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IWSPM2024 조직위원

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Program

Day 1 - 8.28(Wed)

Time	Session	Speaker
13:50 - 14:00	Opening	Jeong Young Park (KAIST)
	Chair	Sangmin An (JBNU)
14:15 - 14:40	Invited Speaker	Doohee Cho (Yonsei Univ.) Multiple insulating domains in a van der Waals material 1*T*-TaS_2
14:40 - 15:05		Jeongjin Kim (Pohang Accelerator Lab.) Probing the surface geometry structures for CO_2 activation
15:05 - 15:30		Zonghoon Lee (UNIST) Advances in two-dimensional materials research using aberration-corrected TEM/STEM
15:30 - 15:45	Oral	Jungsub Lee (POSTECH) Construction of cryogenic magnetic force microscopy with a piezoresistive cantilever and its application to Fe_3GaTe_2
15:45 - 16:00		Pegah Farahi Shandiz (IBS QNS) Ultra Low Temperature Optic combined STM
16:00 - 16:30	Break	
	Chair	Tae-Hwan Kim (POSTECH)
16:30 - 16:55	Invited Speaker	Changyoung Kim (SNU) Spectroscopic studies of altermagnets : spin split bands and their detection
16:55 - 17:20		Woojoo Lee (KRISS) Unlocking Quantum Phenomena by time-resolved ARPES
17:20 - 17:45		Chang Jong Kang (CNU) Nature of electronic correlations in the infinite-layer nickelate superconductors and hidden Hund's physics
17:45 - 18:00	Oral	Jinyoung Yun (POSTECH) Investigation of magnetic domain structure in the van der Waals ferromagnet Fe_4GeTe_2 using a vector-field cryogenic magnetic force microscope

Day 2 - 8.29(Thu)

Time	Session	Speaker
	Chair	Myungchul Oh (POSTECH)
09:30 - 10:10	Tutorial	Donghun Lee (Korea Univ.) Qubits, Novel Experimental Tools for Science : Introduction to Quantum Sensing
10:10 - 10:40	Coffee Break and Workshop picture	
10:40 - 11:05	Invited Speaker	Kyung-Hwan Jin (JBNU) Manipulating flat bands in 1T-transition metal dichalcogenides
11:05 - 11:30		Soo-hyon Phark (Ewha W. Univ. IBS) A qubit platform crafted atom-by-atom
11:30 - 11:45	Oral	Huijun Han (UNIST) Salt dissolution at atomic scale
11:45 - 14:00	Lunch	
	Chair	Jungdae Kim (Ulsan Univ.)
14:00 - 14:25	Invited Speaker	Young Jun Chang (Univ. of Seoul) Quantum phases in 2D chalcogenide thin films
14:25 - 14:50		Dirk Wulferding (SNU IBS) Magnetic field driven scalar-to-axial Higgs mode transition in charge-density wave compounds
14:50 - 15:15		Hyeon Han (POSTECH) Electrical control of emergent phenomena on the oxide thin film surfaces
15:15 - 15:30	Oral	Dowook Kim (POSTECH) Electric-Field-Induced Semimetal Ta_2NiSe_5 at Atomic Limit
15:30 - 16:00	Break	
16:00 - 18:00	Poster Session	
18:30 - 20:00	Banquet	

Day 3 - 8.30(Fri)

Time	Session	Speaker
	Chair	Sangjun Jeon (CAU)
09:30 - 10:10	Tutorial	Wonjun Jang (IBS QNS) Advanced Scanning Tunneling Microscopy
10:10 - 10:35	Invited Speaker	Jun Woo Choi (KIST) Voltage control of magnetism in van der Waals ferromagnetic/ferroelectric heterostructures
10:35 - 11:00		Keeseong Park (DGIST) Physical Properties of Nominal Kagome Antiferromagnet Mn_3Sn Single Crystals from Bi-flux assisted Recrystallization
11:00 - 11:15	Oral	Yeonkyu Lee (POSTECH) Investigation of vdW ferromagnets $Cr(Ge,Si)Te_3$ using a vector-field cryogenic magnetic force microscopy
11:15 - 11:30	Closing	Jeehoon Kim (POSTECH)

The 5th International Workshop on
Scanning Probe Microscopy

Abstract

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The 5th International Workshop on
Scanning Probe Microscopy

Tutorial speaker

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Qubits, Novel Experimental Tools for Science: Introduction to Quantum Sensing

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Many breakthroughs and new findings in science have been accompanied with the invention and development of novel and precise experimental tools. Qubits are not only essential components for quantum information science and technologies, but also can be used as novel experimental tools for science. In this talk, I will introduce examples of the new opportunities using qubits, especially based on solid-state spin qubits; nitrogen-vacancy (NV) centers in diamond. I will focus on basic working principle of quantum sensing and discuss quantum imaging applications at two different length scales, i.e. nanometers, and micrometers. First, the NV center is combined with a scanning probe microscope to map out stray field from magnetic materials and current flows in transport devices at nanometer scale. Second, ensemble of NV centers is combined with a wide field-of-view optical microscope to image magnetic structures at micrometer scale. I will also discuss potential applications of the qubit systems in industry, including characterization of semiconductor devices.

Keywords : qubit, quantum sensing, quantum imaging, diamond NV center

Advanced Scanning Tunneling Microscopy

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Since its invention in 1981, the scanning tunneling microscope (STM) has become an essential tool for studying nanoscience. In recent years, it has also gained significant importance in quantum physics and materials research. In this presentation, I will cover both the fundamentals and advanced techniques of STM. I will discuss the key factors that contribute to a stable STM and its design considerations. Additionally, I will explain how STM techniques can be integrated with other experimental methods, particularly in combination with optical and radio frequency (RF) techniques.

Keywords : STM, optics, RF

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Invited Speaker

IWSPM2024

Multiple insulating domains in a van der Waals material 1*T*-TaS_2

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1T-TaS2 experiences a metal-insulator transition at low temperatures by forming a charge density wave. This insulating state has long been believed to be due to charge localization. However, recent theoretical studies have shown that the vertical arrangement of the non-bonding layers determines the material's electronic structure. The dimerized configuration, which leads to the bonding-antibonding splitting, is energetically favored rather than the undimerized one [1]. Although various surface-sensitive spectroscopy techniques have confirmed this, we still lack an understanding of the stacking faults and their impact on the surface electronic structure. To address this, we used scanning tunneling microscopy (STM) to investigate the stacking-order-dependent electronic structure in a van der Waals material 1T-TaS2. Our STM results reveal that the surface is divided into three band-insulating domains with different band edges. This strongly supports the idea that the surface reconstruction puts the non-bonding (undimerized) layer underneath the surface dimerized one [2, 3]. We will discuss the possible stacking configurations to explain the electronic structures of the multiple insulating domains and compare them with previous experimental results, which have shown some inconsistency.

Keywords : STM, Mott and Band insulators, 1T-TaS_2

References

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Probing the surface geometry structures for CO_2 activation

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The chemical inertness property of carbon dioxide (CO_2) is caused by its stable molecular structure and electronic configuration, which have been considered drawbacks to reforming CO_2 molecules into energy sources. Previous studies have pointed out that CO_2 molecules are rarely bound on metal surfaces under ambient pressure conditions [1]. As a result, the physical properties of CO_2 on the surface have been mainly characterized at cryogenic temperatures in ultra-high vacuum. However, advanced surface science tools, by overcoming pressure gaps, enable the *in situ* characterization of dynamic changes in geometry structures under chemically active conditions [2]. In this talk, I will discuss several surface geometry structures for enhancing CO_2 activation probed with scanning tunneling microscopy (AP-STM) and synchrotron-based X-ray photoemission spectroscopy at elevated pressures and temperatures. Recently studied *in situ* surface observation results indicate that chemically stable CO_2 could be activated on metal surfaces depending on geometry structures under ambient pressures. For example, the vicinal Cu(997) surface structure is able to dissociate adsorbed CO_2 molecules, resulting in the formation of atomic oxygen and carbonate species at step-edge sites [3]. The atomically dispersed neighboring Sn geometries on the inert Au(111) surface also show intriguing physicochemical phenomena for CO_2 activation [4]. Exploring atomic-scale surface geometries may contribute to the development of CO_2 conversion technologies.

Keywords : Scanning tunneling microscopy, Synchrotron-based X-ray photoemission, Carbon dioxide

References

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Advances in two-dimensional materials research using aberration-corrected TEM/STEM

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Aberration-corrected TEM/STEM are indispensable tools for studying two-dimensional (2D) materials. The use of an aberration corrector allows for in-depth studies of the defects, structure, growth, and properties of atomically thin materials at atomic scale. In this context, recent advances in atomic-resolution TEM/STEM include the study of 2D materials.

Firstly, hexagonal boron nitride (hBN) is an insulating 2D material with a large bandgap. My group discovered that the twin boundary is composed of a 6′ 6′ configuration, showing conducting feature with a zero bandgap. This is a one-dimensional hBN conducting channel [1]. This presentation will address the growth of ZnO monolayers on graphene and graphene oxide substrates. My group demonstrated the atom-by-atom growth of zinc and oxygen at the preferential zigzag edge of a ZnO monolayer on graphene through in situ TEM observation [2]. I will also present the formation and analysis of the F-diamane structure, the thinnest diamond layers [3]. In addition, recent studies on 2D materials will be discussed with reference to *in situ* TEM techniques.

Keywords : aberration-corrected TEM, 2D materials, in situ TEM

References

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Spectroscopic studies of altermagnets: spin split bands and their detection

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Altermagnetism is a newly identified fundamental class of magnetism with vanishing net magnetization and time-reversal symmetry broken electronic structure. Probing the unusual electronic structure with nonrelativistic spin splitting would be a direct experimental verification of an altermagnetic phase. By combining high-quality film growth and in situ angle-resolved photoemission spectroscopy, we report the electronic structure of an altermagnetic candidate, α-MnTe. Temperature-dependent study reveals the lifting of Kramers degeneracy accompanied by a magnetic phase transition at $T_N = 267$ K with spin splitting of up to 370 meV, providing direct spectroscopic evidence for altermagnetism in MnTe[1].

While the spin-split bands are clearly observed, spin polarization of each band could not be unambiguously detected. The main reason is the existence of altermagnetic domains. The existence of such domains inevitably average out the spin signal. The most obvious and fundamental way to avoid such problem is to make a system have a single domain. We propose a way to align the domains and will show some preliminary results.

Keywords : Altermagnets, in-situ ARPES, Thin films, MnTe and CrSb,

References

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Unlocking Quantum Phenomena by time-resolved ARPES

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Unveiling the quantum phenomena in new material systems has pushed boundaries of material based science and technology, as evidenced by research on graphene-like materials. Direct visualization of electronic band structures using angle-resolved photoemission spectroscopy (ARPES) provides a powerful way of understanding such quantum effects. Nevertheless, ARPES is limited to observing electronic bands below the fermi-level at equilibrium, which restricts the observation of unoccupied states and various quasiparticle dynamics out of equilibrium. Time resolved ARPES overcomes this limitation by combining pump-probe spectroscopy with ultrafast lasers, adding greater freedom for studying quantum phenomena. In this talk, I will introduce this advanced technique and its applications on 2D quantum materials.

Nature of electronic correlations in the infinite-layer nickelate superconductors and hidden Hund's physics

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We investigate the optical properties of the normal state of the infinite-layer nickelates using density-functional theory plus dynamical mean-field theory. We find a correlated metal which exhibits substantial transfer of spectral weight to high energies relative to the density functional theory [1]. The correlations are not due to Mott physics, which would suppress the charge fluctuations and the integrated optical spectral weight as we approach a putative insulating state. Instead we find the unusual situation, that the integrated optical spectral weight decreases with doping and increases with increasing temperature. We contrast this with the coherent component of the optical conductivity, which decreases with increasing temperature as a result of a coherence-incoherence crossover. Our studies reveal that the effective crystal field splitting is dynamical and increases strongly at low frequency. This leads to a picture of a Hund's metallic state, where dynamical orbital fluctuations are visible at intermediate energies, while at low energies a Fermi surface with primarily dx2-y2 character emerges. The nickelates are thus in an intermediate position between the iron based high temperature superconductors where multiorbital Hund's physics dominates, and a one band system such as the cuprates. To capture this physics we propose a low-energy two-band model with atom centered eg states.

Keywords : Infinite-layer nickelate superconductor, hidden Hund's physics, optical conductivity

References

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Manipulating flat bands in 1T-transition metal dichalcogenides

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Strongly interacting electrons in 1T-transition metal dichalcogenides (TMD) with half-filled flat band exhibit rich phase diagrams of exotic quantum states, including Mott state, superconductivity and correlated topological orders intermixed with magnetic orders. In the first part, I'd like to introduce an approach to realize artificial hexagonal and kagome lattices by metal adsorption on a 2D Mott insulator 1T-TaS_2. Alkali, alkali-earth, and group-13 metal atoms are deposited stably in ($\sqrt{3}\times\sqrt{3}$)R30° and 2×2 TaS_2 superstructures of honeycomb- and kagome-lattice symmetries exhibiting Dirac and kagome bands, respectively. The strong electron correlation of 1T-TaS_2 drives the honeycomb and kagome systems into correlated topological phases. The band filling of these Mott Dirac and flat bands can be tuned by proper choice of adsorbates. Especially, the 2/3- or 3/4-filled system can be achieved with a proper concentration of Mg adsorbates, which can lead to unconventional superconductivity. Furthermore, I'd like to show that the systematic tuning of a trivial insulator into a Mott insulator and a Mott insulator into a correlated metallic and a pseudogap state in 1T-TaS_2 upon the surface K doping. Moving on to the second part, I'll show that novel anion-centered David star structure manifestly breaks inversion symmetry, resulting in flat bands with pronounced Rashba spin-orbit couplings. These distinctive features unlock novel possibilities and functionalities for 1T-TMDs, including the giant spin Hall effect, the emergence of Chern bands, and spin liquid that spontaneously breaks crystalline rotational symmetry. Our findings establish promising avenues for exploring emerging quantum phenomena of monolayer 1T-TMDs with this novel noncentrosymmetric structure.

Keywords : Flat band, Mott physics, DFT, charge density wave, TMDs

A qubit platform crafted atom-by-atom

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Atom-by-atom addressability, using scanning tunneling microscopy (STM) [1], has enabled control of atomic-scale quantum objects as well as bottom-up design of functional quantum devices. A recent advance in the STM equipped with electron spin resonance (ESR), combining high spatial resolution of STM and high energy resolution of ESR, has enabled magnetic resonance of individual spins on surfaces [2], which raised on-surface single spins as a promising qubit candidate at the atomic scale [3]. In this talk, I first introduce a noble qubit platform using tailored Ti nanostructures on a MgO surface, composed of a sensor and remote spins, where coherent driving and readout of single, two, and three qubits were demonstrated in an all-electrical fashion [4-7]. Second, I discuss the spin dynamics of our qubits, in regard to coupling with environments inherent in a tunnel junction, which shed light on a long-coherent quantum platform on surface.

Keywords : STM, ESR, qubit, quantum coherence

References

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Quantum phases in 2D chalcogenide thin films

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Transition metal chalcogenides (TMCs) draw huge attention because of their remarkable quantum electronic states. Single-crystalline ultrathin films of novel chalcogenide phases are readily essential for characterizing the fundamental properties of TMCs in the 2D limit. Here, we present electronic structure studies of TMC films among sulfides, selenides and tellurides, such as semiconductors ($ReSe_2$, $MoSe_2$), correlated metals ($V(S,Se)_2$ [1], $CoSe_2$ [2]), ferromagnet (Cr_2Te_3), and topological Dirac metals (CoSe $NiTe_2$). We further extend our efforts to machine-learning-aided thin film synthesis of 2D materials.[3]

Keywords : 2D material, Epitaxial growth, Quantum electronic structure, ARPES

References

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Magnetic field driven scalar-to-axial Higgs mode transition in charge-density wave compounds

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Recently, the elusive axial Higgs mode was discovered in the layered van-der-Waals material $GdTe_3$ with a unidirectional [1] charge-density wave (CDW) through Raman spectroscopy at ambient conditions [2]. Its axial nature is manifested by a CDW amplitude mode with a two-fold rotational periodicity, and requires the spontaneous breaking of two symmetries simultaneously. Yet, the exact symmetries involved in this process remain hidden.

We present a polarization-resolved comparative Raman spectroscopy study on the two sister compounds $GdTe_3$ (with low-temperature antiferromagnetic order) and $LaTe_3$ (lacking any magnetic order) at various temperatures and with applied magnetic fields. The two-fold rotational periodicity of the Higgs amplitude mode is persistently observed in both materials, ruling out spin degrees of freedom as a relevant ingredient to establish its axial nature. Remarkably, we observe a dramatic increase in Higgs-mode intensity with applied magnetic fields that is linear-in-B, together with a 90° phase shift of its two-fold periodicity with field-reversal. Our observations suggest that RTe_3 compounds realize an exotic charge-density wave phase with broken time reversal symmetry, that allow for an in-situ field-tuning of the Higgs mode's axiality.

Keywords : Charge-density waves, Higgs modes, Raman spectroscopy

References

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Electrical control of emergent phenomena on the oxide thin film surfaces

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Oxide thin films manifest emergent physical phenomena as their structure and physical properties are strongly intertwined [1-3]. The perovskite $SrRuO_3$ (SRO) is a representative strongly correlated ferromagnet, exhibiting intriguing transport phenomena such as the anomalous Hall effect (AHE) and topological Hall effect (THE). Here, I present the reversal of AHE coupled with the octahedral tilting in SRO thin films via the hydrogen spillover [1]. Additionally, the hydrogenated film exhibits a THE-like hump feature upon exposure to air, suggesting the emergence of the hump signal by the formation of mixed phases rather than skyrmions. I will further introduce a new concept of synchronized local ionic gating, allowing for the local control of electrical, magnetic, and optical properties of numerous nanostructures in a thin film [2,3]. This concept enables the formation of all-oxide metasurfaces in addition to the artificial spin ices by the interaction between electrically created nanostructures whithin the oxide layer. Thus, these studies provide novel approaches to tailor lattice symmetry and the associated physical phenomena in correlated oxide systems.

Keywords : Oxides, Thin films, Ionic gating, Metasurfaces

References

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Voltage control of magnetism in van der Waals ferromagnetic/ferroelectric heterostructures

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Recent discovery of intrinsic two-dimensional ferromagnetism in van der Waals (vdW) magnetic materials has stimulated research on the fundamental properties and spintronic applications of the materials and their heterostructures. In this investigation, we fabricated heterostructures, composed of two distinct families of vdW materials, and studied the interfacial interaction between the two materials. Specifically, we observe voltage control of magnetism in vdW ferromagnetic (FM) / ferroelectric (FE) heterostructure devices consisting of vdW FM Fe_3GeTe_2 and vdW FE α-In_2Se_3 [1]. Magneto-optical Kerr effect measurements show that gate voltages can decrease magnetic coercivity of Fe_3GeTe_2 for both positive and negative gate voltages. The change in Fe_3GeTe_2 magnetic coercivity and anisotropy is attributed to the voltage-induced strain generated from α-In_2Se_3 which is transferred to the Fe_3GeTe_2 across the vdW interface. This is confirmed by Raman spectroscopy and density functional theory calculation. Our results demonstrate an effective method to realize low-power voltage-controlled vdW spintronic devices utilizing the magnetoelectric effect in vdW FM/FE heterostructures. Furthermore, we measure the magnetic domain structure of Fe_3GeTe_2 using photoemission electron microscopy (PEEM), and explore the possibility of controlling the Fe_3GeTe_2 magnetic domains via voltage gating.

Keywords : van der Waals magnetic materials, photoemission electron microscopy

References

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Physical Properties of Nominal Kagome Antiferromagnet Mn_3Sn Single Crystals from Bi-flux assisted Recrystallization

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The antiferromagnetic (AFM) Weyl semimetal Mn_3Sn has garnered attention for its intriguing physical properties, though reproducibility of experimental results has been limited. This inconsistency is attributed to the thermodynamically stable $Mn_{3+X}Sn$ phase, resulting from Mn atom substitution at Sn sites, which obscures the intrinsic properties of pristine Mn_3Sn. We present a novel synthesis method using Bi flux to produce high-quality, stoichiometric Mn_3Sn single crystals. These crystals exhibit reproducible physical properties, such as the highest and sharpest magnetic phase transition observed to date, and novel characteristics including an additional helical phase between 250 K and 280 K. Low-temperature studies reveal a smaller Sommerfeld coefficient, suggesting a lower density of states near the Fermi level compared to off-stoichiometric $Mn_{3+X}Sn$. Differential conductance spectra and magnetoresistance results indicate the pristine samples are semimetallic. A new phase diagram of Mn_3Sn is suggested based on the physical properties. Our findings underscore the diverse physical properties of Mn_3Sn and highlight their dependence of Mn content.

Keywords : Mn_3Sn, single crystals, kagome structure, phase diagram

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Construction of cryogenic magnetic force microscopy with a piezoresistive cantilever and its application to Fe_3GaTe_2

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Magnetic Force Microscopy (MFM) has been a remarkable tool to investigate the local magnetic domains and properties in magnetic and superconducting materials. Especially in the case of van der Waals (vdW) ferromagnets, which exhibit magnetic properties layer by layer, samples are formed as flakes, and research using MFM is actively being conducted[1]. We designed and constructed a cryogenic MFM with a piezoresistive cantilever[2] to study the magnetic domain behavior of these vdW ferromagnets. We investigate the magnetic domain behavior of bulk Fe_3GaTe_2, vdW ferromagnet characterized by a Curie temperature (T_c) of 350-380 K and significant perpendicular magnetic anisotropy (PMA)[3]. Using MFM, we present the evolution of magnetic domains during cooling from Tc to 300 K, and analyze magnetic domain images along the hysteresis loop at 4.2 K. From room temperature to Tc, we observe the coexistence of stripe, bubble, and surface spike domains. In contrast, in the zero field cool state at 4.2 K, irregular stripe and enclosed ring domains predominate. The correlation between global and local magnetization suggests that the hysteretic behavior in the magnetization results from the rapid nucleation of a few stripe domains evolving into intricate dendritic patterns, a phenomenon not previously observed in other vdW systems. These findings highlight the delicate balance among interlayer exchange coupling, thermal fluctuations, and PMA in the formation of various domains in a 3D vdW system, where shape anisotropy is minimized.

Keywords : MFM, vdw ferromagnet, Fe_3GaTe_2

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Ultra Low Temperature Optic combined STM

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To study optical properties at the atomic level, we need techniques with atomic resolution. Scanning Tunneling Microscopy (STM) is ideal for this purpose, as placing the STM tip close to the sample allows for localized optical interactions. By combining STM with optical spectroscopy, we can gain precise insights into the electronic, vibrational, and photonic properties of materials. Also it can provide a comprehensive picture of energy conversion at the molecular level.

We have developed a home-built optical STM designed to operate at low temperatures (1 K) in an ultra-high vacuum (UHV) environment. Our system uses an optical fiber for applying the light and features a novel alignment method for the optical unit. To achieve the low temperature, we utilize a homebuilt Joule-Thomson refrigerator. We confirmed the system's alignment and functionality by observing electroluminescence in an Ag(111) sample using an edged gold tip.

Compared to other systems, our optical STM offers significant advantages, such as operation at 1 K, which minimizes thermal noise and enhances resolution. Additionally, we have a novel blind alignment method that is particularly beneficial since the STM head is inside the He Dewar. Our system is also designed for future upgrades, allowing the incorporation of magnetic field capabilities and electron spin resonance (ESR) functionalities, further expanding its experimental potential.

Keywords : STM, luminescence , optic combined STM, Low temperature

Investigation of magnetic domain structure in the van der Waals ferromagnet Fe_4GeTe_2 using a vector-field cryogenic magnetic force microscope

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Various Van der Waals ferromagnetic materials are gaining attention due to their diverse potential applications, particularly as heterostructure devices or spintronic devices. These Van der Waals ferromagnets are influenced by the dimensionality of the system. Although most studies on magnetic domain structures refer to 2D systems, where properties are determined by the interplay between perpendicular magnetic anisotropy (PMA) and shape anisotropy (SMA), studies in bulk provide a platform for understanding the role of magnetocrystalline anisotropy and interlayer coupling while minimizing the impact of SMA. Among the Fe_xGeTe2 compounds, Fe_3GeTe_2 [1], with its PMA, displays an out-of-plane stripe-domain phase, while Fe_5GeTe_2, with weak PMA, exhibits labyrinth-type domains [2]. On the other hand, magnetic domain visualization in F4GT has yet to be performed. Here, we present an investigation of the magnetic domain structure of F4GT single crystals utilizing a cryogenic vector-field magnetic force microscope (MFM) [3].

Keywords : van der Waals ferromagnet, MFM

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Salt dissolution at atomic scale

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Among the simplest and well-established ion-related reactions is salt dissolution in water, where the positive enthalpy change competes with the entropy increase. Despite its simplicity, the microscopic understanding of this process has been limited to theoretical approaches due to the statistical ensemble of aqueous solutions. Here, we demonstrate the salt dissolution by controlling a single water molecule (H_2O) at an under-coordinated site of a sodium chloride (NaCl) [1]. Precise manipulation of H_2O molecules on NaCl provides the insight into ion-water interactions and the surface dynamics of the molecules, which are responsible for the selective dissolution of anions in real space. Our results indicate that the polarizability difference between Na^+ and Cl^- ions contributes to the bond characteristic and cleavage of the ionic bonds by one H_2O molecule. The water dipole attracts an electron cloud of Cl^- ion engaging in the ionic bonds, weakening the bond strength and facilitating the dissolution of the Cl^- ion. This study provides the microscopic mechanism of the salt dissolution.

Keywords : STM, Salt dissolution, Polarizability

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Electric-Field-Induced Semimetal Ta_2NiSe_5 at Atomic Limit

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The tunability of band gaps in 2D materials enables the exploration of diverse quantum phases and the development of advanced electronic devices. Due to their reduced dimensionality and altered dielectric environments, 2D van der Waals (vdW) materials are highly sensitive to external perturbations such as thickness [1-5]. Ta_2NiSe_5, a potential excitonic insulator [6-8], transitions to a semimetallic phase under external influences such as electron doping or pressure, though these transitions are typically studied in bulk. This study investigates the atomic structure and electronic properties of monolayer to tetralayer Ta_2NiSe_5 in an electric-field-induced semimetallic phase using low-temperature scanning tunneling microscopy and spectroscopy. Our findings reveal that semimetallic Ta_2NiSe_5 retains its monoclinic lattice distortion, differing from the orthorhombic structure observed in the high-temperature phase. Additionally, a progressive energy shift in the density of states with increasing layer thickness is observed, caused by charge transfer between the bottom layer of Ta_2NiSe_5 and the substrate. These insights into band gap tunability in 2D vdW materials highlight their potential for innovative electronic device applications based on adjustable electronic properties.

Keywords : scanning tunneling microscopy, van der Waals material, excitonic insulator, semimetal, Ta_2NiSe_5

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Investigation of vdW ferromagnets Cr(Ge,Si)Te_3 using a vector-field cryogenic magnetic force microscopy

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The advancement of magnetic data storage and spintronic devices hinges on the sophisticated manipulation of magnetic domain configurations. The ability to customize the shapes and sizes of magnetic domains is crucial for optimizing device performance. This study explores materials with inherent anisotropies or complex internal interactions, highlighting their capacity to support various domain phases. These phases can be selectively engineered through external parameters, such as temperature and magnetic field adjustments. Utilizing a vector field cryogenic magnetic fore microscopy (MFM) [1], our research provides detailed visualizations of magnetic anisotropy within magnetic materials, specifically $CrSiTe_3$ and $CrGeTe_3$ [2]. Our experiments reveal the capability to modulate both the overarching and localized domain geometries by precise manipulation of external magnetic fields. Significantly, we observe the coexistence of striped and spike-like magnetic domains, showcasing the dynamic control achievable in these systems. The implications of our findings are significant, offering a pathway to the deliberate design of magnetic domains tailored for advanced spintronics applications. This research not only enriches our understanding of magnetic material properties but also paves the way for innovative developments in the spintronics device engineering.

Keywords : MFM, vdW ferromagnet, magnetic anisotropy

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The 5th International Workshop on
Scanning Probe Microscopy

Poster

IWSPM2024

No.	Speaker
P1	Byeongin Lee (Yonsei Univ.) Charge-Ordered States Stabilized by Impurities on Black Phosphorus
P2	Chanjong Haam (Korea Univ.) Imaging spin waves using single spin scanning magnetometer based on diamond NV center
P3	Chanyoung Lee (POSTECH) Penetration Depth in Superconducting NbTi and NbTiN Thin Films Grown at Room Temperature
P4	Cheolhwan Yoon (UNIST) One-dimensional growth of water on KCl
P5	Deokkyu Na (KAIST) In Situ Observation of The Chlorine Evolution Reaction at Platinum porphyrin on HOPG with EC-STM
P6	Dongyeop Yoo (UNIST) Novel method for measuring dielectric constant of ultra-thin insulating film
P7	Gahee Lee (Chung-Ang Univ.) Compact Sample Stage for Scanning Tunneling Microscopy to Measure Flakes of Two-Dimensional Materials
P8	Hunyoung Cho (KAIST) Nanotribology under gas conditions investigated with variable-pressure atomic force microscope
P9	Hwi Je Woo (KRISS) Nano Imaging of Ultrafast Dynamics in 2-Dimensional Materials with s-SNOM
P10	Jaebeom Han (POSTECH) The role of supports in catalytic activity and selectivity of Pt single atom catalysts under CO_2 hydrogenation
P11	Jaehoon Sah (JBNU) Mechanical response of a quartz tuning fork interacted by a scanning electron microscope

No.	Speaker
P12	Jiwon Park (KAIST) *In situ* observations of indium oxide segregation on the bimetallic $Pd_{50}In_{50}$(111) alloy surface using AP-STM and AP-XPS
P13	Jiyoon Lee (Ewha Womans Univ.) Optics Alignment of Optics Combined Low Temperature Scanning Tunneling Microscopy in 1K
P14	Jonggeun Hwang (POSTECH) Quasi-high vacuum tip-enhanced photoluminescence (QHV-TEPL): new techniques for nanocavity spectroscopy
P15	Junho Bang (Yonsei Univ.) Coulomb blockade phenomena in metal nanoislands on a two-dimensional semiconductor
P16	Minseok Kim (SKKU) Precision Manipulation and Topographic Characterization of Au Nanoparticles Using Atomic Force Microscopy for Nanostructure Fabrication
P17	Namryeol Kim (SKKU) Negative pressure-induced strain engineering of the graphene drum head placed on the silicon nitride grid hole
P18	Sangmin Ji (SKKU) Home-built Scattering Type Near-field Scanning Optical Microscope for Nano Imaging and Spectroscopy (s-NSOM)
P19	Sungjin Jang (Korea Univ.) Nanoscale magnetometry using various quantum sensing protocols based on the NV center
P20	Taesun Yun (JBNU) Direct synthesized lead halide perovskite nanowire by using a pipette-combined atomic force microscope with increasing stability by coating Parylene-C
P21	Yeongseo Kim (JBNU) Fabrication enhancement for versatile application of photoresist structures in 2D material-based devices
P22	Yeonju Bae (JBNU) Nanoscale patterning of CNTs using a pipette-combined QTF-AFM with in situ Raman Spectroscopy

Charge-Ordered States Stabilized by Impurities on Black Phosphorus

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Broken symmetry states, such as charge order, often emerge during a phase transition, which may lead to changes in electronic or magnetic properties. In strongly correlated systems, charge-ordered states manifest in many forms, including charge density waves, polaronic lattices, and Wigner crystals. Conventional approaches for inducing charge ordering are lowering a temperature, applying high pressure, and adjusting carrier concentration, which cannot be controlled locally. Here, we employ scanning tunneling microscopy and spectroscopy to visualize charge-ordered states near surface impurities in a two-dimensional semiconductor. By locally manipulating the charge state of a surface impurity, we can control the charge-ordered state in its vicinity. Our results reveal that charge ordering pinned by a negatively charged impurity remains stable until the impurity becomes neutral, at which point the ordering abruptly melts. This work offers new insights into the behavior of charge ordering in semiconductor materials.

Imaging spin waves using single spin scanning magnetometer based on diamond NV center

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Spin waves are collective excitations of the spins of electrons in magnetic materials. They can carry information and energy without the movement of electric charge. We aim to elucidate the magnetic characteristics of Spin wave utilizing the quantum mechanical properties of NV diamond, which offers a resolution of 10 nm and a sensitivity of ~nT at room temperature. NV diamond is connected to the end of a tuning fork and integrated with Confocal microscopy, enabling us to employ quantum sensing techniques such as Electron Spin Resonance (ESR), Echo, and Rabi oscillation to extract the magnetic features of spin wave properties spin waves are gaining attention as a next-generation method of information transmission. To understand their characteristics, we used a Yttrium Iron Garnet (YIG) sample with low damping. We measured the patterns created by the interaction between spin waves and electromagnetic waves using NV centers. Additionally, we wanted to investigate the characteristics of Surface Acoustic Waves (SAWs), so we placed a ferromagnetic material, Nickel, on a piezoelectric material substrate, namely Lithium Niobate (LiNbO3), to measure the interaction between SAWs and magnons. We are conducting research using NV centers to study the magnetic phenomena induced by spin waves and SAWs.

Keywords : Spin wave, Magnons, NV center, Scanning magnetometry

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Penetration Depth in Superconducting NbTi and NbTiN Thin Films Grown at Room Temperature

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Low-temperature superconductors, such as metallic Nb and transition metal nitrides (TMN), are crucial in cryogenic superconducting devices. Material selection for technological applications hinges on properties such as critical fields and penetration depth. The penetration depth is a fundamental property directly related to the performance of superconducting materials. This study reports on the penetration depth of NbTi and NbTiN films measured using a home-built magnetic force microscope (MFM) [1]. NbTi is known for its high critical magnetic field and mechanical robustness, and NbTiN is notable for having the highest superconducting critical temperature among TMNs. Our results enhance the understanding of fundamental superconducting parameters, such as λ and ξ, in nitride thin films [2], with applications ranging from resonant accelerator cavities to Josephson junctions and radiation detectors. Furthermore, NbTi and NbTiN thin films grown at room temperature show superconducting parameters comparable or superior to metallic Nb [3], suggests promising potential for cryogenic applications.

Keywords : penetration depth , NbTi, NbTiN, thin film, magnetic force microscope

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One-dimensional growth of water on KCl

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Water-solid interactions determine the adsorption structure of water, which is attributed to lattice parameter of the substrate and bond strength between water and the substrate. Adsorbed water tends to form closed-loop hydrogen bonding networks like bulk ice [1], but it has been reported to form linear structures on certain substrates [2-3]. Here, we report the water adsorption on a KCl with high-resolution images using low-temperature scanning tunneling microscope (LT-STM). Instead of a closed-loop hydrogen bonding network, water molecules spontaneously assembled into a one-dimensional chain on the KCl (100) surface. We manipulated single water molecules in a row to create an artificial chain. The addition of a single water molecule caused the chain to extend by the length of K-Cl distance (3.13 Å). The formation of one-dimensional water chain is not only influenced by long hydrogen bonds due to the lattice parameter of underlying KCl, but also by the weak adsorption of water molecules on the KCl (100) surface. The details of the water adsorption structure can be described with the result of density functional theory (DFT) calculations. The adsorption energy of a linear water tetramer (-1.88 eV) is estimated lower than that of a cyclic tetramer (-1.69 eV) on the KCl (100). The O-H direction of water was determined from the depressed features in the STM topography of the ends of the water chain and the calculated charge density difference map.

Keywords : STM, DFT, KCl film, 1D water-chain

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In Situ Observation of The Chlorine Evolution Reaction at Platinum porphyrin on HOPG with EC-STM

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Chlorine production is a vital process with many applications in industries essential to modern life, such as water treatment, chemical manufacturing, and various other sectors. Therefore, research on chlorine evolution reaction (CER) is essential for advancing sustainable and efficient chlorine production. However, current CER catalysts suffer from a significant drawback - the concurrent oxygen generation during the CER process [1]. Single-atom catalysts have been focused on as the solution to enhance Cl_2 production selectivity in the condition of the chlor-alkali process. Among these catalysts, metalloporphyrin emerges as an ideally atomic dispersed system that has undergone extensive research. Previous studies have demonstrated that the Pt-N4 site within the platinum octaethyl porphyrin (PtOEP) molecule acts as a single-atom catalyst for the chlorine evolution reaction [2]. However, it still needs to be fully understood about the model system of porphyrin catalysts, including morphological analysis.

Herein, we utilized electrochemical scanning tunneling microscopy (EC-STM) [3,4,5] to reveal the morphological change of PtOEP adlayer during CER. Electrochemical characteristics were analyzed using a linear sweep voltammogram (LSV) and the iodometric titration method. As the reaction proceeds, more unsuspected nanoparticles appear on the PtOEP adlayer, evidence of the reaction. Interestingly, the CER reaction was significantly different depending on the presence of the central metal. After several validation processes, we reiterate our confident confirmation that the central metal atom, Pt, was indeed the active site of the reaction. Moreover, we also obtained the molecular image that the chlorine anion (Cl-) was adsorbed on the platinum atoms, providing a visual confirmation of our findings.

Keywords : Electrochemical scanning probe microscopy (ECSPM), Metalloporphyrin, Chlorine Evolution Reaction (CER), Single Atom Catalyst

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Novel method for measuring dielectric constant of ultra-thin insulating film

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Over the last few decades, the size of electronics has decreased to a few nanometers. The electrical properties of the device are dependent on the vertical dimension of a dielectric material [1], which requires the exact value of its dielectric constant. However, the dielectric constant of ultrathin dielectric materials cannot be obtained from conventional measurements of refractive index [2] or binding energy [3]. These methods are vulnerable to surface roughness and surface pollution in ambient conditions. Here, we introduce a novel method to measure the dielectric constant using scanning tunneling microscope (STM) in UHV condition. The shifts of image potential states on the ultrathin insulating films are used to calculate the dielectric constant. Using this method, we measured the dielectric constant of a monolayer NaBr film on the Au(100) substrate. Therefore, the dielectric constant of the monolayer NaBr film was estimated as 2.14, which was about one third of bulk value 6.34. The lower dielectric constant of the ultrathin film is attributed to the larger effect of the dead layer.

Keywords : STM, Dielectric constant, Size effect

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Compact Sample Stage for Scanning Tunneling Microscopy to Measure Flakes of Two-Dimensional Materials

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Mechanical exfoliation is one of the primary methods for preparing isolated 2D materials [1]. However, this approach faces inherent limitations that prevent the attainment of sample sizes larger than a few tens of micrometers [1], and to locate and measure such small sample directly with Scanning tunneling microscope (STM) remain a significant challenge [2]. Here we report a newly developed sample stage with an integrated precise micron-level position sensor to facilitate research on flakes of 2D materials using a STM in low-temperature environments. The position sensor utilizes capacitance variation between the moving and stationary parts of the double-pocket sample stage, enabling precise detection of the entire range of movement controlled by the piezoelectric actuators. The incorporation of double sample pockets allows for the mounting of two samples, enabling in-situ conditioning of probe tip and precise navigation from a reference sample to the micro-sized 2D flakes. This streamlined process facilitates diverse investigations into the electrical properties of 2D materials.

Keywords : Scanning tunneling microscope, 2D materials, Micron-level position sensor.

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Nanotribology under gas conditions investigated with variable-pressure atomic force microscope

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The atomic force microscope (AFM) is a widely utilized tool for investigating diverse surface properties, including friction, adhesion, topography, and conductance. While conventional AFM setups are typically designed for operation under ambient conditions, our specialized variable-pressure AFM (VP-AFM) instrument has been engineered to facilitate experiments spanning the entire range from ultra-high vacuum (UHV) conditions to 1 atm [1,2]. The unique design of our VP-AFM chamber allows for controlled gas environments, enabling the study of nanotribology under various gas conditions.

To explore the impact of water on tribological properties, we conducted friction measurements on Au(111) surface with the partial pressure of water vapor, ranging from UHV (1.0×10^{-10} mbar) to 1 mbar. Under low vapor pressure conditions, the relationship between friction and normal load adhered to the conventional JKR-DMT model. However, at higher water vapor pressures, friction decreased at low loads, indicating the lubricating effect of water layers. Under higher loads at low humidity conditions, stress distribution became ineffective [3], leading to increased lateral forces due to the AFM tip penetrating the water layer, followed by plastic deformation of the Au(111) surface. Our VP-AFM studies indicates that the presence of water layers effectively passivate the surface, suppressing the plastic deformation, which is the origin of water-induced lubrication, observed in the everyday life. Molecular dynamics simulation indicated that this increase of onset point of plastic deformation comes from dissipation of energy by breaking hydrogen-bond network.

Furthermore, in order to understand the effect of hydration process on the nanomechanical properties, we investigated changes in friction and topography of palladium metallic nanowires under varying the pressure of hydrogen using VP-AFM. During hydrogen absorption, the height increased due to an expansion in lattice constant associated with the phase transition to α-phase palladium. Consequently, friction also increased, as an expanded lattice constant typically results in decreased modulus. Additionally, we performed ambient-pressure X-ray photoelectron spectroscopy (AP-XPS) to observe how spectral peaks changed during the phase transition of palladium. This reversible change of height and friction properties can be revealed only with VP-AFM, emphasizing the importance of in-situ tribological measurement.

Keywords : variable-pressure atomic force microscope, friction, palladium hydride, deformation

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Nano Imaging of Ultrafast Dynamics in 2-Dimensional Materials with s-SNOM

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The elucidation of ultrafast excitonic dynamics in two-dimensional (2D) materials is pi votal for unlocking their potential in next-generation optoelectronic devices. This study harnesses the capabilities of Photo-induced Force Microscopy (PiFM) and scattering-ty pe Scanning Near-field Optical Microscopy (s-SNOM) to spatially resolve the ultrafast dynamics of excitons in 2D materials, especially transition metal dichalcogenides (TM D). Our objective was to directly visualize and understand the behavior of excitons, in cluding their generation, recombination, and transport processes, under ultrafast time sc ales. Utilizing PiFM and s-SNOM, we achieved nanometer spatial resolution and few picose conds temporal precision, enabling the observation of exciton dynamics with unparallel ed detail. The methods involved synchronizing ultrafast laser pulses with the imaging capabilities of PiFM and s-SNOM to capture the transient states of excitons as they e volve in real-time. Our results reveal intricate patterns of exciton dynamics, including their spatial distribution, diffusion, and the influence of material heterogeneities on thei r behavior. Notably, we observed significant variations in exciton lifetimes attributed to various de fect regions of TMD. The study also uncovers the role of defects, grain boundaries, a nd substrate effects in modulating exciton dynamics. The findings from this research u nderscore the importance of nano-imaging techniques like PiFM and s-SNOM in advan cing our understanding of ultrafast processes in 2D materials. By providing a detailed view of exciton dynamics, our study contributes to the foundational knowledge require d for engineering 2D materials with tailored optoelectronic properties, paving the way for innovative applications in solar energy conversion, light-emitting diodes, and photo detectors

Keywords : s-SNOM, Pump-probe, Exciton, Carrier, Dynamics

The role of supports in catalytic activity and selectivity of Pt single atom catalysts under CO^2 hydrogenation

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Single atom catalysts (SACs) have been researched as heterogeneous catalysts due to their theoretically higher atomic efficiency and selectivity compared to nanoparticle catalysts. However, SACs face a significant challenge in stability, tending to agglomerate under high-temperature or reductive reaction conditions. To develop catalysts that can control sintering phenomenon, the properties of the support material for the single atoms are critically important. Commonly used support materials include carbon-based substances (such as carbon nanotubes and carbon nanofibers) [1] and metal oxides. Among metal oxides, reducible oxides known for their ability to transfer oxygen are effective in forming high-loading SACs [2].

Herein, we aim to synthesize SACs supported on carbon nanotubes (CNTs) and reducible oxides like Co_3O_4 and CeO_2. We examined the differences in reactivity and selectivity across different temperature ranges for CO2 hydrogenation reactions using these catalysts. We will then analyze the changes in the surface properties of these catalysts under CO_2 hydrogenation reaction conditions using X-ray photoelectron spectroscopy (XPS). This analysis will provide insights into the mechanisms at play and guide the development of more stable and efficient SACs for industrial applications.

Keywords : Heterogeneous catalyst, Single atom catalyst, X-ray photoelectron spectroscopy

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Mechanical response of a quartz tuning fork interacted by a scanning electron microscope

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When used as a probe in Atomic Force Microscopy (AFM), the Quartz Tuning Fork (QTF) offers advantages in constructing highly sensitive force sensors and straightforward electrical detection systems, making it suitable for use in diverse environments. This has been made possible by the unique physical characteristics of the quartz tuning fork [1-3]. To apply these advantages in Scanning Electron Microscopy (SEM), it is necessary to investigate how QTF components behave in the environment of the SEM chamber, where vacuum and electron beams are emitted. The 32 kHz commercial QTF used in the experiment is sealed with a cap to ensure stable resonance frequency and amplitude, and the interior of the cap is filled with nitrogen. However, removing this cap exposes the QTF to atmospheric conditions, resulting in changes in resonance frequency and amplitude. This indicates that the characteristics of the QTF may also change in the SEM environment where vacuum and electron beams are emitted. To investigate these changes, we fabricated two types of QTF components with the cap removed. They are respectively QTF components with gold-coated borosilicate tip and bare QTF components without tip. These two QTF components were each installed inside the chamber of a SEM, with a focus on observing the behavior of the QTF devices in the environment where vacuum and electron beams are emitted. Through this, we were able to observe how the resonance frequency and quality factor of the QTF varied in different environments: atmospheric pressure, vacuum conditions, and during electron beam emission. In particular, we observed a significant increase in the quality factor in vacuum compared to atmospheric pressure. Furthermore, we also measured changes in amplitude values during electron beam emission. This indicates that understanding the mechanism of QTF components in vacuum and electron beam emission environments is crucial in the context of a hybrid SEM system combining QTF-AFM technology.

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In situ observations of indium oxide segregation on the bimetallic $Pd_{50}In_{50}$(111) alloy surface using AP-STM and AP-XPS

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Selective surface segregation and the formation of interfacial metal-oxide nanostructures can induce unusual surface properties on bimetallic surfaces. Previous studies that deal with FeO_{1-x}/Pt(111) and bimetallic Pt_3Ni(111) show that reducible oxides at the metal-oxide interface play a critical role in active sites under working conditions for enhancing catalytic activity [1,2]. A similar diluted bimetallic alloy, the Pd-In material, has recently been reported as a superior catalyst for CO_2 activation [3]. However, their surface geometries and electronic structures are still uncertain at ambient pressures. In this study, we exhibit the formation of Pd-InO_x interfacial nanostructures on the $Pd_{50}In_{50}$(111) model surface using ambient pressure scanning tunneling microscopy (AP-STM). The clean Pd-In bimetallic surface in ultra-high vacuum (UHV) is abruptly modified due to the upward segregation of indium oxide at elevated O_2(g) pressures, resulting in the selective formation of Pd-InO_x or In_2O_3-enriched surfaces. Synchrotron-based ambient pressure X-ray photoelectron spectroscopy (AP-XPS) results also indicate the correlation between surface modifications and chemical binding properties. Based on our *in situ* observations, we expect that the bimetallic alloy interfacial structures may have synergistic effects to enhance catalytic CO_2 activation under mild conditions.

Keywords : surface science, scanning tunneling microscopy, pressure gap, metal oxide, bimetallic alloys

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Optics Alignment of Optics Combined Low Temperature Scanning Tunneling Microscopy in 1K

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Studying the optical properties of materials, whether in bulk or as 2D structures, enhances our understanding of quantum effects, band structures, and light-matter interactions such as absorption, reflection, and light emission. Combining optical spectroscopy with scanning tunneling microscopy (STM) can provide deeper insights into electronic properties and dynamic processes at the nanoscale. Most STM setups combined with optics use a bottom-loading structure for optical alignment. Here, we introduce a method for optical alignment in a top-loading STM setup. To align the optical focal point precisely at the STM tip, we employed 3-axis piezo motors combined with a fiber and a homebuilt collimator. Using temperature variations induced by the thermal effect of the laser, we successfully aligned the focal point at the tip-sample junction. Utilizing this optical alignment technique, we observed light emission from the Ag(111) surface at 1 K, attributed to the electroluminescence process.

Quasi-high vacuum tip-enhanced photoluminescence (QHV-TEPL): new techniques for nanocavity spectroscopy

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Quartz tuning forks (QTF) has a high quality factor (Q-factor) and is widely used as a sensor for atomic force microscopy (AFM), scanning near-field optical microscopy (SNOM), etc. However, inevitable interactions with air greatly reduce the Q-factor of QTF, and the minimum measurable force sensitivity is also much lowered. Various methods are suggested to restore the lowered Q-factor, such as a mass balance [1] and active Q [2], but the restored Q-factor did not reach the vacuum level. Here, we developed an unprecedented new nano-spectroscopy technique named quasi-high vacuum tip-enhanced photoluminescence (QHV-TEPL) that enables simultaneous imaging of surface potential and photoluminescence with vacuum level sensitivity by preventing the direct interaction of the sensor with air. The uncapped QTF is used as a self-vibrating sensor, and a gold etching probe is attached to one of the electrodes, then the tunneling current between the probe and the metal substrate can be measured with the same sensitivity as a vacuum-level QTF.

Keywords : TERS, TEPL, QTF

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Coulomb blockade phenomena in metal nanoislands on a two-dimensional semiconductor

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Nano-sized metal islands on a semiconductor surface shows eccentric behaviors of electrons due to the limitation of the size and the heterojunction formed between the island and the surface. The interests of quantum dots, or artificial atoms, have been highlighted of late decades, as the realization of the confined quantum states with their unique properties. With the attentions many of interpretations reveal the behaviors of quantum dots on different materials, such as the Coulomb blockade (CB) effect. In an atomic-scale sized metal island, electrons in island causes CB, creating a strong Coulomb repulsion that blocks tunneling current through the island. CB is closely related to the charge of the metal islands, which is highly related to the electronic features of quantum dots. However, the detailed observations of its behaviors, have not been. Here, we visualize the CB phenomena at the indium nanoislands on two-dimensional semiconductor black phosphorus (BP). Using scanning tunneling microscopy and spectroscopy, the distinct behaviors of CB resolved spatially. Further, the continuous CB features are exhibitied outside of the nanoislands, which is related to the effective gating on nanoislands.

Keywords : STM, Coulomb blockade, Metal nanoisland, 2D semiconductor

Precision Manipulation and Topographic Characterization of Au Nanoparticles Using Atomic Force Microscopy for Nanostructure Fabrication

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This study explores the manipulation of gold nanoparticles (Au NPs) using atomic force microscopy (AFM) to fabricate and characterize specific shapes and patterns. By employing noncontact mode (NCM) AFM, we successfully maneuvered individual Au NPs to create predefined geometries and textual designs on a substrate. The resulting topographic images, captured through NCM AFM, reveal detailed representations of the manipulated nanoparticles, showcasing the precision and effectiveness of the technique in nanoparticle patterning. This approach highlights the potential of AFM-based manipulation for advanced nanofabrication applications, providing a powerful tool for designing and investigating nanoscale structures.

Keywords : AFM, Au nanoparticle, manipulation

Negative pressure-induced strain engineering of the graphene drum head placed on the silicon nitride grid hole

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The exceptional mechanical properties of graphene have attracted substantial interest. To the diverse applications of graphene, a comprehensive investigation of its mechanical characteristics is essential. Recently, many studies investigating the properties of graphene under vertical pressure mainly use methods using microcavities covered by graphene [1-3]. These studies, the pressure could not be adjusted directly and may not be accurate because it is only determined by the difference between pressures inside and outside the cavity.

In this study, we fabricated a silicon nitride grid by etching silicon nitride and silicon with CF_4 gas and KOH solution. Subsequently, graphene was transferred onto the grid to form a graphene membrane and pressure was applied directly to the graphene membrane by attaching it over a small hole on top of a variable-pressure chamber. This method facilitates control and clear definition of the pressure exerted on the membrane. we systematically regulated the pressure on the membrane and investigated the mechanical properties of graphene under various pressure conditions.

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Home-built Scattering Type Near-field Scanning Optical Microscope for Nano Imaging and Spectroscopy (s-NSOM)

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s-NSOM is based on AFM, it can measure and analyze the near-field. s-NSOM uses a tip like AFM, and a probe scans after approaching the sample surface up to 20 nm. At this time, the topography information (surface) is obtained through the interaction of the tip and surface. At the same time, the optical signal is scattered by a tip and collected by a photodetector. s-NSOM measures both topographic and optical images simultaneously. We constructed home-built s-NSOM using commercial AFM. Furthermore, Michelson interferometry detection method (i.e. Pseudo heterodyne detection) is applied on home-built s-NSOM that depresses undesired background noise of the optical signal. And then, In addition, by installing a Galvano mirror to focus the laser more precisely on the tip apex, the near-field signal is enhanced. Finally, tip enhanced PL and TERS were attempted using a metal-coated tip and a spectrometer, and optimization was carried out by adjusting various conditions.

Keywords : AFM, s-NSOM, Pseudo heterodyne detection

Nanoscale magnetometry using various quantum sensing protocols based on the NV center

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Sensors with nanoscale spatial resolution and high sensitivity are becoming more crucial of many demands on microscopic scale of research field and industries recently. Sensors with nanoscale spatial resolution and high sensitivity are becoming more crucial because of many demands on microscopic scale of research field and industries recently. Nitrogen-vacancy (NV) center in diamond is a quantum sensor suitable for highly sensitive magnetic field detection. Integrating this spin qubit with a scanning probe enables the acquisition of nanoscale real-space magnetic field images, with various scanning techniques. Here we showcase various images of magnetic fields from different physical quantities like electrical current profiles and magnetization measured by NV center [1]. Also, comparison between conventional magnetometry and gradiometry will be provided [2]. These results underscore the suitability of single NV magnetometry technique as a technique for quantum magnetometry and its efficacy in nanoscale imaging with high performance.

Keywords : AFM, Nitrogen-vacancy center, Gradiometry

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Direct synthesized lead halide perovskite nanowire by using a pipette-combined atomic force microscope with increasing stability by coating Parylene-C

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Halide perovskites have been the subject of extensive research in the context of LEDs, solar cells, and laser applications, largely due to their high absorption coefficient and exceptional color purity with narrow full width at half maximum (FWHM) [1]. In particular, nano-microwires (NWs) with a one-dimensional structure have recently been the subject of considerable interest in the context of halide perovskite applications. This is due to their capacity to restrict the diffusion of carriers in a single direction, thereby enhancing the overall performance of the device [2]. Nevertheless, the technology to form NWs arrays still requires further investigation. Additionally, halide perovskite is an ionic compound, which renders it susceptible to degradation under ambient conditions. To address these challenges, numerous studies have been undertaken, including the coating of organic materials on halide perovskite and metal doping [3]. In this study, we present the in situ synthesis of $CH_3NH_3PbI_3$ NMs by micropipette-based QTF-AFM and investigate the mechanism of stability enhancement of halide perovskite through the coating of parylene-C, a type of organic material.

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Fabrication enhancement for versatile application of photoresist structures in 2D material-based devices

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The analysis of 2D semiconductor properties has become increasingly significant due to their potential applications in next-generation Semiconductor devices. [1] Recent trends focus on diversifying the understanding and manipulation of these materials to know another potential. A variety of approaches have been explored to investigate devices composed of various 2D materials, such as Molybdenum disulfide or Tungsten disulfide, aiming to enhance Micro Electro Mechanical Systems (MEMS) structure for examining diverse electrical, optical, and mechanical properties. [2,3] Utilizing photoresist-based fabrication, it is possible to create three-dimensional structures capable of withstanding strain, which facilitates the subsequent deposition of metals and fabrication of other structures. To assess the structural stability, strain was applied to clamped few-layer MoS2, and Raman spectroscopy was employed to observe peak shifts. By leveraging characteristics of PR to deposit Cr and Au will facilitate the examination of the electrical properties of these 2D structures.

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Nanoscale patterning of CNTs using a pipette-combined QTF-AFM with in situ Raman Spectroscopy

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Advancements in photolithography, electron beam lithography, and dip-pen lithography have significantly improved nanoscale patterning and printing technologies. However, each of these techniques has its own limitations. Photolithography is restricted by diffraction issues, which limit resolution and make very fine patterning challenging. Electron beam lithography requires high voltages, leading to substantial costs for equipment installation and operation, making it less suitable for commercial large-scale production. Dip-pen lithography faces issues such as tip damage due to contact with the surface during patterning and difficulties with performing multiple prints. These drawbacks particularly hinder the accuracy and efficiency of nanoscale patterning [1]. To address these technical limitations, this study has utilized a micropipette-combined QTF-AFM setup to precisely pattern CNTs into nanowire structures on a surface [2],[3]. This approach eliminates the need for high voltage, minimizes tip damage, and resolves diffraction issues. Additionally, by integrating the micropipette-combined QTF-AFM setup with an in-situ Raman spectroscopy setup, the Raman spectrum of the nanowires can be immediately obtained right after patterning. Raman spectroscopy is an analytical tool that allows for the real-time examination of a material's chemical composition and structural characteristics by analyzing the molecular vibrational modes of the sample. This method measures the vibrations of specific chemical bonds to generate a unique spectrum for the material, providing detailed information about its structural and chemical properties [4]. This approach is particularly advantageous for patterning and performing Raman measurements on materials with short lifetimes. The results of this study enhance the precision of nanoscale patterning technologies and improve research efficiency by enabling in-situ Raman measurements of the patterned CNTs.

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