromagnetic particles, hadrons and jets. Position resolution depends on the energy resolution and the granularity of a calorimeter. Which for electromagnetic particles and hadrons are studied with the high precision high-granularity dual-readout fiber calorimeter design achieved by attaching SiPMs to all individual fibers. This presentation will show the predictions for the position resolutions of the dual-readout fiber calorimeter based on GEANT4 simulations.

Keywords:

dual-readout, calorimeter, GEANT4, simulation

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P2-pa.08

A simulation study of the Electroweak Zγjj process with Machine Learning approach

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Abstract:

The Electroweak Zγjj process is predicted in the Standard Model, but it has not obviously been observed yet. The current analysis shows the possibility that the process will be observed with enough data. In this study, we focus on data analysis methods based on Zγjj process. Machine learning techniques have been known as the most promising analysis method to solve difficult classification and pattern recognition problems. Therefore, we explore the Machine learning approaches in the analysis of Zγjj process.

Keywords:

Zγjj, Vector Boson Scattering, Multi-boson production, Standard Model, Machine learning, Deep learning

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P2-pa.09

Vts measurement in top pair production at 13 TeV

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Abstract:

The top quark is the heaviest known elementary particle, and has therefore been the subject of intense experimental scrutiny since its discovery. The CKM element Vts is one of the important properties of the top-quark. It is a measure of the braching fraction into the s-quark, which is much smaller than the dominate b-quark decay. This quantity is well-known under the assumption of the unitarity of the CKM matrix, but in BSM scenarios, the unitarity may be broken, and the effective Vts may be far from the assumed value. In this analysis, we plan to directly measure the branching rate of the decay of the top quark into s-quarks, using machine learning to discriminate s-jets from top and background jets. This will then allow us to directly measure Vts.

Keywords:

CKM matrix, Vts, top, s quark, LHC, CMS, particle physics

S-tagging using machine learning for the dileptonic channel at top-pair production

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Abstract:

The element Vts in the CKM matrix describes the flavor change of t-quarks to s-quarks, due to the weak interaction. Previous studies have focused on measuring Vts indirectly using the unitarity of the CKM matrix, which is an assumption of the Standard Model. But this study measures it directly from events in which two t-quarks are produced and decay into an s-quark and a b-quark separately. Since it is important to improve performance of discrimination between s-quark and b-quark, we try using machine learning algorithms and check the performance for each algorithm.

Keywords:

Vts, s-quark, machine learning, CKM

P2-pa.12

Study of the Dark Matter at e+ e- collider using MadGraph

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Abstract:

The Standard Model (SM) of particle physics is well established with discovery of Higgs boson which is the last particle to be discovered in SM. Since SM can not give a description of dark matter, dark matter is barely known and under research through various method.

In this work, we would like to study dark matter at e+ e- collider using MadGraph as a tool and to see the cross section value according to various parameters such as dark matter mass and dark photon mass where dark photon decays to either dark matter or the SM particles.

The theoretical model for studying dark matter is Simplified Model which covers SM particles, dark matter, and dark photon particles. This result will be helpful for searching for dark matter at e+e- collider of experiments such as Belle II, CEPC and ILC.

Keywords:

dark matter, e+ e- collider, dark photon, MadGraph

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P2-pa.13

Monte Carlo study for searching $B^{0(+)} \rightarrow K_S^0(K^+)K_S^0$gamma in the Belle experiment

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Abstract:

The Belle experiment, at KEK in Japan, recorded 711 fb^{-1} data collated at Υ(4S) resonance with an asymmetric-energy e^+e^- collider. $B^0 \rightarrow K_S^0K_S^0$gamma and $B^+ \rightarrow K^+K_S^0$gamma are rare decay modes via $b \rightarrow d\gamma$ transition which is forbidden at the tree level in the standard model (SM). The decays are expected to be sensitive to new physics beyond the SM. They have not been measured yet and we aim to search them using the full data sample of BB-bar pairs collected at the Belle experiment. We report Monte Carlo study for signals and backgrounds in order to suppress continuum and BB-bar backgrounds.

Keywords:

Belle experiment, e+e- collider., B0→KS0KS0gamma, B+→K+KS0gamma, b→dγ

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P2-pa.14

Muon Trigger using Neural Network accelerated by FPGAs

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Abstract:

Accuracy and latency are crucial to the trigger system in high luminosity particle physics experiments. We investigate the usage of deep neural networks (DNN) to improve the accuracy of the muon track segment reconstruction process at the trigger level. Track segments, made by hits within a detector module, are the initial partial reconstructed objects which are the typical building blocks for muon triggers. Currently, these segments are coarsely reconstructed on FPGAs to keep the latency manageable. DNNs are ideal for these types of pattern recognition problems, and so we examine the potential for DNN based track segment reconstruction to be accelerated by dedicated FPGAs to improve both processing speed and latency for the trigger system.

Keywords:

Data reduction methods, Triggering system, FPGA-based machine learning, real-time pattern recognition, neural network

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P2-pa.15

Search for Double Higgs Production at the CMS Phase2 Using Machine Learning

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Abstract:

We present classification methods using machine learning techniques for searches of double Higgs production at the CMS Phase2, which is one of High Luminosity LHC (HL-LHC) experiments. Higgs particle was discovered at LHC experiments in 2012, but the Higgs potential is not fully understood yet. In order to understand the potential more precisely, measurements of multiple Higgs production at HL-LHC experiments are essential. Therefore, it is critically important to develop efficient classification methods to identify multiple Higgs production because its final states are very similar to those of other processes such as top quark pair production. In this analysis, we compare results of various machine learning techniques such as Boosted Decision Trees and Deep Neural Network for classification of the double Higgs events. We use Madgraph for event generation and Delphes for detector simulation (CMS Phase2) for our studies.

Keywords:

Double Higgs production, Higgs potential, HL-LHC, CMS Phase2, Machine Learning

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P2-pa.16

Efficiency estimation using 252 Cf source at JSNS2

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Abstract:

JSNS^2 is an experiment to search for sterile neutrinos with Δm^2 near 1eV^2. 3 GeV J-PARC proton beam incident on mercury target produces neutrino beam from muon decay at rest and $\bar{\nu}_\mu$ to $\bar{\nu}_e$ neutrino oscillation is detected by inverse beta decay (IBD) interaction.
The detector has a fiducial volume of 17 tons filled with GdLS and is located at 24 m baseline from the target. Some radioactive elements emit particles of specific energy, they are widely used for calibration. Especially, spontaneous fission of ^{252}Cf generates gammas and neutron producing IBD-like events.
In this presentation, the detection efficiency of IBD events are studied using detector simulations of ^{252}Cf radioactive source

Keywords:

JSNS2, sterile neutrino, J-PARC, Cf calibration, simulation

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LED run without LS in the JSNS2 experiment

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Abstract:

The JSNS2 experiment aims to search for the existence of sterile neutrino at J-PARC. A 1 MW beam of 3 GeV protons incident on a spallation neutron target produces an intense neutrino beam from muon decay at rest. The experiment will search for muon anti-neutrino to electron anti-neutrino oscillations which are detected by the inverse beta decay interaction, followed by gammas from neutron capture on Gd. Before the first physics run, a LED run without liquid scintillator (LS) was performed to check the PMT gain and signal timing in each channel. In this presentation, the configuration of the experimental apparatus is described and the preliminary results from the LED run are shown.

Keywords:

JSNS2, sterile neutrino, J-PARC, electronics, LED run

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P2-pa.18

Monitoring framework for Belle II experiment

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Abstract:

The Belle II experiment operates at the SuperKEKB $e^+ e^-$ energy-asymmetric collider on or near the Upsilon(4S) resonance energy. Early Belle II experiment data taking was done and instantaneous luminosity is continuously increasing. To achieve the many physics goals for the Standard Model (SM) precision measurements and finding new physics beyond the SM with the high luminosity beam, we need to keep stable detector operation. In this presentation, we report Belle II monitoring framework status including EPICS archiver for detector information, monitoring GUI improvement, new alarm components for detector information and monitoring framework itself.

Keywords:

Belle II, Slow control, DAQ

P2-pa.19

PMT gain calibration for the JSNS^2 Experiment

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Abstract:

The JSNS^2 experiment will search for neutrino oscillations with Δm^2 ' 1 eV^2 from ¯νμ to ¯νe, detected via the IBD reaction and tagged via gammas from neutron capture on Gadolinium. A 3 GeV 1 MW proton beam incident on a mercury target at the MLF at J-PARC produces an intense neutrino flux from mu-DAR. The JSNS^2 experiment consists of a 50 tons liquid scintillator detector, that is already completed and located at a distance of 24m from the neutrino source. JSNS^2 is the only experiment that can directly test the LSND anomaly without having to rely on theoretical scaling assumptions. The commissioning of the detector has started already using LEDs with nanosecond-pulse width, and the data taking is expected to start in May 2020 after filling the detector with LS. In this poster we will introduce the results of the calibrations runs including PMT gain adjustment.

Keywords:

JSNS2 experiment, sterile neitrino, neutrino, PMT

A simulation study of TOF detector in the GBAR experiment

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Abstract:

GBAR experiment aims to confirm the weak equivalence principle using anti-hydrogen.
TOF(time of flight) detector in the GBAR will measure the time of annihilation of anti-hydrogen after its free fall. Annihilation of anti-Hydrogen at the wall of Free Fall Chamber(FFC) generates several charged particles that can be measured by the TOF detector. We have simulated the TOF detector and check the stand-alone performance of it. We report the performance on cosmic ray rejection, sensitivity of sign determination of gravitational acceleration as a function of the anti-hydrogen temperature, and rough annihilation position determination.

Keywords:

GBAR, Antiproton, Antihydrogen, time of flight detector

2020 KPS Spring Meeting
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P2-pa.21

Study of position dependence of the Time-Of-Flight detector for the GBAR experiment

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Abstract:

The GBAR experiment is to measure the gravitational acceleration of antihydrogen atoms in terrestrial gravitational field. The Time-Of-Flight(TOF) detector is developed to measure the free fall time and annihilation position of antihydrogen atoms. The time resolution and the spatial resolution of the TOF detector are studied by cosmic ray muons. The mean time resolution of the TOF detector is good enough to separate the cosmic ray background from the signal. However, the time resolution can differ depending on the hit position of the detected particle. We present the result of the position dependence study of the time resolution of the TOF detector.

Keywords:

Time-Of-Flight, Antihydrogen, Gravity, Plastic Scintillator

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

Dark photon search using B to Klll decay at Belle

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Abstract:

In this presentation, we are going to present current status of our analysis of B to KA'A' decay.
In this analysis we assume B to KA'A' decay, where A' is dark photon which decays to 2 leptons. This presentation includes signal extraction procedure, expected upper limit of branching fraction and control sample study. We estimated expected upper limit of branching fraction as $O(10^{-6})$ ~ $O(10^{-8})$ order.
We used 10 stream of BB, 6 stream of qq 50 stream of rareB and 20 stream of ulna to evaluate this result. Each stream is corresponds to 711fb^-1 full Y(4S) Belle Montecarlo samples that equivalent to 772M BB pairs.

Keywords:

Belle, dark photon

P2-pa.23

Search for ALP through B → K a (a → γγ) decay

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Abstract:

In this research, we are looking for spin 0 scalar AxionLikeP article(ALP), which is predicted to decay into a photon pair, through B → Ka(a → γγ) decay mode, which is not allowed in Standard Model. This research is based on Monte-Carlo search for B meson decays to 2 γs with Kaon using the full Y(4S) sample of 772M B $\bar{B}$ pairs collected with the Belle detector at the KEKB asymmetric energy e + e− collider. By reconstructing B meson from 2 γs and Kaon, We will find special signal box for this decay mode exclude well known other mode.

Keywords:

Belle, KEKB, ALP, B meson

P2-pa.24

Search for B^0 -> l τ decays at Belle

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Abstract:

We study the rare leptonic decays $B^0 \rightarrow l\ \tau$ (τ to one lepton and 2 neutrinos), using Monte Carlo based simulation data from Belle detector at KEKB e^+e^- collider. One of the B meson from $\Upsilon(4S) \rightarrow B^0\overline{B^0}$ is fully reconstructed by semi-leptonic full event interpretation(FEI), while remaining particles are from signal B decay. The Toolkit for Multivariate Data Analysis with ROOT(TMVA) is used to improve signal purity.

The momentum of primary lepton on center-of-mass frame(p_l^*) in semileptonic tagged smaple is selected. Expected upper limit is calculated by fit of p_l^b or p_l^* distribution in signal region. Control sample study with $B^0 \rightarrow D^- \pi^+$ are used to calibrate signal mode. Both systematic and statistical uncertainties are studied.

Keywords:

Belle Ⅱ, KEKB, B meson

2020 KPS Spring Meeting
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P2-pa.25

Development of Photo-Diode for X-rays Detection

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Abstract:

Photo-diodes (PDs) are frequently used as diagnostic tool and 0-D detector for scientific experiments at the photon science facilities. At Pohang Accelerator Laboratory X-ray free-electron laser (PAL-XFEL) has diagnostic systems which are very important at optimizing the XFEL beam, monitoring the XFEL beam status, normalizing the experimental data. Existing diagnostic systems are pop-in monitor (PM) and quadrant beam position monitor (QBPM), those systems are currently using PDs for beam alignment or beam status checking. All of existing PDs are commercial goods, so it is hard to find out proper types of the PDs and also had a political issue with the selling country. For this reason we designed PDs and they were fabricated at ETRI. Our PD's designs are 10 mm x 10 mm (PAD1), 20 mm x 20mm (PAD4), and 30 mm x 30 mm (PAD9). All of these PDs were designed p-side for signal readout and n-side for beam entrance. PAD1 is main design because PD of this size is widely used at the laboratory. PAD1 is divided by four types according to their metal structures of each side to determine how metal structures of each side affect sensor performance. Other sensors are design for large area sensor. They were divided by existence and nonexistence of guarding structures or their sensor size. We measure the electrical characteristics of PDs and test its performance by using the radioactive source. We present the PDs performance depending on the types of metal structure with signal-to-noise ratio (SNR) measurement data.

Keywords:

Photodiode, PAL-XFEL

Searching for CP violation in hadronic D0 decays in the Belle II experiment

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Abstract:

The Belle II experiment and the SuperKEKB collider at KEK, Japan started Phase III, the physics focused run period on February 2019. The experiment is a dedicated effort to find new physics beyond the Standard Model and is a step up in precisions measurements based on a large scale data set. One of the promising channels in such an enviroment is a CP violation study in hadronic D0 decays.

In this poster, we are going to discuss the analysis strategy for this channel, which will be further developed and optimized based on the accumulated Belle II collision data.

Keywords:

Belle II, SuperKEKB, D0, CPV, flavor phyisics

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P2-pa.28

Track Reconstruction System in g-2/EDM Experiment at J-PARC

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Abstract:

The J-PARC muon g-2/EDM experiment is under development with a new approach. Compared to the previous experiment, this experiment will use lower emittance muon beam with a smaller storage ring. The 300 MeV/c muon will be injected into the 3 T MRI-type solenoid storage magnet. Tracking detector will measure the momentum of decay positrons with time in the storage magnet. We discuss our track reconstruction system for positron track .

Keywords:

: g-2, EDM, J-PARC, muon, fitting, Kalman filter, track fitting, fitter, GENFIT, positron tracking, track reconstruction, Track finder

2020 KPS Spring Meeting
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P2-pa.29

Quality Control of GE1/1, ME0 and GE2/1 GEM chambers of the CMS

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Abstract:

The new detector is installed in the inner part of the Compact Muon Solenoid(CMS) where sector GE1/1 during Long Shutdown 2(LS2). This is called Gas Electron Multiplier(GEM) detector. For this installation, there are 10 steps Quality Control(QC) test performed for the best quality for the GEM detector. To introduce the QC process from QC2 to QC4, the QC2 is the high voltage(HV) test of the GEM foil, QC3 is gas leak test after assembled, and QC4 is the HV test for the GEM detector. The total 144 GE1/1 chamber will installed in the inner part of CMS during LS2 and being prepared additional new detector ME0 and GE2/1 for installation during the next LS3.

Keywords:

GEM foil, detector, Compact Muon solenoid, LHC, CERN

2020 KPS Spring Meeting
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P2-pl.02

Simulation Studies for THz Coherent Transition Radiation generated from multiple dielectric medium foils

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Abstract:

Transition radiation (TR) is generated when a charged particle passes through a boundary between different media. If an electron beam has an appropriate longitudinal bunch duration of hundreds of fs, which can be obtained easily from the laser-plasma acceleration (LPA), TR can be added up coherently in the terahertz (THz) range. In this presentation, simulations based on a particle-in-cell (PIC) code are performed to study characteristics of the coherent transition radiation (CTR) that is generated by an electron beam and a perfect conductor or a dielectric medium. In addition, simulations are performed using multiple foils to generate intense CTR which is in the THz range. In this presentation, detailed simulation results are shown.

Keywords:

coherent transition radiation, terahertz

P2-pl.03

Single-shot detection of the strong THz from coherent transition radiation(CTR) mechanism

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Abstract:

Coherent transition radiation(CTR) is an intriguing radiation generation mechanism that takes place when an electron beam and a dielectric or metallic material interacts. Over the last two decades, the accelerator community has investigated the THz radiation emitted from CTR experiments. In practical point of view, however, it is hard to diagnose the THz radiation because the electron beam is generated in a very low repetition rate or single-shot mode in most electron accelerators around the world. Hence, the implementation of a proper single-shot detection method is of great importance. In this presentation, we introduce the features of our CTR experiment which is based upon electron beams from the laser wakefield acceleration, and we show some candidates of the single-shot detection scheme that would be applied in practice.

Keywords:

terahertz, coherent transition radaition(CTR), laser-plasma, laser wakefield acceleration, single-shot THz detection

2020 KPS Spring Meeting
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P2-pl.04

Enhancement of the fringe visibility in femtosecond laser interferometry

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Abstract:

A broadband femtosecond laser interferometry is widely used for ultrafast dynamics studies of laser-matter interactions. However, it is well known that fringe patterns of the broadband laser interferometry are blurrier than those of the narrowband case. So it is not easy to employ the broadband laser interferometry for fast dynamics studies. In this research, therefore, we studied a new method to improve the blurry fringe problem in the femtosecond laser interferometry. To enhance the visibility of the blurry interference patterns, the bandwidth of the probe beam in the interferometer was controlled by using narrowband pass filters in this research. This technique was applied for diagnostics of the laser-produced plasma in the air.

For our research, we employed the pump-probe interferometry for air-plasma diagnostics. In the experiment, a Mach-Zehnder interferometer was used with various bandwidth filters and their differences were studied. Here, the Ti:sapphire regenerative amplifier laser with an energy of 3.3 mJ/pulse, a pulse duration of 34 fs, and a repetition rate of 1 kHz was used. The laser pulse was divided into two beams: the main beam with an energy of 2.3 mJ was focused in air to produce a plasma and the other beam was sent to the Mach-Zehnder interferometer for plasma diagnostics. We found that the interference fringe with a narrower band-pass filter has a higher visibility and it can give a more accurate plasma density information. The proposed method in this research is simple, but it was demonstrated to be a very useful tool for better plasma diagnostics using the interferometry.

Keywords:

fringe visibility, femtosecond interferometry

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P2-pl.05

Investigation of atomic bonding of carbon under the high energy density conditions

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Abstract:

Warm Dense Carbon (WDC) is of particular interest as its basic properties have been debated, while our understanding has been hampered in part due. to the complicate interplay of physical processes under the High Energy Denstiy (HED) conditions. A femtosecond Ti:Sapphire laser pulse which has 800 nm as a central wavelength and 30 fs duration, ischorically heats a 70 nm tick amorphous carbon (a-C) sample to HED conditions. A broadband soft x-ray pulse, which has photon energy from 250 to 500 eV, is produced by irradiating 150 TW Ti:Sapphire laser pulse (5 J, 30 fs) to the 15 um Ta foil. This broadband x-ray pulse transmits through the WDC to probe atomic bonding structure of it. The transmitted x-ray will be resolved with the flat-field soft x-ray spectrometer, which has high resolution of 0.5 eV around carbon K-edge. By analyzing x-ray absorption spectra, ratio between π and σ bonding of WDC will be presented. Furthermore, hydrodynamic simulation results will be presented to support experimental results.

This work was supported by Institute for Basic Science (IBS-R012-D1) and National Research Foundation of Korea (NRF-2019R1AC2002864).

Keywords:

warm dense matter, x-ray absorption spectroscopy, laser-plasma x-ray source

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P2-pl.06

Design study for the RAON LEBT section with 14.5 GHz ECR-IS

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Abstract:

The RAON accelerator is currently under construction with the goal of completing it by the end of 2021. In this RAON accelerator, the various beams generated by ion sources will pass through superconducting accelerator sections and then will be used in many kinds of scientific experiments. Among ion sources, a 14.5GHz ECR-IS has been manufactured newly, and thus the lattice design from 14.5GHz ECR-IS to RFQ, which includes the 180-degree bending section, has been conducted. Here we will present the results of ongoing achromatic lattice design and simulation studies of beam dynamics for the LEBT section with 14.5GHz ECR-IS in the RAON accelerator.

Keywords:

RAON accelerator, lattice design, beam dynamics

2020 KPS Spring Meeting
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P2-pl.07

레이저유도형광 진단법 및 전자방출 탐침을 이용한 비침습적 홀추력기 플라즈마 전위 분포 측정

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Abstract:

홀추력기는 자기장 및 전기장의 교차장을 활용한 DC 방전 이온빔 소스로 인공위성 및 우주탐사선의 추진 장치로 활용되고 있다. 홀추력기 방전채널 끝단에 형성된 고자기장 영역에는 $10^{12\text{-}13}$ cm^{-3}의 높은 플라즈마 밀도가 형성되며, 이온화 영역과 이온 가속 영역이 겹쳐진다. 추력의 근원이 되는 이온의 발생 및 가속을 이해하기 위해서는 이온화 영역에서부터 가속 영역까지 진단이 이뤄져야 하지만, 랑뮈어 및 전자방출 탐침을 이용한 진단은 플라즈마 밀도가 높은 구간에서 플라즈마에 심각한 섭동을 일으켜 정확한 진단이 어렵다. 본 연구에서는 레이저유도형광 진단과 전자방출 탐침 진단을 연계하여 플라즈마 전위의 공간분포, 즉 전기장 분포를 측정하였다. 실험에 사용한 홀추력기는 방전채널 직경과 깊이가 각각 50 mm와 24 mm인 원통형 홀추력기였으며, Xe^+ 의 준안정 상태인 $5d^2F_{7/2}$ 를 여기시키는 레이저유도형광 진단은 방전채널 끝으로부터 100 mm 까지의 구간에서, 전자방출 탐침 진단은 방전전류 증가가 3% 이내인 50 – 100 mm 구간에서 수행하여 전위를 측정하였다. 플라즈마에서 전위분포는 레이저유도형광 진단의 전위 측정값을 50 – 100 mm 구간에서의 전자방출 탐침 측정값으로 교정하여 얻었으며 분포 모양은 상당히 높은 일치도를 보였다. 본 발표에서는 여러 방전조건에서의 전위측정 결과와 전위 교정 분석의 상세 과정이 소개될 예정이다.

Keywords:

홀추력기, 레이저유도형광, 전자방출 탐침, 플라즈마 전위

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P2-pl.08

KOMAC 양성자 가속기 200 MeV 에너지 업그레이드를 위한 HWR 튜너 기초 설계

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Abstract:

KOMAC 100 MeV 양성자 가속기의 확장을 대비해 100 MeV 양성자 가속기 이후의 남아있는 터널을 이용하여 최종 양성자 에너지를 200 MeV로 업그레이드 하고자 준비하고 있다. 100 ~ 200 MeV 양성자 가속에 가장 적합하다고 생각되는 HWR (Half Wave Resonator) 형태의 초전도 가속관을 사용하기로 하였고, 터널 크기의 제한으로 인해 CM (Cryo Module) 은 HWR 형 가속관인 경우 일반적으로 사용되는 직육면체형 대신 원통형으로 선정하였다. 이 CM 의 모양 및 크기 제한으로 인해 HWR 의 주파수를 조절하기 위한 기계적 저속 튜너는 크기가 작고, 구조가 단순하고, 조립이 용이하며, 장기간 운전에 대한 신뢰성이 높아야 한다. 일반적으로 HWR 가속관 원통의 둘러싸는 형태의 HWR 튜너와 달리, 100~200 MeV 영역에서의 HWR은 원통 직경과 원통 길이가 비슷하기 때문에 HWR 가속관의 원통 길이 방향으로 튜너 프레임이 설치되며, 헬륨 용기가 프레임의 일부가 되도록 설계되었다. 고압 헬륨 기체로 구동되는 벨로우즈, 와이어 및 캔틸레버로 구성된 튜너로 HWR 의 빔 파이프 플랜지에 압축 힘이 전달되어, HWR의 주파수를 조절하게 된다. 지금까지 설계된 내용을 본 학술대회에서 발표하고자 한다.

Keywords:

KOMAC, 양성자가속기, HWR, 튜너

2020 KPS Spring Meeting
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P2-pl.09

Beam Dynamics for beam commissioning of injector, SCL3, and KoBRA beam line

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Abstract:

The beam commissioning for the low energy part of RAON facility is scheduled in this year. It includes an injector, a SCL3, and a KoBRA beam line. The injector consists of an ECR ion source, an LEBT, an RFQ, and a MEBT. The superconducting linac called SCL3 has two different type of cavities, QWR and HWR. The KoBRA beam lines delivers beams from the end of SCL3 to the entrance of KoBRA facility. For the beam commissioning, we are considering argon or oxygen beams. This work summarizes the beam dynamics for beam commissioning in this year.

Keywords:

RAON, Beam Dynamics, Beam Commissioning

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.12

Transverse Beam Emittance Measurement on KOMAC LEBT with Solenoid Scan

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Abstract:

High-intensity microwave ion source produce proton beam with energy of 50 kV and current of 20 mA in KOMAC. A scintillating screen was installed behind the first solenoid focusing magnet in low-energy beam transport section. Ion beam transverse profiles were sequentially measured with solenoid scan. Transverse beam emittance was then estimated by profile measurement data using thin-lens approximation. Following experiments will be carried out to identify self-neutralization of low energy beam space charge and compared with self-consistent theoretical model.

Keywords:

Multi-pinhole Faraday cup, Transverse beam emittance, solenoid scan, self-neutralization, Scintillating screen

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

Preliminary study of beam dynamics for 200 MeV energy upgrade of KOMAC proton linac

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Abstract:

Korea Multitpurpose Accelerator Complex (KOMAC) proposes an energy upgrade of the existing 100 MeV proton linac. The design of the extended linac is based on superconducting RF cavities and consists of a beam matching section of high energy beam transport and cryomodules containing four Half Wave Resonator cavities with doublet focusing lattice structure. It will work with the beam current of 20 mA and have the final energy of 200 MeV. We report the preliminary study of the beam dynamics of the 200 MeV superconducting linac carried out at KOMAC.

Keywords:

proton linac, half wave resonator, superconducting linac, proton linac

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.15

Metal beam current measurement depending on arc current and extraction voltage of the MEVVA ion source

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Abstract:

금속 증기 진공 아크 (Metal Vapor Vacuum Arc, MEVVA) 이온원은 진공 아크 방전을 이용하여 금속 이온빔을 인출하는 장치로, 기존 금속 이온원에서는 인출이 어려운 텅스텐, 흑연과 같은 고융점 물질, 실리콘/게르마늄과 같은 반도체 물질의 이온빔도 인출이 가능하다는 특징을 가진 이온원이다. 또한 MEVVA 이온원은 고전류 금속 이온빔 인출이 가능하며, 특히 대면적 이온빔 조사가 가능하다는 장점으로 인해 관심을 받아 왔다. 이런 이유로 양성자과학연구단에서는 최대전압 80kV, 빔전류 5mA의 MEVVA 이온원을 설치하여 특성 시험 중에 있다. 본 연구에서는 MEVVA 이온원의 아크전류 및 인출전압에 따른 금속 이온빔 인출전류에 대한 측정 결과에 대해 보고한다.

Keywords:

Metal vapor vacuum arc ion source, Vacuum arc discharge, Extraction voltage, Beam current measurement

KOMAC 양성자가속기 200MeV 에너지 업그레이드를 위한 HWR Cryomodule 기초 설계

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Abstract:

KOMAC 양성자가속기 200 MeV 에너지 업그레이드를 위한 가속관으로 HWR (Half Wave Resonator) 형태의 초전도 가속관을 고려하고 있으며, 이를 위한 Cryomodule에 대한 기초 설계를 진행하였다. 설계중인 Cryomodule의 가장 큰 제한조건은 이것이 설치될 터널의 크기이다. 이를 고려하여 실린더 형태의 Cryomodule을 선택하였다. Cryomodule 내부에는 HWR cavity, Helium vessel, magnetic shield, heat shield, space frame이 설치되며, 이것 이외에 RF power coupler, pick up, 튜너 및 헬륨 배관을 포함한 극저온 시스템이 설치된다. 본 학술대회에서는 HWR Cryomodule의 기초설계 내용에 대해서 논한다.

본 논문은 과학기술정통부 연구비 지원을 받았음

Keywords:

양성자가속기, 초전도 HWR, Cryomodule

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.17

Electromagnetic design study on superconducting half-wave resonator for 200 MeV energy upgrade of KOMAC proton linac

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Abstract:

A superconducting half-wave resonator(HWR) has been developed for the 200 MeV energy upgrade of KOAMC proton linac. It was carried out that the electromagnetic analysis of the medium-beta HWR which is suitable for accelerating the proton from 100 MeV up to 200 MeV. The design of HWR was optimized to reduce peak values of the electric and the magnetic field normalized to the accelerating gradient. This EM analysis is a first step of the HWR design, and further design study will be followed.

Keywords:

Proton linac, Superconducting accelerator, Half-wave resonator, Electromagnetic analysis

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.18

지구 저궤도 플라즈마 환경모사를 위한 링-커스프 자기장 기반의 플라즈마 발생장치 개발 및 플라즈마 특성 조사

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Abstract:

저궤도 위성이 존재하는 200 – 2000 km 상공에는 전자온도 1 eV, 전자밀도 $10^{4\text{-}7}$ cm^{-3} 수준의 플라즈마가 존재한다. 저궤도 상에서 플라즈마와 위성 간의 상호작용은 전자장비에 영향을 주어 복구가 불가능한 손상을 초래할 수 있다. 따라서 저궤도 플라즈마 진단은 위성의 위험 방지 및 대응 방안 마련에 필수적이며, 지상에서 진단 장비 검증 및 시험을 목표로하는 저궤도 환경 모사용 플라즈마 발생장치가 반드시 필요하다. 본 연구에서는 저 전자 밀도 및 온도의 플라즈마 발생을 목적으로 하는 반지름 100 mm, 길이 300 mm의 원통형 플라즈마 발생장치를 개발하였다. 장치 내부에는 원통 둘레와 상단 및 하부에 영구자석을 각각 20, 15, 10개 배치하고 강자성 물질을 사용하여 방위 대칭성을 갖는 링-커스프 형상의 자기장을 마련하였다. 이 자기장 형상은 원통 경계로부터 약 60 mm까지 40 G 수준의 자기장을 생성하여 원통 중앙으로부터 반지름 약 30 mm의 전자 구속 영역을 만든다. 본 연구실에서 개발한 저전류 할로우 음극을 사용해 전자를 플라즈마 발생장치 내부로 공급하고, 출구면에 양극을 위치시킴으로서 전자들이 방전을 개시 및 유지하며 소수의 이온과 전자만이 장치를 빠져나갈 수 있도록 설계하였다. 본 발표에서는 저궤도 플라즈마 환경 모사를 위해 개발된 장치의 상세 구동원리 및 구성과 할로우 음극 운전변수에 따른 장치의 기초 방전특성을 소개하고자 한다.

Keywords:

플라즈마, 저밀도 저온 플라즈마 소스, 할로우 음극

중이온가속기의 RF Reference 시스템 설치 및 시험

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Abstract:

중이온가속기구축사업단에서는 상전도 가속관 81.25 MHz RFQ 및 초전도 가속관 81.25 MHz QWR (Quater-wave resonator), 162.5 MHz HWR (Half-wave resonator), 325 MHz SSR (Single-spoke resonator)를 개발 구축하고 있다. 중이온 가속기를 위한 RF 시스템은 HPRF (High-power RF) SSPA, LLRF (Low-leve RF) 제어 시스템, RF reference distribution 시스템으로 구성되며, QWRs를 위한 22세트, HWRs을 위한 106세트, SSRs을 위한 213세트가 구축될 예정이다. 각 cavity에서 요구되는 RF stability는 크기 +/-1%, 위상 +/-1도 이내이며, 각각의 LLRF 시스템 및 BPMs (Beam positon monitor)으로 안정된 RF reference 신호를 공급해주는 RF reference distribution 시스템이 요구된다. RF reference를 위한 Master oscillator는 설계 및 제작이 완료되었으며, SCL3 (QWR, HWR) 가속기를 위한 RF reference rigid line은 설치가 완료되었다. 본 발표에서는 중이온가속기의 RF reference 시스템 설치 및 시험에 대해 논한다.

* 대한민국의 과학기술정보통신부와 한국연구재단의 재원으로 기초과학연구원 중이온가속기장치구축사업의 지원을 받아 수행된 연구임(2013M7A1A1075764)

Keywords:

중이온가속기, RF reference

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.20

중이온가속기 초전도 저에너지 선형가속기 운용을 위한 LLRF 개발 현황

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Abstract:

기초과학연구원 중이온가속기건설구축사업단에서는 U, C 등의 중이온 가속을 통하여 희귀동위원소 생성을 위한 가속기를 구축하기 위한 연구를 진행하고 있다. 이 가속기에는 RFQ에서 나온 빔을 가속시키기 위하여 81.25MHz, 162.5MHz, 325MHz의 주파수에서 운전되는 초전도 가속관을 사용하는 초전도 선형가속기가 설치될 예정이다. 이 초전도가속관은 특성상 반치폭이 매우 좁은 상태에서 운용되고 Lorentz Force Detuning 효과에 의한 공진주파수의 변화 등이 일어날 수 있는데, 이를 극복하기 위해서는 SEL 등의 RF 제어 알고리즘의 개발 및 적용이 필요하다. 현재 이를 위하여 여러 제어 알고리즘의 구현이 유연한 FPGA 기반으로 저에너지 초전도 선형가속기를 위한 LLRF의 개발과 제작이 진행되고 있다. 이 발표에서는 현재까지 진행된 관련 현황과 실험 결과가 소개될 예정이다.

Keywords:

RISP, RAON

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.21

Construction of a In-situ Beam Intensity Monitoring System at KOMAC Proton Irradiation Facility

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Abstract:

The Korea Multi-purpose Accelerator Complex (KOMAC) has been operating a 100 MeV linac proton accelerator since 2013, and has provided proton beam irradiation services. Recently , a dose monitoring system was constructed for improving the beam quality. The system consists of a monitoring chamber and a Farmer ionization chamber (IC). The Farmer IC is typical dosimeter for absolute dosimetry of the charged particle beam, therefore it will be located at the position of sample. During the proton beam irradiation process, the transmission monitoring chamber is required for the in-situ beam intensity monitoring absence of the Farmer IC. The calibration factor between the monitoring chamber and the Farmer IC should be obtained and calculated through the former calibration process. After then, the proton beam irradiation process will be performed using only the output of monitoring chamber with calibration factor installed in front of the sample. In addition, w e have implemented a user interface (UI) using an experimental physics and industrial control system (EPICS) framework and a control system studio (CSS) program. The flux and fluence is automatically calculated and displayed in real time using the calibration factor value. Therefore, it can be easily reach the target fluence using the real time dose monitoring system during the beam irradiation service. In this report, the construction of a real time dose monitoring system will be discussed in detail.

Keywords:

Beam diagnostics

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.22

Test of an Electron Gun Assembly for LHCD 5-GHz Klystron

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Abstract:

The Lower-Hybrid Current Drive (LHCD) system for the ITER and KSTAR requires klystrons having 5 GHz frequency and C.W 500 kW power output. We have been developing this high power klystron tube in sub-components base i.e., electron gun assembly, RF cavity section, and beam collector system. The electron gun is a diode type to simplify high voltage power supply, and employ air-cooling design for easy maintenance. The E-GUN code (SLAC beam trajectory program) was used for the beam trajectory design, and the ANSYS code was used for the hot cathode thermal design analysis. FCI (Field Charge Interaction) code is used for the design of RF cavity section, CST Particle Studio was used for cross verification of a beam characteristic. As a part of the klystron development program we have manufactured the full scale electron gun assembly and the performance tests has been carried out, which include the measurements of the beam perveance and the beam envelope evolution along the beam axis. In this paper, we present the design and fabrication processes and the performance test results of the electron gun assembly for the 5 GHz high power klystron tube.

Keywords:

Klystron, Electron Gun, LHCD

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.23

Control of electron beam properties by using corrugated pipe at PAL-XFEL

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Abstract:

X-ray Free-Electron Laser (XFEL) facilities are usually utilizing the electron beam with a bunch length of a few tens of femtoseconds through the undulator line and generating X-ray pulses with a pulse energy of few milli-joule and a temporal duration of a few tens of femtoseconds. To decrease the pulse duration up to a few hundreds of attoseconds, the longitudinal properties of the electron beam have to be manipulated. At the PAL-XFEL, the corrugated pipe is installed in front of the undulator line to control the electron beam properties. By using the corrugated pipe, the longitudinal properties of the electron beam can be changed by the wakefield, which is generated from the pipe by electron beam itself. Therefore, the longitudinal properties of the electron beam can be optimized by adjusting the parameters of the corrugated pipe. In this presentation, the effect of the corrugated pipe on the electron beam is studied.

Keywords:

PAL-XFEL, corrugated pipe

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.24

Reinstallation and Commissioning of RISP RFQ LINAC

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Abstract:

A radio-frequency quadrupole (RFQ) at Rare Isotope Science Project (RISP) was constructed as the front accelerator of the heavy ion superconducting linac. The preliminary test was conducted to verify the RFQ performance at the off-site test facility before tunnel preparation. The accelerator installation was started from April 2019 and the RFQ reinstallation was commenced in January 2020. The injector system commissioning, including low energy beam transfer (LEBT), RFQ and medium energy beam transfer (MEBT), began in May 2020. In this paper, the reinstallation process and some commissioning results of the RFQ are summarized.

* This work was supported by the Rare Isotope Science Project of Institute for Basic Science funded by the Ministry of Science, ICT (MSIT) and the National Research Foundation (NRF) of Korea (2013M7A1A1075764).

Keywords:

RFQ, heavy ion, Linear accelerator

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

Self-seeded Free electron laser at 14.4 keV

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Abstract:

The X-ray free-electron lasers (XFELs) with an unprecedented peak brightness and femtosecond scale enables revolutionary scientific experiments for physics, chemistry, material, and biology. The typical operation mode for XFEL facilities is self-amplified spontaneous emission (SASE) mode. This mode starts from the shot noise of the electron beam so that the longitudinal coherence is poor and the spectrum has noisy spikes that can limit user experiments. To improve the longitudinal coherence of XFEL, nowadays the self-seeded FEL can be available. The PAL-XFEL has commissioned this self-seeding FEL, which results in an increase of spectral intensity up to more than 10 times at 9.7 keV. In this presentation, we have successfully produced the seeded FEL at 14.4 keV. These seeded FELs are very stable and robust as comparable to the SASE mode; these results pave the way for new sciences.

Keywords:

Free electron laser, Self-seedede FEL, 14.4 keV

주입 잠금에 의한 상용 S-Band 마그네트론 위상 및 주파수 안정화

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Abstract:

우주 전력용 장거리 무선전력전송 시스템의 고효율 경량화를 위하여 마그네트론 기반 정밀 위상배열 시스템 개발이 선행되어야 한다. 위상배열 시스템에서 요구하는 수준으로 마그네트론 출력 모듈의 주파수와 위상을 정밀하게 고정하고 제어하는 기술을 확보하기 위하여 주입 잠금에 의한 상용 S-Band 마그네트론의 위상 및 주파수 안정화를 수행하였다.
마그네트론에서 발생하는 잡음의 주요 원인인 구동 전압 안정화를 위하여 고전압 필터를 적용하여 주파수 잡음을 최소화 한 후에 초고주파 주입 잠금 위상제어 기법을 적용하여 위상 안정도를 극대화 하였다. 마그네트론 캐소드 가열을 위한 전류를 차단하여 저주파 잡음을 제거하고 애노드에 인가되는 고전압 전원에 실려있는 76-kHz switching 주파수를 최대한 억제한 상태에서 외부 주입 신호에 의한 위상잠금루프(PLL)를 적용하여, 최대 출력의 80%(>800W)에서 동작하는 마그네트론의 noise floor를 중심 주파수 대비 -60dBc이하로 낮추고 시간에 따른 위상변화를 0.3° (peak-to-peak) 이내에서 억제할 수 있는 극한 제어를 달성하였다. 장시간(>0.5초) 위상변화도 peak-to-peak 기준 1° 이내, RMS((root-mean-square) 기준 0.24° 이내로 안정화 가능함을 입증하였다.
고출력 고효율 마그네트론에 대한 위상 및 주파수 안정화를 시연하여 초고주파 장거리 무선전력전송을 위한 위상배열 시스템의 요구조건을 충족시킬 수 있음을 확인하였다.

Keywords:

wireless power transfer, magnetron, phase, frequency, stabilization

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-pl.29

Development of 2D Cylindrical Numerical Code for high energy density plasmas of X-pinch Plasmas

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Abstract:

X-pinch is a novel technique to create a plasma by ablating metallic wire with the high current flow on a *ns*ns time scale. Recently, X-pinch is drawing attention worldwide as an efficient X-ray source and as a way to explore the high-density regime which was not accessible with the conventional methods [1, 2, 3]. It has been shown that 1D Magneto-Hydrodynamics (MHD) model well simulates the major properties of the hotspot of X-pinch even though its inherent 3D configuration [4]. To capture more dynamics of X-pinch plasma, 2D (r,z) cylindrical MHD code is under development. It adopted the resistive MHD model and used the FVM based shock capturing method, and TR-BDF2 method for spatial and temporal discretization respectively [5, 6, 7]. The simulation results of MHD code test problems including cylindrical Noh problem and of benchmarks with FLASH, a well-known MHD code, will be presented.

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Keywords:

X-pinch, Magneto-hydrodynamics, Shock Capturing, Finite Volume Method, Relaxation scheme

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.01

Plasma engineered monolayer MoS_2 for an efficient hydrogen evolution reaction electrocatalyst

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Abstract:

Among electrocatalytic water splitting hydrogen evolution reaction (HER) research areas, numerous studies have been currently carried out on two-dimensional (2D) materials to alternative for non-precious metals catalysts, in which single layer MoS_2 (SL-MoS_2) has been considered to be an ideal candidate. However, pristine MoS_2 is limited HER activity because of small density of the active edge sites and poor conductivity. Interestingly, active sites can be effectively engineered within the continuous MoS_2 sheets by treating it with plasma in a controlled manner. Here, we employed Argon plasma on a large-area continuous-monolayer MoS_2 synthesized via metal–organic chemical vapor deposition (MOCVD) to acquire maximum active sites that are indeed required for an efficient HER performance. The samples are optically characterized by PL and Raman spectra. From linear sweeps measurements, we found the optimum condition, 30 second of Ar plasma treatment time, that induces the maximum HER activity with the overpotential and Tafel slope much lower than that of pristine sample. Our work show that the Ar-plasma treatment is an effective way for improving the HER efficiency of large-scale 2D MoS_2-based electrocatalysts.

Keywords:

electrocatalytic, hydrogen evolution reaction, MoS2, Ar/H2-plasma

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.02

$CuCo_2O_4$ 나노 구조의 합성 및 슈퍼커패시터에 대한 전기 화학적 특성

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Abstract:

슈퍼커패시터는 빠른 충전-방전 능력, 높은 에너지 저장 능력, 긴 사이클링 안정성 및 친숙성이라는 뛰어난 특성으로 인해 녹색 에너지 저장 시스템으로서 상당한 관심을 받고 있다. 한편, 슈퍼커패시터 응용을 위해 최적화된 나노 구조 물질을 준비하는 것이 의미가 있다. 특히, 잘 정렬된 형태를 갖는 다공성 3차원 flower-like 나노 구조의 제조는 다양한 구조적 특징으로 인해 에너지 저장 연구 분야에서 상당한 관심을 끌고 있다. 본 발표에서는 간단한 실리콘 오일 방법을 사용하여 열 처리를 통한 $CuCo_2O_4$ 다공성 nanoflakes 기반 3차원 nanoflowers를 나타낸다. 상이한 용매를 변경함으로써 형태학적 변화가 확인되었다. 용매가 변경될 때, 고체 나노 flakes는 다공성으로 변형되었다. 표면 형태로 인해 전기 화학적 성능이 크게 향상되었으며, 활성 물질 부위로의 더 많은 이온 확산을 허용한다. 제작된 물질은 우수한 사이클링 보유력으로 우세한 산화 환원 화학 및 높은 용량을 나타냈다. 또한, 하이브리드 슈퍼커패시터는 음극으로서 다공성 활성탄으로 구성되었다. 이 소자는 우수한 에너지 밀도 및 전력 밀도를 나타냈다. 이러한 하이브리드 슈퍼커패시터는 또한 5000 충전 및 방전 사이클 후에 높은 유지율로 우수한 사이클링을 보여주었다.

Keywords:

슈퍼커패시터, 나노 구조, 전기화학적특성

Dibenzo[b,f][1,5]diazocine Organic Semiconductors for an Efficient Photo Electrochemical Water Splitting

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Abstract:

A solar water splitting is one of the promising technologies towards clean energy production through direct conversion from water and sunlight to electricity and hydrogen gas. Conventionally, much research was conducted on the inorganic semiconducting materials with high efficiency despite several disadvantages such as a difficulty in tuning the innate properties such as bandgaps, relatively higher cost due to limited availability and low structural tenability. Therefore, the development of a new class earth-abundant organic semiconductors with tunable bandgap, energy levels and charge transport mobility is in high demand. In this study, we synthesized various dibenzo[b,f][1,5]diazocine derivatives from substituted 2-aminobenzophenones. Chemical and physical properties were characterized as well as their self-assembly behavior to successfully make interfaces. Moreover, dibenzo[b,f][1,5]diazocine derivatives stability at aqueous electrolytes which is a critical concern for organic semiconductors used in water splitting, showed promising results in various test conditions. We propose dibenzo[b,f][1,5]diazocine derivatives as a new class of organic semiconductors with low cost, easy processing and optoelectronic tunability for solar driven water splitting.

Keywords:

Organic Semiconductors, Solar water splitting, Stability

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.04

$LiTaO_3$ 기반의 압전 나노 제너레이터의 제작 및 특성 분석

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Abstract:

에너지 수요을 충족하기 위해 전기 에너지를 생성하거나 수확하는 다양한 기술이 지금까지 연구되어 왔다. 다양한 에너지원 중에서 기계적 에너지는 일상적인 인간의 다양한 기계적 활동으로 인해 풍부한 재생 에너지 원으로 간주될 수 있다. 이 문제에서 나노 제너레터는 기계 에너지를 수확하고 수확된 에너지를 활용하여 다양한 휴대용 전자 기기에 전력을 공급하고 자체 구동 전자 시스템에서 기능을 수행하는 데 중요한 역할을 해왔다. 본 연구에서는 강유전체 물질인 리튬 탄탈 라이트 ($LiTaO_3$)를 고체합성법으로 합성하여 압전 나노 제너레이터 제작에 활용하였다. 합성된 $LiTaO_3$ 입자를 플루오르화 폴리비닐리덴 (PVDF)에 로딩하여 가요성 필름을 형성하였다. 또한, 제작된 필름을 2개의 알루미늄 전극 사이에 끼우고 캡톤 테이프로 적층하여 외부 환경으로부터 장치를 보호하였다. 그 후, 제작된 나노 제너레이터의 전기적 거동을 평가하기 위해, 각각 ~ 4 N 및 5 Hz의 일정한 추진력 및 주파수하에서 작동되었다. 더욱이, 소자의 견고성 및 안정성은 장기간의 작동주기에서 조사되었으며, 안정적인 전기 성능 및 기계적 내구성을 나타냈다.

Keywords:

나노 제너레이터, 리튬 탄탈 라이트, 전기적특성

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.06

THz electromagnetic wave generation via AC phonon-electron interaction

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Abstract:

Role acoustic (AC) phonon-electron interaction in determining the thermal [1] and electrical [2] characteristics has been well investigated, but less has been studied in terms of electromagnetic radiation [3, 4]. We demonstrated generation of electromagnetic wave in terahertz (THz) frequency range induced by AC phonon-electron interaction. We measured THz time-domain spectroscopy at excitation wavelength of 400 nm in GaP/Si heterostructures with different GaP thicknesses *d* of 16, 35, 45, and 56 nm on *n*-type Si substrates. Under the femtosecond laser excitation, photoexcited carriers are accumulated at at air/GaP and GaP/Si interfaces due to interfacial electric field, then, the accumulated photocarriers generate AC wavepackets via deformation potential coupling [5]. The THz electromagnetic wave is generated mainly at *d+w*, when the propagating AC wavepackets interacts with electrons out of depletion region in Si layer. The lineshape of THz wave via AC phonon-electron interaction is proportional to convolution of electron density profile in Si layer and spatial second-derivative of strain profile. The time-domain signals of THz wave via AC-phonon-electron interaction show different lineshapes with temporal periods depending on *d*, which are well consistent with the simplified calculation. Our study suggests a new concept of THz wave radiation which results from AC phonon-electron interaction.

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- Acknowledge

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning(2018R1A2B6008101).

Keywords:

THz radiation, electron-phonon interaction, coherent acoustic phonon

P2-se.07

Influence of residual sodium at the interface of a NaCl-assisted CVD grown large-scale MoS_2 monolayer on SiO_2/Si substrate

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Abstract:

Alkali metal halide-assisted chemical vapor deposition (CVD) methods can produce wafer-scale uniform monolayer transition metal dichalcogenides (TMDs). Further defect engineering is necessary to obtain high-performance functional devices. While defect engineering has focused on the surface of the monolayer TMDs or the contact property, interface defect engineering is rare and non-trivial. Here, based on a NaCl-assisted CVD-grown large-scale uniform MoS_2 monolayer on a SiO_2/Si substrate, a trace amount of Na cations is present, residing at the SiO_2 substrate during the CVD-growth process and contribute to the n-type doping into the supported monolayer MoS_2. Furthermore, the residual Na cations electrically moved toward the bottom side of monolayer MoS_2 to passivate the interfacial defects. The interface defect curing results in approaching low intrinsic defect levels of the supported monolayer MoS_2 and inducing a neutral semiconducting state. The findings provide a way for accelerating the realization of high-performance functional devices of wafer-scale monolayer TMDs.

Keywords:

Transition metal dichalcogenide monolayer, NaCl-assisted CVD growth, Interface defect engineering

The ballistic conductance of Dirac Electrons through Magnetic Quantum Rings

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Abstract:

The energy spectra and a ballistic conductance of Dirac electrons through a quantum Hall graphene nanoribbon in x-y plane is investigated. The nanoribbon contains a magnetic quantum ring and this ring is formed by inhomogeneous magnetic fields. The magnetic fields are zero inside the ring and constant elsewhere and it is directed to z-direction. Because electrostatic potentials are unable to confine Dirac electrons to the ring, inhomogeneous magnetic fields are introduced in the nanoribbon. The energy spectra and the probability density of edge states of the Dirac magnetic quantum ring is analyzed by comparing with results of Schrödinger electrons. The energy dispersion is calculated analytically with the continuity of the wave functions across the boundary of the magnetic quantum ring and the ballistic conductance across the magnetic quantum ring in the graphene nanoribbon is calculated numerically with the scattering matrix formalism based on the tight-binding method. Between Dirac electrons and Schrödinger electrons, there are characteristics of similarity and diversity in the energy dispersions and in the ballistic conductance. In quantum hall regime and in the low-energy limit, these characteristics are presented in detail.

Keywords:

ballistic conductance, magnetic quantum ring, graphene nanoribbon, probability density of edge states, energy spectra

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.09

Improvement of Quantum Efficiency of UV light via Quantum Dots Si CMOS Image Sensor: Application in Our Lives

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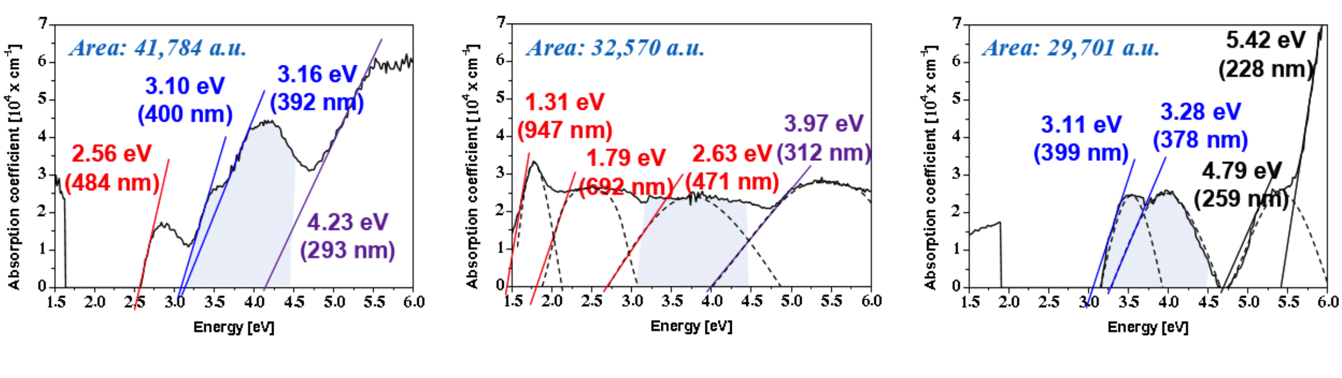
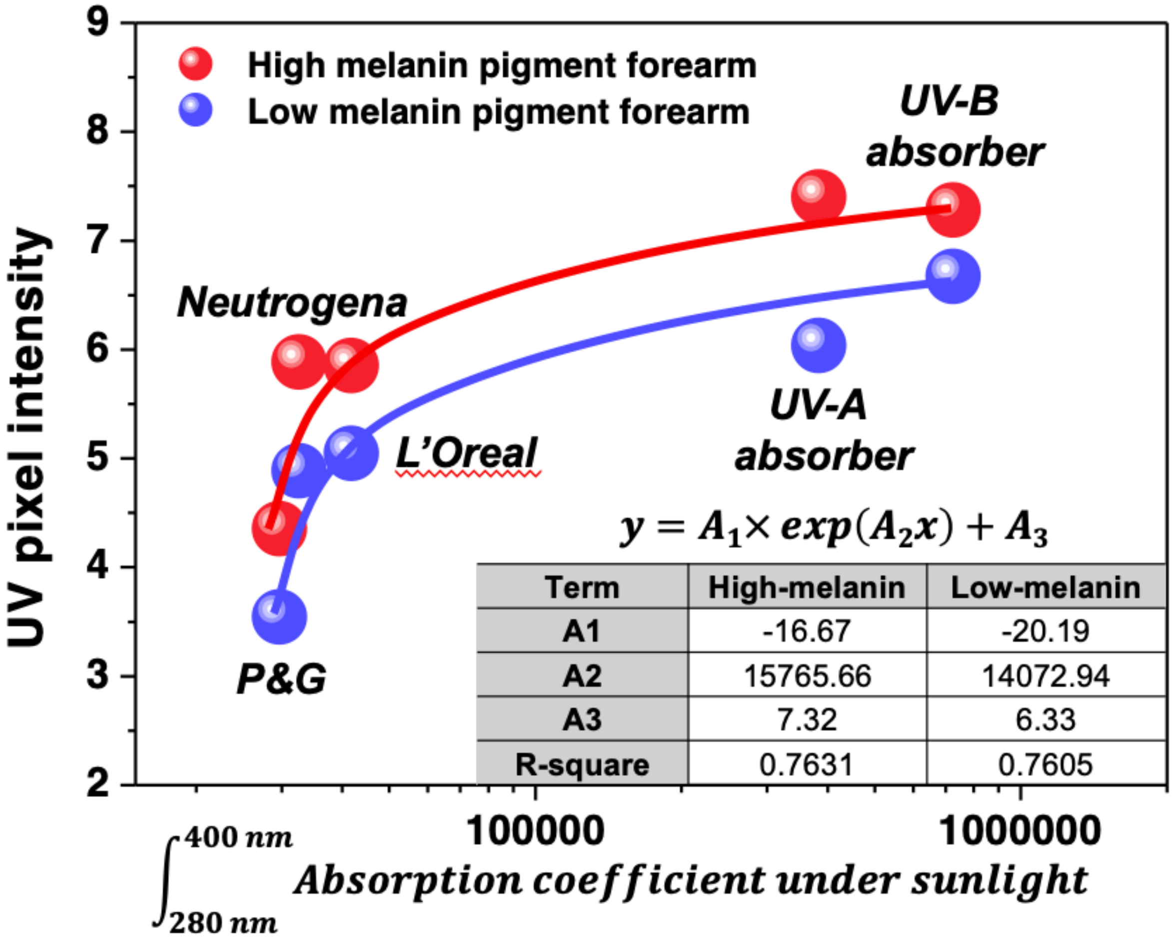
Abstract:

As the commonly used Si CMOS image sensors have theoretical limitations which is that the quantum efficiency of Si-based photo-detector is low under the 400-nm of UV wavelength, many researchers tried to enhance the quantum efficiency of the UV wavelengths using wide bandgap materials (ZnO, TiO_2, IZGO, etc.). However, these technologies are difficult to be commercialized because of higher-priced materials and fabrication complexity which directly lead to the cost increment of devices.

In this study, we applied the quantum-dots on the Si-based CMOS image sensor (QD CIS) to selectively sense under 400-nm-wavelength of the UV light without any wide bandgap materials. Therefore, we can visualize the UV light that the general Si CMOS image sensor or human eyes are impossible to sense. To evaluate the UV-sensing QD CIS, we investigated the effect of sunscreens applied on human skin which are really close to our living. Generally, the sunscreens consist of materials which absorb or reflect the UV lights. The absorption coefficient and material band-gap were measured by spectroscopic ellipsometry to evaluate the three different sunscreens respectively. Particularly, we analyzed the bandgap of each material of the unknown mixture which composing the sunscreen and compared those materials with the UV pixel intensity of the image captured by the quantum-dot CMOS image sensor. As a result, we proved the correlation between the absorption coefficient of the sunscreens measured by spectroscopic ellipsometry and the UV-light intensity of the image captured by QD CIS. Thus, the QD CIS illustrates the potential application for the high-sensitivity of UV light using the Si CMOS image sensor with quantum-dots, which could photograph and analyze the UV illumination by simply capturing UV images.



[Fig. 1. Spectroscopic ellipsometry analysis about three different sunscreens which consist of unknown chemical mixture]



Term	High-melanin	Low-melanin
A1	-16.67	-20.19
A2	15765.66	14072.94
A3	7.32	6.33
R-square	0.7631	0.7605

[Fig. 2. Correlation between the absorption coefficient of the sunscreens measured by SE and the UV-light intensity measured by QD CIS]

Keywords:

CIS, QD, UV

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.10

수소 열 어닐링을 통해 인위적으로 산소 결함이 생성된 다층 a-$MoO_{(3-x)}$의 전자 이동도 향상 및 전계 효과 유도

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Abstract:

대표적인 이차원 물질인 그래핀의 밴드 갭 부재와 전이 금속 화합물(TMDs)의 상대적으로 낮은 캐리어 이동 특성을 극복하기 위해, 최근 물리적 또는 화학적인 조작을 통해 높은 유전 상수(high-k)를 가진 2D 반도체 금속 산화물의 밴드 갭을 조정하여 높은 전자 이동도를 얻을 수 있는 연구가 진행되고 있다. 대표적인 금속 산화물인 a- MoO_3는 큰 유전 상수(11.2)와 넓은 밴드 갭(3.06 eV)을 가지는 절연 물질로 캐리어 농도가 낮아 전자 장치에 적합하지 않지만, 두께 조절과 Oxygen vacancies생성을 통해 밴드 갭을 조절하여 ~1100$cm^2V^{-1}s^{-1}$의 높은 캐리어 이동도를 가지는 반도체 특성을 관찰한 연구가 보고되었다. 하지만 차세대 반도체 물질로 응용되기 위해선 낮은 on-off ratio(~10^3)와 뚜렷하지 않은 off 영역을 극복하는 등 더욱 명확한 전기적 반도체 특성 향상이 요구된다.
본 연구에서 우리는 a-MoO_3의 산소 결함 생성 조건에 대한 전자 이동도와 온도에 따른 저항 변화를 관찰하였다. 단결정 구조로 성장된 벌크 MoO_3를 기계적 박리 방법으로 수십 나노미터 이하의 두께로 층간 분리하여 Si/SiO_2(300 nm) 기판에 전사한 뒤 수소 분위기에서 500 ℃ 열 어닐링을 통해 산소 결함을 가지는 a-$MoO_{(3-x)}$ 구조를 유도하였고, Raman spectroscopy 측정 결과 819.244 cm^{-1} 에서 735 ~ 741 cm^{-1} 로 이동한 Mo_2-O 관련peak이 관찰되어 어닐링에 의한 구조 변화를 확인할 수 있었다. 산소 결함 형성 조건에 따른 전기적 특성을 확인하기 위해 1. 기존의 a-MoO_3, 2. 500 ℃ 수소 어닐링된 a-$MoO_{(3-x)}$, 3. 산소 부족 환경 (진공)에서 성장시킨 a-$MoO_{(3-x)}$과 같이 세 가지 조건의 MoO_3 전계 효과 트랜지스터를 제작하였고, 각각의 IV 측정을 통해 산소 결함에 의해 수 메가 옴에서 수 키로 옴으로 감소한 저항을 확인하였다. 하지만 Si/SiO_2(300 nm)기판을 통해 게이트 전압을 인가한 결과 게이트에 대한 의존성은 나타나지 않았고, 이온 전해질 용액을 통한 게이트 전압을 인가하여 MoO_3 트랜지스터의 보다 효율적인 전계 효과를 유도하여 비교하였다. 명확한 스위칭 효과와 높은 전계 효과 이동도를 충족하는 이차원 물질 개발은 차세대 반도체 물질로서 다양한 응용이 가능할 것이다.

Keywords:

전기적 특성, FET, 2차원 구조, 밴드 갭, MoO3

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.11

The development of statistical uniformity and reliability of artificial synaptic device for neuromorphic system

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Abstract:

Recently, neuromorphic computing system has been intensively developed to replace conventional CMOS computing technology due to their big data processing capability with arithmetic and energy efficiency. The electrical conductance of analogue switchable synaptic device cell can be strengthened or weakened depending on the quantitative properties of pre-synaptic pulse in terms of synaptic plasticity, and the memorizing and computing process in neuromorphic system are simultaneously performed in each synaptic device. Thus, the artificial synaptic memory device have required more improved analogue switching properties to actualize more accurate neuromorphic recognition and learning process.
In this study, we achieved the uniform and stable titanium oxide synaptic memory device with matrix array structure presenting the highly accurate neuromorphic functionality. The artificial synaptic device showed excellent fabrication yield (100%) with uniformity of analogue resistive switching property, and high accuracy of image recognition for the neuromorphic simulation.

Keywords:

Neuromorphic sysntem, analogue switching, resistive memory

2020 KPS Spring Meeting
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P2-se.12

Two-dimensional optoelectronic devices based on organic ferroelectric polymer

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Abstract:

Two-dimensional material has attracted considerable attention because of their possible applications in ultrathin, nearly transparent optoelectronic devices. Among them, conventional pn junctions are usually made by heterojunction or chemical doping, but it is difficult to manufacture and cannot return to its original state. Thus, pn junction was implemented by using a split gate, but it also has the disadvantage of adding more gates.
In this study, we report a gate-free, homo-pn junction in tungsten diselenide(WSe_2) by controlling the polarization of the ferroelectric polymer material, PVDF-TrFE, through conductive AFM. Through this, a high rectification ratio and open circuit voltage(V_{OC}) were obtained while being able to return to the original state.

Keywords:

Optoelectronic device, PN junction, Ferroelectric, PVDF-TrFE

2020 KPS Spring Meeting
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P2-se.13

Effects of Iodine Doping on Electrical Characteristics of Solution-Processed Indium Oxide Thin-Film Transistors

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Abstract:

Oxide semiconductors received considerable attention as active channel materials in thin-film transistors (TFTs) due to their high charge-carrier mobility, high optical transparency, excellent chemical stability, and processing versatility. Thus, TFTs fabricated from oxide semiconductors hold promise in terms of broad electronic applications such as electronic memory devices, chemical sensors, and active matrix displays. High-resolution organic light-emitting diode displays that employ an oxide TFT backplane correspond to an example of recent advancements in the technology. Although initial research focused on oxide semiconductors fabricated using vacuum deposition processes, there is growing interest in solution-based deposition methods including spin coating, dip coating, spray pyrolysis, and various printing techniques. This is because solution-based processes are applicable to large-area substrates, and their processing simplicity makes it possible to fabricate electronic devices at low cost. Researchers recently focused on developing solution-based manufacturing processes for oxide semiconductors to demonstrate the next generation of flexible and disposable electronics. In this work, we investigated the effects of iodine doping on the performance of solution-processed indium oxide thin-film transistors. Raman spectroscopy was used to explore the structural characteristics in the solution-processed films. The experimental results show that the iodine doping decreased free electrons in solution-processed indium oxide semiconductor films, thereby dedrading the TFT performance. This enables us to demonstrate iodine gas sensors based on solution-processed indium oxide TFTs.

Keywords:

solution process, indium oxide, thin-film transistor, iodine gas, sensor

2020 KPS Spring Meeting
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P2-se.15

Forming Free and Self-rectifying Resistive-switching Memory Based ON Al_2O_3/AZO Bi-layer

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Abstract:

In this study, we fabricated Al_2O_3/AZO Bi-layers and achieved a self-rectifying resistive switching device.
ReRAM(Resistive random-access memory) is a representative next-generation non-volatile memory. The device has a two-terminal structure that allows high integration and stacking structure. It also has advantages such as nonvolatile, fast operation speed and CMOS fabrication process. Metal oxides which are typical materials on ReRAM can practice various resistance states by adjusting the amount of oxygen vacancy. And also, ReRAM is easy to implement X-point structure for high integration, but it is essential for controlling sneak current.
AZO is a composite film of Al_2O_3 and ZnO. This material can control Al_2O_3/ZnO ratio using nanolaminate method by Atomic layer deposition. It can change the bandgap on AZO film and make rectifying property by the Schottky barrier at the metal/oxide junction. And also, it can be changed the resistance state by charge trapping/de-trapping on Al_2O_3/ZnO interface. So, the appropriate Al_2O_3 ratio in AZO film is very important in our experiment for rectifying property and resistance change.
In this study, Pt was deposited for top-bottom electrodes by E-beam evaporator and Al_2O_3/AZO thin film was sandwiched between Pt electrodes by ALD with Al_2O_3, ZnO supper cycle. By electrical property measurement, we could confirm the LRS(Low Resistance State) / HRS(High Resistance state) without forming process and self-rectifying property.

Keywords:

Memory, Reram, self-rectifying, Al2O3, ZnO

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.16

Polarization-charge inversion at ultrathin high-k/GaN interfaces through a post-deposition annealing

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Abstract:

GaN power switching elements have attracted significant attention for high power operations in renewable energy, smart/micro grid, wireless communication, and electric vehicle. The GaN switching devices control power generation, delivery, and distribution, which affects total efficiency of conversion.
In this work, a formation of polarization-charge inversion at the ultrathin high-k/Ga-polar GaN interfaces through a post-deposition annealing (PDA) is confirmed by chemical, physical, and electrical measurements. Ultrathin high-k material is deposited on GaN surface by atomic-layer deposition, followed by PDA at 500 °C, 700 °C, and 900 °C, separately. X-ray photoelectron spectroscopy is utilized to determine surface potential and energy band bending at the high-k/GaN interfaces. The interface oxide layers formed through PDA induce net positive charges, thereby leading to downward band bending at the high-k/GaN interfaces. Interface charge densities are estimated based on the GaN surface potentials.
The effects of PDA-induced interface oxide layers with a positive polarity on the conduction properties in GaN Schottky junctions are examined, too. The electrical properties improved with PDA, in terms of leakage current level, ideality factor, and on/off ratio. The enhancement is mainly attributed to the increase in Schottky barrier heights by the formation of interface oxide layers, in addition to the surface passivation ability of ultrathin high-k material.
These results are applicable to the performance improvement in GaN Schottky-gate high-electron-mobility transistors and light-emitting diodes where interface and surface states work important role in operational efficiency and reliability.

Keywords:

Interface charge density, High-k/GaN, Post-deposition annealing, Energy band bending, Schottky junction

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.17

Improved performance of GaN electronic components with ultraviolet/ozone-produced Ga_2O_x interfaces

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Abstract:

Leakage and recombination currents associated with the unavoidable threading dislocation (TD) surface states are the main drawbacks of GaN electronic components. Defect centers at the TD-related surface pits lead to current collapse, breakdown voltage, and current loss. Ultraviolet/ozone (UV/O_3) treatment can counteract the effects of defect centers on conduction in GaN electronic components by producing Ga_2O_x interfaces.
In this work, the UV/O_3 treatment is applied to the improvement in the performance of metal/GaN Schottky diodes (SDs) and metal-oxide-semiconductor (MOS) capacitors. The physical and chemical features of ultrathin Ga_2O_x passivation layers formed through UV/O_3 treatment are analyzed by high-resolution transmission electron microscopy, scanning electron microscopy, energy-dispersive X-ray spectroscopy, and X-ray photoelectron spectroscopy. The GaN SDs and MOS capacitors are fabricated with the generation of Ga_2O_x thin layers at metal/GaN and high-k/GaN interfaces, respectively. Current-voltage (I-V) measurements of SDs reveal that the leakage current and breakdown voltage improved due to the formation of Ga_2O_x interfaces as Schottky barrier. Capacitance-voltage (C-V) measurements of MOS capacitors exhibit that the trapped charge density and interface trap density reduced through UV/O_3 treatment. Detailed mechanism for the improved interface properties in GaN active and passive components is discussed. These results can be further applied to the enhancement in the performance of GaN Schottky-gate and MOS high-electron-mobility transistors.

Keywords:

GaN, Ultraviolet/ozone treatment, Schottky diode, Capacitor, Ga2Ox

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.18

Angle-resolved photoemission spectroscopy study of electronic structure of epitaxial GaN thin flim

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Abstract:

Gallium nitride (GaN) is a wide direct band gap semiconductor material, widely used in light-emitting diodes (LED). Recently, it also has attracted huge interest for its application to the high electron mobility transistor (HEMT) in next-generation power switching devices. It is important to study its electronic structure for understanding its high electronic mobility and other related physical phenomena. However, the fine electronic structure of GaN is not yet thoroughly studied and requires deliberate experimental evidences. In this presentation, we investigated the electronic structure of GaN thin films by using the angle-resolved photoemission spectroscopy (ARPES). Our samples were epitaxially grown on Si(111) substrates by metal organic chemical vapor deposition(MOCVD), which are developed for commercial HEMT devices. We analyzed band structure dispersions at the top of valence band and try to understand the high mobility transport properties. We also analyzed the chemical composition of the sample surfaces by x-ray photoelectron spectroscopy (XPS). Therefore, our work provides electronic structure information on the commercially important GaN thin films.

Keywords:

Gallium nitride, ARPES, XPS, Epitaxy

P2-se.19

양성자 조사 조건에 따른 AlGaN/GaN on Sapphire의 결함 분석 연구

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Abstract:

AlGaN/GaN 이종접합구조는 우수한 물성(wide bandgap energy, high electron saturation velocity 등)과 이종접합 계면에 존재하는 2차원 전자층(2-dimensional electron gas, 2DEG)으로 인하여 고주파수/고출력 전자소자 제작에 적합한 물질로 각광을 받고 있고 있다. 해당 전자소자는 GHz 대역의 차세대 이동통신을 위한 핵심부품으로 관심을 받고 있으며, 특히 위성통신 송수신 회로의 능동소자 부분에서 기존의 Si 및 GaAs 기반 전자소자를 대체할 수 있을 것으로 기대된다. 위성통신용 부품으로 사용되기 위해서는 우주환경에서 정상적으로 동작하는 지에 대한 환경 평가가 필수적이며, 위성통신이 주로 작동되는 저궤도 또는 정지궤도에서는 우주방사선 중에 양성자가 가장 많이 분포한다. 따라서 양성자 조사를 통해 해당 영역에서 전자소자가 방사선에 의해 어떠한 영향을 받는 지에 대한 확인이 반드시 필요하다.

일반적으로 양성자에 의한 방사선 영향을 평가할 경우에 displacement damage에 의해 반도체 내 결함 발생 및 전기적 특성 저하 현상이 보이는 것으로 보고되고 있다. 결합 발생 원인을 규명하기 위해 XRD, Raman 등의 결함 분석법을 도입하였지만, 수 MeV급의 고에너지 양성자에 의해 발생한 결함을 확인하기에는 적합하지 않는 것으로 보고된 바 있다. 따라서 본 연구에서는 GaN 기반 방사선 영향 평가 연구에서 일반적으로 적용되지 않았던 전자 상자기성 공명(EPR, Electron Paramagnetic Resonance) 분석법을 도입하여 양성자에 의해 발생된 AlGaN/GaN 이종접합구조의 결함을 분석하고자 하였다. 5 MeV 에너지의 양성자를 1E+13 ~ 1E+15 /cm^2 범위로 조사한 시료에 대하여 상온 EPR 분석을 수행하였다. 양성자가 조사되지 않는 시료에서는 자성 특성이 보이지 않는 반면에, 양성자가 조사된 시료에서는 자성 특성이 보이는 것을 확인할 수 있었고, 조사량이 증가함에 따라 공명신호가 확실하게 보이는 것을 확인할 수 있었다. 이러한 결과는 양성자 조사에 의해 발생한 결함과 연관된 라디컬(radical) 전자가 존재하기 때문인 것으로 판단되며, 조사량과 결함 발생 정도의 연관성을 설명할 수 있는 근거가 된다. 본 학술대회에서는 추가 분석을 통하여 규명된 결함과 자성 특성과의 상관관계, 전자소자 특성에 미치는 영향 등에 대해 발표할 계획이다.

사사(Acknowledgement)
이 논문은 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원(No. 2018R1D1A1B07051027, 2018R1D1A1B07047259)과 한국원자력연구원 양성자과학연구단 운영사업의 지원을 받아 수행된 연구임.

Keywords:

양성자, 질화물반도체, GaN, 결함, 전자 상자기성 공명

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.20

Topological characteristics of Bi thin films grown on the MoS_2 surface

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Abstract:

Bulk Bi is topologically trivial in theory. However, Bi bilayers are expected to be a two-dimensional (2D) topological insulator with a large bulk bandgap due to the strong spin-orbit coupling. Although the epitaxial growth of Bi thin films has been intensely exploited on various substrates, it remains a significant challenge to construct free-standing Bi film experimentally. Here we report that Bi thin films epitaxially grow on the MoS_2 surface without interfacial interaction by a combination study of low-energy electron diffraction, transmission electron microscopy, angle-resolved photoemission spectroscopy, and density functional theory. With increasing Bi coverage, Bi thin films favor the Bi(111) facet with indicating the topological state. More interestingly, the air exposure of the Bi thin films induces a large bandgap. The characteristic of the topologically nontrivial or trivial phase transition through surface oxidation is discussed. Our study might provide a comprehensive understanding of the emergent electronic properties of the 2D topological insulator

Keywords:

Quantum spin Hall effect, 2D Topological insulator

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.21

Cu를 도핑한 ZnSe 양자점 제작 및 도핑 농도에 따른 광학적 특성 분석

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Abstract:

양자점은 나노미터 크기를 가지는 반도체로 전자, 정공이 3차원적으로 구속되는 양자 구속 효과로 인해 불연속적인 양자화된 에너지 준위를 가지게 된다. 이는 기존 벌크와는 상이한 특성을 가지게 되기 때문에 태양전지, LED, 바이오 등 다양한 분야에서 활용성이 뛰어나지만 양자점을 합성할 때 특히 주로 사용되는 카드뮴, 납과 같은 물질들은 강한 독성을 가지기 때문에 소자로서 상용화되기 어려운 문제점을 보이고 있다. 이러한 문제점을 극복하기 위해서 무독성 물질을 이용한 연구들이 다수 진행되고 있지만 색순도와 발광 안정성을 높여주기 위해서는 다양한 공정 과정이 요구되고 있다. 이 중에서 단파장 영역대에서 발광하는 ZnSe 양자점의 경우 전이 금속 이온인 Cu^{2+}를 첨가하여 T_2 전이 준위를 통해 발광 영역을 확장할 수 있을 뿐만 아니라 자기 소광에 대한 문제를 해결할 수 있다. 따라서 본 연구에서는 성장 도핑 과정을 통해 ZnSe 양자점에 전이 금속인 Cu를 도핑하여 파장을 제어하고 도핑 농도에 따른 광학적 특성을 분석하였다.

Keywords:

콜로이드 양자점, ZnSe, Cu 도핑, 성장 도핑, 광학적 특성

P2-se.22

Growth mechanism and optical properties of $CsPbBr_3$ perovskite quantum dots

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Abstract:

Organic-inorganic lead halide perovskite which has excellent properties with long carrier diffusion length, long carrier lifetime, and proper optical gap. These properties enable to meet development of high efficient optoelectronic devices such as solar cells and light-emitting diodes. However, low thermal stability of organic-inorganic lead halide perovskite such as $MAPbX_3$ induce degradation phenomena and phase transition. $CsPbBr_3$ quantum dots (QDs) as all inorganic lead perovskite can overcome these phenomena due to high thermal stability. High thermal stability and defect tolerance in $CsPbX_3$ QDs are appropriate to understand kinetic mechanism and investigate optical properties for annealing process. In this work, we investigate the growth mechanism and optical properties of the $CsPbBr_3$ QDs using hot injection technique. From this, we study the relation between obtained band gap energy and edge length of $CsPbBr_3$ QDs. Absorption and fluorescence measurements are carried out to investigate the optical properties of $CsPbBr_3$ QDs.

Keywords:

Perovskite quantum dots, CsPbBr3, Growth mechanism, Optical properties, Thermal stability

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2020-07-13 - 2020-07-15

P2-se.23

Brightening of dark exciton via residual interface strain in monolayer WSe_2 on SiO_2/Si substrate

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Abstract:

Monolayer transition metal dichalcogenide (TMDC) materials, as direct-gap materials with strong light-matter interactions, have been the subject of recent interest. Because of their spin splitting by strong spin-orbit coupling at the conduction band edges, the lowest-lying excitons in W-based TMDCs are expected to become optically dark. Recently, temperature-dependent photoluminescence (PL) behavior influenced by non-degenerate spin state in unstrained TMDCs has been investigated [1]. However, temperature-dependent PL behavior induced by the spin-state mixing via the strain remains unclear.

Here, we show brightening of the dark exciton in strained monolayer WSe_2 compared with strain-free monolayer WSe_2. The strained monolayer WSe_2 was grown on the SiO_2/Si substrate using pulsed-laser-deposition-assisted selenization. Raman shift variation of A_{1g} mode between experiment and reference [2] reveals the presence of the residual strain that is induced by lattice mismatch between monolayer WSe_2 and SiO_2.

By tracing the PL intensity at dark exciton (X_D) peak as a function of temperature from 30 K to 300 K, we extracted the PL peak intensity of the X_D. We note that the PL intensity decreases with increasing the temperature. Such temperature-dependence has been reported to originate from dark excitonic feature shows the trend opposite to the bright exciton behavior in unstrained monolayer WSe_2 [1] and implies the role of the residual strain in the brightening of dark exciton.

- References

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- Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (2018R1A2B6008101).

Keywords:

strain, photoluminescence, dark exciton, WSe2

Luminescence manipulation via external shear strain in monolayer transition metal dichalcogenides

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Abstract:

Strain engineering in two-dimensional transition metal dichalcogenides (TMDCs) targets to control electronic band structures, and therein to modify their electronic and optical properties. Recently, the focus in the strain engineering have been interested in intervalley scattering under the application of normal strain while the intra-band mixing at K valley via the shear strain have remains unclear in the TMDC materials. Here, we probe brightening (darkening) of dark (bright) exciton in WSe_2 ($MoSe_2$) under application of out-of-plane shear strain and in-plane normal strain using strain-dependent PL measurement. The well-known valley-specific carrier population via normal strain was used to calculate the PL intensity. The measured PL intensity, however, seriously deviated from the calculation both in monolayer WSe_2 and $MoSe_2$. This significant variation in the PL intensity originates from spin-state mixing in lowest-lying excition state via the shear strain. The lowest-lying excitons in W-based and Mo-based TMDCs are expected to become optically dark and optically bright due to spin-orbit splitting at the K valley of the conduction band. In this way, such spin-state mixing in the dark (bright) exciton state via the shear strain induces the enhancement (suppression) of the PL intensity. i.e., excitonic brightening (darkening) in the monolayer WSe_2 ($MoSe_2$).

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- Acknowledgment
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (2018R1A2B6008101)

Keywords:

shear strain, spin-state mixing, WSe2, MoSe2, dark exciton

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.25

Effect of surrounding materials on photoluminescence of WSe_2 monolayer

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Abstract:

Monolayers of transition metal dichalcogenides (TMDs) have attracted considerable attention owing to their intriguing optical and electrical properties and possible applications in optoelectronic devices. Recently, layered material based heterostructures with different stacking orders have been subject of intense research due to their newly emerging physical phenomena. Particularly, encapsulating TMDs monolayer in hexagonal boron nitride (hBN) has become a beneficial method of producing high quality TMDs monolayers. For instance, hBN-encapsulated TMDs monolayer shows narrow excitonic emission linewidth, which enables to observe the excitnoic complexes. However, while physical properties of atomically thin TMDs monolayers are highly dependent on the surrounding material, the effect on photoluminescence when monolayers are transferred to place around hBN flakes is still not fully explored.
In this study, we fabricated WSe_2 monolayer with a Scotch tape method on a PMMA coated quartz substrate and encapsulated the monolayer in hBN flakes. In the fabrication process, photoluminescence spectra were measured at each transfer steps. We observed the PL spectra change on the different environmental materials such as the WSe_2 monolayer on PMMA, on hBN, and hBN-encapsulated. The FWHM of the emission peaks show 56, 41, and 34 meV on PMMA, on hBN, and in hBN respectively. The PL energy undergoes a distinct red shift from 746 nm to 756 nm in hBN-encapsulted WSe_2 monolayer compared to one on the PMMA substrate. As our study reveal the PL spectra change of WSe_2 monolayers in different surrounding materials which is used in the transfer process, this can provide useful information for the design of heterostructure-based optoelectronic nanodevices.

Keywords:

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.26

Distinguished electrical behavior in variable two-dimensional materials

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Abstract:

After graphene was first discovered, hexagonal boron nitride (hBN), transition metal dichalcogenides (TMDCs), and black phosphorus were found in succession. Among them, TMDCs are two-dimensional materials in which transition metal and chalcogenide component are combined. TMDCs contain various materials such as MoS_2, WS_2, and WSe_2, which are known to have n-type or p-type characteristics. For example, MoS_2 has a bandgap of 1.6 eV, conduction band level of -4.3 eV, and valence band level of -5.9 eV in multi-layers. The work-function energy of chromium is -4.5 eV, so it is n-type because there is MoS_2 fermi level near the conduction band. In order to confirm the electrical characteristics, We fabricated field-effect transistors (FETs) using these TMDCs. Multi-layer graphene (MLG) is used as the gate electrode. FETs were fabricated with the structure of TMDCs / hBN / MLG

Keywords:

MoS2, WS2, WSe2

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Measurement of anisotropic refractive index of Black Phosphorus

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Abstract:

Black Phosphorus (BP) is a two-dimensional material that has been attracting attention as the next generation of semiconductor materials. Because BP has a direct band gap and it could be easily controlled by the number of layers, research about BP is actively underway.
Anisotropic properties of BP imply a possibility of different refractive indices along the polarizations. Because of such properties, identifying the refractive index along the polarization is an essential element in utilizing BP.
We measured transmittance along the polarization for 2 samples that each have different thicknesses. Sample has exfoliated with the scotch tape and placed on the fused silica substrate. We used super continuum pulsed laser so that we could measure the whole-visible spectrum. Simulation show us transmittance spectrum of thin film under arbitrary refractive indices and it contains codes that compute the multiple reflection and absorption. By comparing those transmittance data and simulation, we figured out the refractive index.

Keywords:

Keywords: Black Phosphorus, Refractive index

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.28

Ellipsometric Characterization of Monolayer WS_2 from 41 to 300K

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Abstract:

The layered transition metal dichalcogenides (TMDCs) have recently gained significant interest due to their distinctive physical properties. Tungsten disulfide (WS_2) is well known as one of transition metal dichalcogenides, which suggests promise as a potential substitute for silicon in state-of-the-art transistors, sensors, and photodetectors. A systematic study on temperature dependence of the dielectric function and critical point energies of WS_2 is therefore strongly needed.

In this work, we investigate the dielectric function of monolayer WS_2 in 1.5 to 6.0 eV energy range at temperatures from 31 to 300 K by spectroscopic ellipsometry. The CP transitions are observed and their energies are obtained by fitting standard analytic expressions to second energy derivatives of the data. Origins of the CPs were identified by band structure calculation obtained by density functional theory method. We found three new CPs at low temperature beside another eleven CPs realized at room temperature. Blue shift and enhancement of most CP energies at low temperatures were observed and understood by the reduced lattice constant and electron-phonon interaction. The temperature dependences of these CPs were determined by fitting the data to the coefficients in a phenomenological expression that contains the Bose-Einstein statistical factor. The dominance of charged excitons over the neutral excitons is also observed at all temperatures due to n-type nature of monolayer WS_2 on sapphire substrate. Additionally, the electronic band gap, binding energies, and spin-orbit splitting are also reported

Keywords:

Spectroscopic Ellipsometry, Monolayer Tungsten Disulphide (WS2), Critical Point, Temperature Dependence

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.29

Surface Potential and Transport Studies of MoS_2/WS_2 and WS_2/MoS_2 Heterostructures

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Abstract:

Heterostructures consisting of 2D transition metal dichalcogenides (TMDs) enable us to control the carrier transport and radiative recombination behaviors, like conventional 3D semiconductors. The electrical and optical properties of the heterostructures are determined by the band alignment. Stacking order of the 3D heterostructures could affect their strain states and chemical reaction at interface, leading to modification of the physical characteristics. In this work, we comparatively investigated surface potential and transport behaviors of MoS_2/WS_2 and WS_2/MoS_2 heterostructures grown on single crystal Al_2O_3 wafers, using sulfurization of pre-deposited transition metal layers. The surface potential in dark and light allowed us to suggest band diagrams of the 2D TMD heterostructures. The transport measurements of the heterostructures helped us to understand the influences of the band alignment on the carrier transport.

Keywords:

Heterostructures, MoS2, WS2, Band alignment

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.30

Structural and Spectroscopic Properties of Hexagonal CdS (h-CdS) Thin Films

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Abstract:

h-CdS는 II-VI족 화합물 반도체로서 약 2.50 eV 정도의 에너지밴드갭을 가지며, 직접천이형 반도체로서 자외선과 가시광선 영역에서 광전도전지나 광전자장치에 효과적으로 널리 사용되고 있다. h-CdS 박막들은 열벽적층성장법 (Hot-Wall Epitaxy;HWE)으로 GaAs(111) 기판위에 성장시켰다. 성장된 박막들의 결정구조와 결정성을 알아보기 위하여 XRD 회절패턴과 HRXRD의 반치폭을 이용하였고, 표면상태를 확인하기 위하여 Nomarski 간섭현미경과 SEM-EDS을 사용하였다. 또한 분광학적 특성을 알아보기 위하여 분광학적 엘립소미트리 (타원편광분석법)를 이용하였고, 측정된 박막의 데이터들은 복소 유사유전함수인 $\langle\varepsilon\rangle = \langle\varepsilon_1\rangle + i\langle\varepsilon_2\rangle$를 실온에서 2.0~8.5 eV의 포톤에너지 범위에서 얻는데 사용되었다. 또한, 이들 광학적 유사유전함수의 결과로부터 반사율(R), 굴절지수(n), 소광계수(k) 흡수계수(α) 등을 얻을 수 있었다. 타원편광분석법을 이용하여 획득된 데이터의 이계도함수를 이용하여 E0, 두 개의 E1, 두개의 E2, F1 임계점 피크 등을 구하였다.

Keywords:

h-CdS, 타원편광분석법, 열벽적층성장법, 구조적 특성, 분광학적 특성

2020 KPS Spring Meeting
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금속화합물 첨가에 의한 Ga_2O_3 박막의 결정성 및 전기적 전도성 변화

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Abstract:

에너지 밴드갭이 넓은(큰) 반도체의 경우, 가전자대의 상단이 진공 준위로부터 매우 가까운 위치에 존재하기 때문에 p-type doping 특성을 얻는 것은 매우 어려운 과제였다. 같은 이유에 의해서Ga_2O_3의 경우에도 p-type dopant로 작용할 것으로 예상되는 원소를 단순히 결정 성장에 활용하는 것만으로는 p-type 전도도를 얻는 것이 쉽지 않을 것으로 판단된다. 그러나 Ga_2O_3는 GaN와 Si에 비해서 더 넓은 에너지 밴드갭과 더 큰 절연 파괴 전압 값을 가지고 있어서, p-type 전도도 제어가 가능한 Ga_2O_3 박막을 성장할 수 있다면 Ga_2O_3를 이용한 훨씬 우수한 성능의 p-n 접합 전력 반도체의 개발이 가능할 것으로 판단된다. 본 연구에서는 금속원자를 포함하는 수용성 금속 화합물을 이용하여 Ga_2O_3의 p-type 전도성 제어의 가능성을 확인하고자 하였다. 종래의 MOCVD 결정 성장 기술을 개량하여 III족 원료인 갈륨(Ga) 원자의 공급을 위해서는 TMGa 원료를 사용하며, VI 족 원료인 산소(O) 원자의 공급을 위해서는 H_2O가 포함된 버블러(bubbler)를 사용하는 한편, 버블러 내부의 H_2O에 수용성 금속 화합물인 $Mg(CH_3COO)_2{\cdot}4H_2O$, $Zn(CH_3COO)_2{\cdot}2H_2O$ 그리고 $CuSO_4$를 첨가하여 금속 원자가 박막 내부에 도핑 되도록 하였다. Ga_2O_3박막 성장을 위한 기판은 c-sapphire를 사용하였으며, 박막표면의 우수한 평탄도를 위하여 사파이어 기판과 동일한 육각형 결정대칭성을 가지는 ε-Ga_2O_3박막을 우선 성장하면서 앞서 언급한 금속 원소들을 도핑하였다. 이후, ε-Ga_2O_3박막 내의 금속원소들의 활성화를 위해 열처리를 실시하여 β상으로 변이시켰다. 열처리까지 완료된 박막의 전기적 전도 특성은 I-V 측정과 Hall 측정을 이용하여 평가하였으며, 결정성 평가를 위해 XRD 및 SEM 측정도 실시하였다.

Keywords:

ga2o3, thin film, MOCVD, doping

2020 KPS Spring Meeting
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상 변이 메커니즘을 이용한 고품질 β-Ga_2O_3박막의 형성 및 전기전도도 제어

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Abstract:

β-Ga_2O_3는 4.9 eV에 달하는 넓은 밴드갭을 가지고 있으며, n-type doping을 통한 전도성 제어가 가능하고, 열적, 화학적으로도 매우 안정하여 다양한 활용이 기대되는 물질이다. 또한, 현재 전력반도체로 주목받고 있는 GaN와 SiC보다 높은 항복 전압 특성을 가지고 있어 차세대 초고전력반도체 재료로 응용될 것으로 기대된다. 하지만 β-Ga_2O_3는 헤테로 성장에 의한 박막 형성 시 기판들과의 정합성이 좋지 않고, 결함이 많아 고품질(특히 표면이 매우 평평한)의 박막 성장이 쉽지 않다는 단점을 가지고 있다.
반면, ε-Ga_2O_3의 상 박막은 β-Ga_2O_3에 비하여 비교적 낮은 온도에서 성장을 실시하고, 대부분의 육각 대칭성을 가지는 상용 기판들(c-sapphire, Si(111), GaN, SiC 등)과의 결정 구조 대칭성이 유사하여, β-Ga_2O_3에 비해 상대적으로 쉽게 고품질 박막(결정성과 표면 거칠기 특성이 우수한)을 얻을 수 있다는 특징을 가진다. 그러나 ε-Ga_2O_3 박막은 낮은 성장온도에 의한 활성화 에너지 문제로 아직까지 n-type 전기 전도도가 자유롭지 못하고 그에 대한 연구 결과도 많지 않은 편이다.
이에 본 연구에서는 ε-Ga_2O_3 박막의 우수한 평탄도를 유지하면서 열처리에 의해 β상으로 변환 시킨 Ga_2O_3 박막의 전기적 제어 특성에 대하여 조사하였다. Metal Organic Chemical Vapor Deposition (MOCVD)를 이용하여 c-sapphire 기판 위에 n-type doping된 ε-Ga_2O_3박막을 성장하였고, 열처리를 통해 β상으로 변이 시켰다. ε-Ga_2O_3박막 성장 시, 산소 공급원으로 사용된 H_2O bubbler에 수용성 Sn 화합물을 첨가하여 doping을 진행하였고, 수용성 Sn 화합물의 농도와 열처리 온도에 변화를 주어 전도성을 제어하였다.
X-Ray diffraction(XRD)와 Field Effect - Scanning Electron Microscope (FE-SEM), Photo Luminescence (PL), Hall Measurement를 이용하여 박막의 구조적, 광학적, 전기적 특성을 평가하였다.

Keywords:

Ga2O3, MOCVD, power semiconductor, thin film, doping

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P2-se.33

Extraordinary Suppression of Thermal Conductivity in Wedge-like Phonon Cavity Structure Based on Wave Nature of Phonons

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Abstract:

The heat transport characteristics of materials in nanoscale where the wavy features of phonons become crucial in clearly contrasting to bulk-scale thermal diffusion, are gaining recent research interests in terms of, thermal management of electronic/optoelectronic devices, thermoelectric energy conversion, and design of metamaterials with thermally desirable properties [1]. In this work, we investigate the abnormal suppression of cross-plane thermal conductivity (κ) in the phonon cavity structure. Figure 1(a) shows the illustration of the phononic cavity structure where the cavity thickness (d_c) varies from 14 to 37 nm on top of phononic distributed Bragg resonators (DBRs) consisted of AlAs/AlGaAs superlattice layer. DBRs form the phononic bands in reflection based on which the acoustic confinement within cavity at d_{on} should be contrasted to almost perfect transmission at d_{off}, which has been scarcely investigated before. The average thermal conductivity in our structure of cavity-DBRs was measured as 8.19 W m^{-1} K^{-1} by using time-domain thermoreflectance measurement technique. Intriguingly, when the cavity thickness well-matches with the phonon wavelength of forbidden mode in DBR, the κ was suppressed to 7.39 W m^{-1} K^{-1}. Please note that the d_c of 34 nm correlated with acoustic cavity modes, which are described as 153 GHz×(n-1/2), where the n indicates the number of mode. These phenomena are associated with standing wave condition, which constructive interference of the phonons reflected from the DBRs. The decrease in κ, which indicates the phonon confinement in the cavity layer, is further correlated with the reduction of the thermal boundary conductance. In this regard, our experimental results imply that thermal transports in nanoscale devices could be further manipulated by adjusting the parameters in the interfacial acoustic mismatch.

References:

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Acknowledgment This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (2018R1A2B6008101)

Keywords:

Time-domain thermoreflectance, Thermal conductivity, nonasclae thermal transport

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

Detection of Thermally Significant THz Acoustic Phonon

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Abstract:

The detection of acoustic (AC) phonon dephasing in the THz frequency range has been important tasks because the THz AC phonon lifetime is a key parameter for determining thermal conductivity in semiconductor materials such as GaN [1]. However, in the conventional linear photoelastic (PE) regime, as only the Brillouin frequency components are sampled from AC wavepakcets [2], the dephasing of THz AC phonon is hardly accessible. In this work, we investigate AC dephasing dynamics as a function of strain packets by measuring the time-varying phase of the differential reflectivity spectra (DRS) in the nonlinear PE regime, where the overall AC components beyond Brillouin frequency are measurable. The AC wavepackets are manipulated by external bias in piezoelectric diodes with InGaN/GaN multiple quantum wells. In order to understand spectrally broad nonlinear detection, the DRS are plotted in Figure 1(a) and (b) for the linear regime at E_{probe}=3.163 eV and for the nonlinear regime at E_{probe}=3.289 eV, respectively. The phases of DRS and corresponding dephasing times are further extracted in Figure 1(c) and 1(d) before and after surface reflection. In contrast to the phase-invariant oscillation of the linear PE regime, both the abrupt phase jumps during the AC reflection ($t_{Rf} > t > t_{Ri}$) and the gradual phase change during the AC propagation imply that AC decay beyond Brillouin frequency is revealed by the nonlinear PE. Furthermore, the extracted dephasing time in Figure 1(d), which is associated with the phonon lifetime at the bandwidth of strain packet, reveals that AC dephasing can be measured in the thermally significant THz frequency range.

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Acknowledgment This work was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning(2018R1A2B6008101).

Keywords:

phonon, Acoustic phonon, phonon dephasing, nonlinear photoelasticity

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-se.35

분광타원계, 반사계, 투과계를 동시 적용한 노광용 마스크의 두께, 복소굴절률 정밀 결정 방법

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Abstract:

박막과 소재의 물성을 측정, 분석하는 광학적 기술에는 반사율, 투과율, 타원상수등 다양한 방법이 존재한다. 반사율이나 투과율은 광량을 측정하기 때문에 상대적으로 간편한 방법이다. 간섭에 의한 반사광의 파장별 간섭의 정도를 측정하여 두께를 결정하는 반사법을 사용할 경우 단일파장에서는 물질의 복소굴절률 (n,k) 값을 알고 있을 때 두께 계산이 가능하다. 분광 반사법을 사용하면 측정속도가 높고 사용법이 간편하며 아주 좁은 영역내의 측정이 가능하므로 미세 패턴 상에서 두께 측정이 용이한 장점들을 가지고 있다. 하지만 분광 타원법과 비교하여 훨씬 두꺼운 막에 대해서만 적용할 수 있고 막 두께의 측정 정밀도가 매우 낮다. 분광 투과법을 사용할 경우 막의 두께 측정이나 막질의 분석보다는 소재 자체의 굴절률, 특히 흡수 계수인 k값의 분산 형태를 두께와 연계하여 결정하는데 유리한 특성을 갖고 있다.

EUV용 마스크를 포함하여 노광용 마스크에는 빛의 흡수가 큰 물질들이 사용되고 있다. 특히 위상천이 마스크(Phase Shift Mask, PSM)에서는 위상각도와 함께 투과율을 조절하여 노광 후 형성될 패턴의 선명도를 향상시키는데 투과율과 위상천이 각도의 제어가 매우 중요하다. 다층 초박막의 두께와 물성을 바꾸며, PSM의 위상천이 각도와 투과율을 정밀하게 제어하기 위해서는 다층 초박막의 두께와 물성을 정밀하게 파악하는 것이 매우 중요하다.

분광 타원계는 투명하거나 빛의 흡수가 작은 물질의 경우 두께와 복소 굴절률을 정밀하게 결정할 수 있게 하지만 흡수에 의해 박막 아래에서 반사하는 빛이 매우 약해질 경우 박막이 두께 측정 정밀도가 현저하게 감소한다. 이를 보완하는 방법으로 투과율과 반사율을 함께 분석할 경우 박막의 두께와 흡수계수 결정의 정밀도를 크게 향상시킬 수 있다. 본 연구에서는 분광 타원계, 반사계, 투과계, 세개의 광계측기에서 얻은 데이터를 동시에 이용하여 노광용 마스크의 광물성을 정밀하게 분석한 결과를 발표한다.

Keywords:

Spectroscopic Ellipsometry, Spectroscopic Reflectometer, Spectrophotometer, Blank Mask, Optical Properties

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P2-se.36

Optical and Structural Properties of Perovskite Films on Well-aligned ZnO Nanorods

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Abstract:

In perovskite-based solar cell devices, many studies have been conducted on ZnO nanorods (ZONs) to perform the function of electron extraction. The surface morphology and orientation of ZONs are crucial for achieving high-efficient perovskite solar cells. To grow ZONs with different densities and sizes (diameter and length) of nanorods, ZnO seed layers were prepared in different conditions using a sol-gel method on the FTO substrates. ZONs were synthesized using a hydrothermal method. As the concentration of the seed layer increased, the orientation of ZONs improved. The thickness of the seed layer becomes thicker as the concentration increases, and the roughness of the FTO substrate is alleviated to promote the growth of well-aligned ZONs. $MAPbI_3$ films were deposited on top of ZONs using a one-step solution process. The structural and optical properties of the perovskite layers synthesized on top of various alignments of the ZONs were investigated using X-ray diffraction, scanning electron microscopy, UV-vis absorption, and photoluminescence measurements.

Keywords:

perovskite, zinc oxide, nanorod, electron transport layer, photoluminescence

2020 KPS Spring Meeting
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P2-se.37

Near-ultraviolet broadband emission from a 2D perovskite single crystal: BA2PbI4

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Abstract:

Research into halide perovskite materials has been actively conducted in recent years. Especially, 2D perovskites have attracted significant attention because they have several features that are superior to other conventional semiconductors. For example, the exciton binding energy can be readily controlled, the quantum efficiency of photoluminescence (PL) is high, and long carrier lifetimes and high defect tolerance can be realized. Therefore, 2D perovskites are potential materials for various optoelectronic applications such as solar cells, photodetectors, transistors, memory devices, etc. In order to understand the basic optical properties that essentially lead to these fascinating features, we investigated the PL from a single crystal of the 2D perovskite, BA2PbI4 (BA: butyl ammonium) grown by inverse temperature crystallization. In order to suppress the reabsorption effect, the reflection geometry was used, and the PL measurement was conducted over a wide temperature range from 300 K down to 10 K. Quite intriguingly, we observed a very intense broadband PL emission at the near infrared (1.75 eV), which has not been reported so far to the best of our knowledge. In this talk, we will talk about the nature of this transition based on temperature-, wavelength-, and intensity-dependent PL spectroscopy. Our analysis may indicate that this strong PL arises from radiative recombination of self-trapped excitons that cause local crystal deformation. This polaron picture well explains the broadband nature of the emission occurring far below the bandgap.

Keywords:

Organic−InorganicHybrid Ruddlesden−Popper Perovskite, Near-ultraviolet broadband emission , Low-temperature, self-trapped exciton, polaron

P2-st.01

Specific Heat of the Kagome-Lattice Ferromagnetic Ising Model in a Magnetic Field

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Abstract:

Two-dimensional Ising models have played important roles in our understanding of the thermodynamic properties of various materials.
The properties of two-dimensional Ising models have been properly understood in the absence of an external magnetic field.
On the other hand, the properties of two-dimensional Ising models in an external magnetic field have never been known except for few cases.
The properties of the specific heat of the ferromagnetic Ising model on a kagome lattice in an external magnetic field are investigated, calculating the specific heat as a continuous function of temperature and magnetic field.

Keywords:

Kagome lattice, Specific heat

2020 KPS Spring Meeting
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P2-st.02

Study on the Thermodynamic Properties of the Ising Model on a Simple-Cubic Lattice

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Abstract:

The thermodynamic properties of the Ising model on a simple-cubic lattice have never been known well even in the absence of an external magnetic field.
Densities of states of the Ising model on finite simple-cubic lattices are estimated by using Wang-Landau Monte Carlo simulation method.
Based on the estimated densities of states, the specific heats of the Ising model on finite simple-cubic lattices are obtained for whole temperature interval.
Then, the scaling properties of the specific heat of the Ising model on a simple-cubic lattice are studied.

Keywords:

Simple-cubic lattice, Thermodynamic properties

2020 KPS Spring Meeting
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P2-st.03

Characteristics of the Schottky Anomalies for the Ising Ferromagnet and the Ising Antiferromagnet

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Abstract:

The ferromagnetic Ising model and the antiferromagnetic Ising model have been the fundamental systems in investigating the various thermal and magnetic properties of condensed matter.
The thermal and magnetic properties of the ferromagnetic Ising model and the antiferromagnetic Ising model have been relatively well known in the absence of an external magnetic field.
However, the thermal and magnetic properties of the ferromagnetic Ising model and the antiferromagnetic Ising model in an external magnetic field have never been well known.
Here, the characteristics of the Schottky anomalies for the ferromagnetic Ising model and the antiferromagnetic Ising model in an external magnetic field are studied.

Keywords:

Schottky anomalies, External magnetic field

Impact of degree-weighted influence in the Majority-vote dynamics on Complex Networks

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Abstract:

본 연구에서는 복잡계 네트워크 위에서의 Majority-vote model 의 상전이 현상을 연구하였다. 기존의 Majority-vote model 과 달리, 본 연구에서는 각 투표자의 연결선 수(degree)에 비례하는 가중치를 부여하여 불균질한 영향력을 이웃 투표자에 행사하도록 하였다. 이 때 가중치를 조절하는 parameter α 와 투표자가 다수결을 따르지 않을 확률 q 의 변화에 따른 계의 상전이 현상을 연구하였다. 네트워크의 구조에 따른 상전이 현상의 차이를 비교하기 위해 Erdős–Rényi 네트워크와 scale-free 네트워크 위에서 전산 시뮬레이션을 시행하였다. 특히 α 와 degree exponent λ 의 변화에 따라 임계지수들이 변함을 발견하였으며, 네트워크의 구조가 degree-weighted Majority-vote 모형의 보편성군에 미치는 영향을 연구하였다.

Keywords:

Sociophysics, Complex Networks, Phase transition

2020 KPS Spring Meeting
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P2-st.05

Efficiency of a fuel-consuming active Stirling engine

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Abstract:

Stochastic heat engines powered by active particles have recently gained much attention, especially in connection with the possibility of overcoming the Carnot efficiency. However, due to the phenomenological nature of the models as well as the ill-defined notion of temperature, the proper definition of engine efficiency in such systems has been under debate. In this study, we analyze a simple heat engine consisting of a harmonically trapped dimer whose activity comes from a constant chemical potential difference driving the fuel consumption. This model has two advantages. First, it naturally leads to the definition of engine efficiency in terms of the amount of consumed fuel, which is of practical importance. Second, it allows us to study two different types of engines: one with active forces keeping their sign under time reversal (even-parity propulsion), the other with forces changing their sign (odd-parity propulsion). Based on analytical and numerical studies of finite-time Stirling cycles, we compare the energetics and efficiency of these two types of engines in various settings. This approach provides us a deeper understanding of the far-from-equilibrium characteristics of active heat engines.

Keywords:

active matter, heat engine, efficiency, stochastic thermodynamics

2020 KPS Spring Meeting
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P2-st.06

Thermodynamic uncertainty relation for Otto cycle

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Abstract:

Recently, the thermodynamic uncertainty relation (TUR) has been proved for overdamped Langevin dynamics. However, the TUR for underdamped Langevin dynamics is still unclear, so that the following question is posed: under what conditions and for what currents, is the TUR guaranteed? In this research, we test the TUR for Otto cycle, where the working fluid is a harmonic oscillator and the Otto cycle is modelled by an underdamped Langevin dynamics. We find the tighter bound for energetic currents than that from the ordinary TUR, which implies the relative error of energetic currents does not decrease even when the relative error increases.

Keywords:

Thermodynamic uncertainty relation, Otto cycle, Underdamped Langevin dynamics, Nonequilibrium thermodynamics, Heat engine and refrigerator

P2-st.07

Inertial effects in two-temperature Langevin dynamics

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Abstract:

As the experimental realization of Brownian gyrator becomes possible, it is necessary to investigate how inertia affects the particle dynamics. To clarify the inertial effects in the nonequilibrium steady state, we consider a particle moving on a 2D-plane with two different heat baths and an anisotropic harmonic potential in underdamped regime of Langevin dynamics. We find that the rotational motion of the particle changes significantly according to its mass by solving the Fokker-Planck equation. Particularly, it is observed that the fluctuation of the rotational motion shows an interesting counter-intuitive behavior. We confirm our results by using the underdamped Langevin dynamics simulation.

Keywords:

Brownian gyrator, Inertial effects, Langevin equation, Fokker-Planck equation

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P2-st.08

Anomalous diffusion for active Brownian particles cross-linked to a networked polymer: Langevin dynamics simulation and theory

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Abstract:

Quantitatively understanding of the dynamics of an active Brownian particle (ABP) interacting with a viscoelastic polymer environment is a scientific challenge. It is intimately related to several interdisciplinary topics such as the microrheology of active colloids in a polymer matrix and the athermal dynamics of the in vivo chromosome or cytoskeletal networks. Based on Langevin dynamics simulation and analytic theory, here we explore such a viscoelastic active system in depth using a star polymer of functionality f with the center cross-linker particle being ABP. We observe that the ABP cross-linker, despite its self-propelled movement, attains an active subdiffusion with the scaling $\langle \Delta \mathbf{R}^2(t) \rangle \sim t^{\alpha}$ with $\alpha \leq 1/2$, through the viscoelastic feedback from the polymer. Counter-intuitively, the apparent anomaly exponent $₩alpha$ becomes smaller as the ABP is driven by a larger propulsion velocity, but is independent of the functionality f or the boundary conditions of the polymer. We set forth an exact theory, and show that the motion of the active cross-linker is a gaussian non-Markovian process characterized by two distinct power-law displacement correlations. At a moderate Péclet number, it seemingly behaves as fractional Brownian motion with a Hurst exponent $H = \alpha/2$, whereas, at a high Péclet number, the self-propelled noise in the polymer environment leads to a logarithmic growth of the mean squared displacement ($\sim \ln t$) and a velocity autocorrelation decaying as $-t^{-2}$. We demonstrate that the anomalous diffusion of the active cross-linker is precisely described by a fractional Langevin equation with two distinct random noises.

Keywords:

Active polymer, Active Brownian particle, Polymer gels, Rouse dynamics, Fractional Brownian motion

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P2-st.09

Non-Gaussian diffusion and energy balance of a Brownian particle in active baths

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Abstract:

We present a minimal model to generalize the iconic feature of active matter that Brownian particles diffusing in a harmonic potential are kicked by external forces to engender mobility beyond that attributable to thermal energy. The wide time and length scales of usual active matter systems are mapped onto the generic concept of a single Brownian diffusion time (a particle diffusing in a harmonic potential) and kicks from external forces that arrive at random intervals with a defined, programmable, duration time for each kick. Our experiments using an optical trap agree in showing enhanced diffusion that is Gaussian only if the kick duration time is larger than the Poisson interval time. In addition, we conclude that maximum energy dissipation occurs at the time-scale of the geometric mean of the kick duration time and the particle thermal equilibration time. Usual active matter systems do not allow this independent variation of thermal motion, active motion, and the relative time scales of both. In this streamlined system they are varied independently, allowing one to rapidly prototype the limits of various stochastic thermodynamic models.

Keywords:

Active particle, Non-Equilibrium, Diffusion

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P2-st.10

An object gains motility in an active fluid through spontaneous symmetry breaking

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Abstract:

In fluids at equilibrium, a moving object typically experiences a drag force that opposes its velocity. In contrast to this conventional wisdom, we find that the drag force can apply in the direction of velocity in an active fluid. Using a simple model of a soft object immersed in an ideal gas of active particles, we analytically and numerically show that the active particles can give extra propulsion to the object by accumulating in its wake. This implies that active particles can impart their motility even to symmetric bodies through a spontaneous symmetry-breaking mechanism. While previous studies of such effects require the presence of polar or nematic order in the active fluid, our mechanism is more generically applicable even in dilute and disordered fluids.

Keywords:

active matter, negative mobility, spontaneous symmetry breaking

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P2-st.11

Continuum boids model

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Abstract:

It has been argued that active spin systems can exhibit orientational order by undergoing spontaneous symmetry breaking. However, recent large-scale numerical simulations suggest that the symmetry breaking in early numerical simulations could be a finite-size effect. To address this question, we consider a continuum version of the boids model and derive its exact Lyapunov functional. Orientational order is absent in our numerical simulation, unless the interaction length scale is comparable to the system size.

Keywords:

Boids model, Partial differential equation, Orientational order, Active matter

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P2-st.13

Emergence of power laws in machine learning: case studies

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Abstract:

Recent studies [1,2] have proposed an information-theoretical framework, according to which machine learning is a constrained optimization balancing the detailed representation of relevant information and the compression of redundant information. The optimization, if successful, naturally produces a power-law distribution of the internal state frequency. However, it remains to be checked how generically such power laws occur in various kinds of machine learning. In this study, we observe when and how the power laws emerge from the unsupervised learning of restricted Boltzmann machines and the supervised learning of feed-forward neural networks. In particular, we discuss the effects of infinite and continuous state space on the emergence and detection of the power laws.

[1] R. Schwartz-Ziv and N. Tishby, arXiv:1703.00810
[2] R. J. Cubero, J. Jo, M. Marsili, Y. Roudi, and J. Song, J. Stat. Mech. **2019**, 063402 (2019).

Keywords:

restricted Boltzmann machines, machine learning, power law, information bottleneck theory, feed-forward neural network

2020 KPS Spring Meeting
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P2-st.14

Dynamical analyses of visibility network in financial stock markets

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Abstract:

In this paper, we study the statistical metrics of the visibility network in three stock markets, that is, the S&P500, SSEC, and Nikkei225. Data are extracted from the daily prices of all three stocks that are exchanged during a period from 1996 to 2010. The topological properties may ameliorate by implementing the method and its technique from converted data of financial networks. In these networks, the degree distributions are found to be proportional to a power law than the Poisson distribution. It is not particularly tractable to treat universal and irregular properties of financial statistical quantities in three financial markets.

Keywords:

Visibility graph, S&P500, SSEC, Nikkei225, Modularity

P2-st.15

Representations of Object Size and Numerosity in Artificial Neural Networks

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Abstract:

Humans and animals estimate object size and numerosity from sensory stimuli to guide their behavior. Our brain is known to process these quantities associatively by having populations of neurons that show selective response to object size and numerosity simultaneously (Harvey, 2015). However, the underlying network architecture that orchestrates the formation of these selective responses and their correlated structure is not fully understood. Previous studies suggested that numerosity selective neurons can arise in a deep neural network without training, suggesting that innate numerosity selectivity may develop from the statistical variation in the complex feedforward projection across the hierarchy of the visual pathway (Kim, 2019). Here, we advance the notion and show that size-selective neurons can arise in deep neural networks, as well as number selective neurons, without training. Using a convolutional neural network, a class of artificial deep neural network model designed from the structure of the biological visual pathway, we found that object size tuning arises spontaneously in randomly initialized deep neural networks. Interestingly, although neurons tuned for object size and numerosity were measured separately with different stimulus sets, two populations were significantly overlapped and showed a correlation between preferred object size and preferred numerosity as observed in the brain. Furthermore, these neurons showed distinctive tuning spectra for object size and numerosity respectively, following tuning properties observed in the human parietal cortex. Our results suggest that object size selectivity, numerosity selectivity, and their associated representation may develop solely from the structure of the visual pathway, initializing innate systems for information processing of general quantities in the brain.

Keywords:

Artificial neural network, Neural encoding, Neural information processing

2020 KPS Spring Meeting
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P2-st.17

Machine Learning Approaches on the Stability Prediction of Power Grid

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Abstract:

The complex network analysis has provided the clues to improve a power grid to be more stable. However, the high computational cost of the numerical simulation has inhibited the approach when it comes to the dynamic properties of power grids such as the synchronization phenomenon. In this study, we applied machine learning techniques to estimate the stability of the synchronization of power grids. We apply three different machine learning techniques—random forest, support vector machine, and artificial neural network—to the systemically generated samples of two distinct types of power grids: homogeneous and heterogeneous power generation strategies. We find that machine learning approaches show good performance for both strategies. The detailed comparison between the learning algorithms and sampling models are also discussed.

Keywords:

machine learning, power grid

2020 KPS Spring Meeting
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P2-st.18

Evolving open system with Lotka-Volterra dynamics

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Abstract:

Ecosystems consist of many individuals interacting with each other, showing their diversity. As one of the mechanisms to sustain this diversity, interaction structures have been extensively studied. A huge volume of work has focused only on static interactions. Recently, evolving open systems have drawn attention, considering the emergence of new species and their extinction in nature. Thus interaction structures can change over time, but it is poorly understood yet. To investigate interaction structures and diversity in evolving open systems, we introduce an ecological model in which new species constantly emerge and evolve. We implement a Lotka-Volterra type equation on a signed directional network, which describes interactions between species. Numerically solving the equation, we examine how the evolving interaction structure and strength affect the diversity of species.

Keywords:

Evolving open system, Diversity, Lotka-Volterra equation, Network analysis

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P2-st.19

Revealing the evolution of composition of landscape painting through the lens of information theory

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Abstract:

Painting has played a major role in human expression and evolved under an interplay with social environments of the times. From the qualitative work of individual art historians emerges a meta-narrative, which remains difficult to evaluate in its validity with respect to its inherent dynamics and the historical evolution it depicts. Therefore, quantitative analysis on the creative process in painting could shed light on systematic verification on the narratives. Yet, quantitative understanding of spatial composition and geometric proportion by which painters compose paintings is still lacking. Here, we systematically analyze the compositional proportion in landscape paintings using a simple yet coherent information-theoretic dissection method. We apply the dissection algorithm on a dataset of paintings depicting landscapes consisting of 14,916 paintings covering a period from the Western Renaissance to Contemporary art. We analyze commonly preferred composition across nations characterized by partition directions. The frequency distributions of dissection ratio were found to serve as a meaningful signature for distinct time periods, artistic styles, and individuals capturing their unique compositional characteristics and evolved smoothly and systematically over time. Network analyses based on family resemblance between dissection ratios uncover three distinguished super groups of artist and style periods clustered in time with impressionism taking a bridge function. Interestingly, diverse isms in the modern era behaved similarly with respect to proportional dissections suggesting that it is not individual isms that correspond to conventional style periods, but it is sum of the isms that compose actual style periods.

Keywords:

information theory, image analysis, art history, complex system, data science

2020 KPS Spring Meeting
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P2-st.20

Quantifying team chemistry in scientific collaboration

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Abstract:

The increasing prevalence of collaborations in scientific knowledge production raises several interesting questions: Who should I collaborate with to get a better outcome? Can we predict a team's success by the individual careers of its members? Here, we explore the relationship between the scientific impact of teams and their members building on the Q-model[1] that explains the evolution of individual impact in terms of luck and unique ability represented by a parameter Q. A non-negligible number of recurrent collaborations allow us to trace the publication histories of not only individual scientists but also teams. We find that the highest-impact paper in a team's career is randomly distributed among all the papers, implying that shared experiences do not increase the chance of success systematically and each team also has a sustained ability Q. We postulate that if there is no chemistry between the members, a team's Q is given as the geometric mean of the members' Q. We identify non-additive interactions between scientists and construct a scientist-scientist interaction network. We reveal nontrivial modular structures in the network by using stochastic blockmodels.

[1] R. Sinatra, D. Wang, P. Deville, C. Song, and A.-L. Barabási, Science 354, aaf5239 (2016).

Keywords:

science of science, team science, collective intelligence

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-st.21

Extracting hidden network from interacting system via neural network

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Abstract:

Interacting systems with underlying networks are prevalent in nature, yet revealing its structure solely from data remains as a challenging task up to date. Previous attempts to address this conundrum are often restricted to retrieve a simple, undirected and unweighted interaction graph, along with various limitations. In this study, we propose a neural network model RAIN (Relational Attentive Inference Network) to extract a most general form of interaction graph only from data of system dynamics. RAIN encodes time series data from nodes and infer its relation via unnormalized attention between each nodes, while jointly predicting the future state of the system. We demonstrate the capability of RAIN by simulated physical and epidemic systems.

Keywords:

Network, Complex systems, Statistical Inference, Neural network

2020 KPS Spring Meeting
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P2-st.22

Urban traffic dynamics through percolation analysis

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Abstract:

교통 네트워크는 사람들의 삶에 밀접한 관련이 있다. 특히 대도시같이 인구가 밀집된 지역의 교통 네트워크의 경우, 사람들의 생활 패턴과 연관되어 있다. 출근과 퇴근시간에 많은 사람들이 교통을 이용하지만, 업무시간이나 휴일의 경우 비교적 교통의 이용이 줄어든다. 시간에 따라 변하는 교통량을 고정된 도로(링크)에 가중치로 두어 특정 시간의 네트워크 특징을 볼 수 있다. 교통흐름의 원활 정도를 판단하는 매개변수(control parameter)를 이용해 퍼콜레이션 모델을 적용하였다. 교통이 원활한 클러스터 분포를 통해 퍼콜레이션 임계지수(critical exponent), τ를 측정할 수 있다. τ는 클러스터 분포의 기울기 크기를 나타내며, 값이 클수록 큰 사이즈의 클러스터 수가 빠르게 감소한다는 것을 의미한다. 임계지수 τ가 2.05일때 2차원 격자와 비슷한 특징을 가지며, '작은 세상 효과(small worldness)'를 가질수록 2.5에 가까운 값을 가진다. 시간에 따라 τ를 측정하여 교통량이 많은 출퇴근 시간과 나머지 경우의 도로 네트워크의 행동이 달라지는 것을 보았다. 고속도로, 고가도로와 같은 고속화 도로들의 실질적 활용 여부에 따라, 즉 지름길(shortcut) 역할을 할 때 네트워크가 '작은 세상 효과'를 나타내는 것을 보았다. 도로 네트워크의 연구는교통 체증 해소에 대해 도움을 줄 것이며, 이때 발생하는 경제 비용, 환경 오염을 줄이는데 영향을 줄 것이다.

Keywords:

traffic, percolation, critical exponents, phase transition

How lawmakers work in the 20th National Assembly of Korea

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Abstract:

We investigate co-sponsorship among lawmakers by applying the principal-component analysis to the bills introduced in the 20th National Assembly of Korea. The most relevant factor for co-sponsorship is their party membership, and we clearly observe a signal of a third-party system in action. To identify other factors than the party influence, we analyze how lawmakers are clustered inside each party, and the result shows significant similarity between their committee membership and co-sponsorship in case of the ruling party. In addition, by monitoring each lawmaker's similarity to the average behavior of his or her party, we have found that it begins to decrease approximately one month before the lawmaker actually changes the party membership.

Keywords:

Lawmakers, Principal-component analysis, Clustering similarity

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-st.25

Statistical Property of Price and Volatility Record Breaking Events in Korean Housing Market

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Abstract:

본 연구에서는 한국 주택 시장의 아파트 실거래 가격 데이터를 기반으로, 주택 시장의 최고가 및 변동성에 대한 통계적인 특성을 연구하였다. Bernoulli process를 기반으로 하여, 주택시장의 가격 및 변동성에 대해 평균 record-breaking 횟수 (R(n)) 및 record-breaking rate (<I(n)>)의 거동을 연구하였다. 특히 한국 주택 시장에서의 경제 사건 또는 정책 등으로 특정되어지는 기간에 따라, R(n) 및 <I(n)>의 거동이 달라짐을 발견 하였으며, 시간 및 지역에 따라 간단한 Bernoulli process 로 예측 되는 거동에서 벗어남을 발견하였다. 실데이터로 부터 얻어진 결과를 바탕으로 간단한 Bernoulli process와 구별되는 특성을 유발하는 원인에 대한 이론적 근거를 제시 하고자 한다.

Keywords:

Econophysics, Complex system

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-st.26

Ice flow sensitivity analysis of Pine Island Glacier using ISSM

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Abstract:

According to the 5th IPCC Evaluation Report (2014), if the global warming continues with the current trend, the sea level will increase by 45-82 cm (average 63 cm) in 2100, but at the September 2019 meeting, this figure increased by an average of 10 cm. It predicted that it could be up to 1.1 m high and warned that by 2050, the survival of one billion people in the oceans, polar regions and mountainous regions would be threatened.

An important factor in sea level rise is the inflow of fresh water due to sea ice in Antarctica and Greenland, and understanding of key control measures involved in predicting material balance between the two continents is becoming important. We try to verify the confidence level of the model using the Ice Sheet System Model (ISSM), one of the ice flow models. This model is the result of Larour et al.'s simulation for the error margins of the mass flux of the West Island's Pine Island Glacier glacier. It focuses on the amount of ice flow in some sections, so its accuracy may be low over time. Therefore, we want to analyze the reliability of the model by verifying the change in velocity across the glacier. Particularly, for the velocity values of several path lines in which ice sheet flows are rapidly changing, the results of the existing prediction section will be reduced by integrating the difference between the observations and the simulation predictions, using them as a new uncertainty quantification index. It shows that it is possible to reduce prediction uncertainty because the integral method displays errors that are not offset by accumulation.

Keywords:

IPCC, sea level rise, Ice Sheet System Model, ice sheet flows

2020 KPS Spring Meeting
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Causal-state reconstruction from the movement of zebrafish in response to chemical stimuli

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Abstract:

Although the movement of a fish school is a prominent example of collective behavior, relatively little is known about what an individual fish experiences from its local environment. From observed movements of zebrafish in vivo, we extract the minimal underlying model (epsilon machine) and measure its complexity by applying the causal-state splitting reconstruction algorithm. Chemical exposure increases behavioral complexity of each individual fish, but the variance decreases. This finding suggests the presence of an external stimulus can marginalize individual differences in describing collective movements.

Keywords:

Animal behavior, Time series analysis, Epsilon machine

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-st.29

Tensile elasticity of semiflexible polymers with reversible hinge defects

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Abstract:

The widely used uniform wormlike chain model appears to be inadequate to explain the complex elastic response of some important biomolecules. For example, the unexpectedly large flexibility of short ds-DNA chains is attributed to kink of hinge defects. The latter can be denatured bubbles or nicks. Hinge defects are usually reversible, opening and closing in a stochastic fashion. In order to undestand the basic statistical physics of such structures, we analyse a minimal theoretical model of a freely jointed chain with reversible hinges. A hinge can be open or closed and this change is characterised by an activation energy. At a higher level of complexity, we associate these two states of a hinge with the attachment and detachment of a virtual or real particle controlled by a chemical potential. A key question that we want to address is how the probability of opening a hinge depends on the tension of the chain. In this poster, we present exact analytic results for a chain with a few links. We propose a mean-field approximation for a chain with a large number of links. We also discuss the relevance of this model to the sharpening of the Langmuir adsorption due to Casimir forces.

Keywords:

semiflexible polymers, elasticity, DNA, defects

2020 KPS Spring Meeting
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P2-te.02

손상 및 부하의 위치가 거미줄 그물망 구조에 미치는 영향

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Abstract:

거미줄의 그물망 구조는 줄 한두 개가 끊어지거나 그물에 걸린 먹이가 있어도 전체적인 형태를 유지한다. 이러한 그물망 구조의 내구성을 탐구하기 위하여 고무줄을 이용한 방사형 거미줄 모형을 만들고, 이 모형의 각기 다른 부위를 손상 시키거나 부하를 가하며 변화를 측정하였다.

지름방향 거미줄 손상 시에는 손상 부위 (1) 양옆의 지름 장력은 증가하고 (2) 반대편의 지름 장력이 감소하며, 손상 부위보다 (3) 바깥쪽 나선의 나선 장력은 증가하고, (4) 안쪽 나선의 장력은 감소한다. 나선방향 거미줄 손상 시에는 손상 부위 (1) 안쪽과 바깥쪽의 나선 장력이 모두 증가하며, (2) 양옆의 나선 장력은 감소한다. 거미줄의 중앙에 먹이가 걸렸을 때에는 지름 장력은 증가하고 나선 장력은 감소하나, 거미줄의 주변부에 먹이가 걸리게 되면 지름과 나선 장력 모두 증가한다.

학생들도 손쉽게 구할 수 있는 고무줄과 열쇠고리를 이용하여 거미줄 모형을 제작하고, 각 부위별 손상 및 부하에 따라 모형의 반응을 즉시 확인할 수 있어 교육 도구로 활용이 기대된다.

Keywords:

거미줄, 그물망 구조

2020 KPS Spring Meeting
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P2-te.03

아두이노를 활용한 1차원 초음파 스캐너와 초음파 간섭 실험

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Abstract:

중등 교육 현장에서 파동 교육을 위한 도구로서, 초음파 송신기 및 초음파 스캐너 시스템을 제작하였다. 초음파 송신기로부터의 거리 및 방향에 따라 초음파의 세기가 어떻게 변화하는지를 리니어 액츄에이터 상에 설치된 초음파 수신기의 위치를 프로그램으로 조절해 가며 측정할 수 있도록 하였다. 수신기의 위치를 이동시키며 초음파의 세기를 측정하는 프로그램은 아두이노를 통해 구현하여 학생 수준에서 따라할 수 있도록 하였다. 이 시스템을 활용하여 하나의 초음파 송신기에 의해 공간에 형성되는 초음파를 확인한 후, 두 개의 송신기를 동시에 작동시켰을 때 나타나는 간섭 현상도 관찰하였다.

아두이노를 활용한 실험 장치 개발 과정을 경험할 수 있고, 동시에 음파의 물리적 특성 및 파동의 간섭 현상에 대해 교육할 수 있다.

Keywords:

초음파, 아두이노, 파동성

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-te.04

Proposal of the Experiments Utilizing the Transparent Screen for Understanding of the Properties of Light in the Elementary-school Science Classes

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Abstract:

빛의 직진, 반사, 굴절 등의 빛의 성질에 대한 개념은 초등과학교육에서 다루어야 하는 기본적인 개념들에 속한다. 초등학생들에게 올바른 빛의 성질을 이해시키기 위해 다수의 교수-학습 방법과 실험 방법들이 개발되고 제안되어 왔지만(김효남, 1990; 박지선과 박일우, 2009; 백성혜와 이수희, 2009; 권경필, 2011), 초등학생들은 빛의 성질에 대한 학습이 끝난 후에도 여전히 높은 비율의 학생들이 비과학적 개념이 남아있는 것으로 보고되고 있다. 이러한 이유들 중에 주된 이유로는 빛이 비가시적이어서 인지능력이 낮은 초등학생들로서는 빛의 성질을 이해하기 어렵다는 것이다.
이 연구에서는 초등과학교육에서 다루고 있는 빛의 성질을 탐구하기 위해 투명 스크린을 활용하는 방법들을 제안하고자 하였다. 현동걸 등(2016)에 의해 개발된 투명스크린은 스크린 위에서 난반사되거나 스크린의 뒷면에서 산란 투과되는 빛다발(light flux)의 단면을 관찰할 수 있는 유용한 도구이다.
이 연구에서는 빛의 전파 상태에 대한 정보를 제공하는 투명 스크린 위의 빛다발을 근거로 초등학생들이 귀납적인 추리와 조작적인 관찰이 가능하도록 설계된 실험을 제안하였다. 광원, 물체, 그림자, 거울, 렌즈 사이의 관계를 연결시켜줄 수 있는 실험적 근거는 초등학생들이 광원에서 나온 빛이 물체에 의해 그림자를 만들거나 또는 거울에 의해 반사되거나, 렌즈를 통과하는 현상들을 귀납적으로 이해하는 데 효과적인 전략이 될 수 있을 것이다.

Keywords:

투명 스크린, 빛의 성질, 빛다발, 귀납적 추리, 조작적인 관찰

2020 KPS Spring Meeting
2020-07-13 - 2020-07-15

P2-te.05

Practical Uses of Scientific Application Programs in Elementary Science Experiments

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Abstract:

The scientific application programs can be useful as auxiliary learning tools in elementary science educations. The simulation experiments about the titles of Weight of Object, Using Magnet, and Shadows and Mirrors were conducted using the scientific application program. The program of the Interactive Physics was applied to produce the nature of the spring and the properties of the springs in the title of Weight of Object. In the title of Using Magnets, the program of Vizimag had obtained various distributions of magnetic field lines in addition to the existing methods of using iron powder and small compasses. The drawing of light rays using the program of CAD had obtained the focal lengths of the concave mirrors for various variables the title of Shadows and Mirrors with addition to the theoretical formula.

Keywords:

Spring Constant, Magnetic Field, Focal Length

P2-te.06

긴 필라멘트 전구의 빛그림자 모양에 대한 불일치 상황 제시 전략에 따른 중학생들의 개념변화 특징

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Abstract:

이 연구에서는 긴 필라멘트 전구의 빛그림자 모양에 대한 개념 변화를 위해, 불일치상황을 제시하는 전략과 단계적 상황을 제시하는 전략을 사용하여 학생들의 개념변화의 특징을 분석하였다. 연구대상은 빛그림자 모양이 만들어지는 원리를 이해하지 못하는 학생, 즉 전구 2개, 전구 3개, 긴 필라멘트 전구의 빛 그림자 모양에 대해 모두 틀린 응답을 한 중학생이다. 불일치상황 제시 집단에는 긴 필라멘트 전구의 빛 그림자 모양을 관찰하게 하여 인지갈등을 유발시킨 후, 전구 2개, 전구 3개에 의한 빛그림자 모양으로 원리와 함께 과학적 개념을 설명한 후 직후검사와 지연사후검사를 하였다. 단계적 상황 제시 집단에는 전구 2개, 전구 3개, 긴 필라멘트 전구에 의한 빛 그림자 모양을 차례로 관찰하게 한 후 각 현상 관찰 후 인지갈등을 측정하였다. 그 뒤 과학적 개념을 설명한 후 직후검사와 지연사후검사를 실시하였다. 불일치 상황 제시 집단은 지연사후검사에서 긴 필라멘트 전구에 의한 빛그림자 모양에 대해서는 90.9%의 정답률을 보였지만, 그 원리를 설명할 수 있는 전구 2개, 전구 3개에 의한 빛그림자 모양에 대해서는 45.5%의 정답률을 보였다. 단계적 상황 제시 집단은 지연사후검사에서 긴 필라멘트 전구에 의한 빛그림자 모양에 대해서 뿐만 아니라, 전구 2개, 전구 3개에 의한 빛그림자 모양에 대해서 각각 95.0%의 정답률을 나타내었다. 같은 개념으로 설명할 수 있는 현상임에도 불구하고 상황에 따라 다르게 응답하는 상황의존적 반응을 보였다. 이러한 상황의존적 반응을 보이는 학생을 위해서는 단계적 불일치 상황 제시와 같은 전략이 추가적으로 필요하다고 판단된다.

Keywords: