SW2 : 산화물 기반 미래 신소재 연구회 심포지엄

SW2-1 | MIM capacitors and interface properties

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The development of DRAM capacitors has progressed significantly, with the evolution from poly-Si to TiN electrodes and from SiO_2 to ZrO_2-based multilayers for dielectrics. This has helped suppress the formation of low-k layers at the electrode/dielectric interface. However, as devices have become smaller, the thickness of the dielectric film has been reduced to a few nanometers, and the ultra-thin TiO_xN_y formed at the current ZrO_2/TiN interface has also impacted the reduction of effective permittivity. Various treatments and additional layer interposition are being used to reduce the thickness of the low-k layer, but these approaches do not completely solve the fundamental problem. Improving the interfacial properties of MIMs is a major topic for the development of next-generation capacitors unless the conventional structure of current DRAM capacitors with a pillar structure is transformed. An electrode/dielectric combination that does not form a deleterious interfacial layer that leads to capacitance degradation is essential. The formation of defects that can increase leakage current must be minimized through an ideal sharp interface. Moreover, when the dielectric is composed of multilayers, controlling the interface properties between the insulating layers for better dielectric properties is also crucial. In this talk, the atomic layer deposition of TiO_2 and $SrTiO_3$, which are promising candidates for future dielectrics, and the improvement of their interface properties would be discussed.

SW2-2 | Light-induced enhancement of piezoelectricity in BiFeO3

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Piezoelectricity, which is a conversion between mechanical and electrical energy, is one of the key functional properties that has attracted considerable attention for energy harvesting devices. Enhancement of piezoelectricity in ferroelectrics often has been realized mainly by syntheetical approaches via structural engineering of materials, using a variety of processing methods and parameters. In this regard, $BiFeO_3$ is one of the most promising multiferroic materials due to its largely enhanced piezoelectricity when mixed with other materials, doped with other elements, or even epitaxially grown in compressively strained thin films by hosting morphotropic phase boundaries. While these structural approaches are well-known, enhancing piezoelectricity by external stimuli has yet to be clearly explored, despite their advantages of offering not only simple and in-situ control without prior processing requirement, but compatibility with other functionalities. Here, we show that light is a new pathway to enhance the piezoelectric property in $BiFeO_3$. Our results by piezoresponse force microscopy scans and spectroscopy measurements on $BiFeO_3$ reveal nearly a sevenfold enhancement of piezoelectric signal under laser illumination. This light-induced enhancement of piezoelectricity is attributed to two main contributions from the bulk photovoltaic effect and Schottky barrier effect, involving the key role of open-circuit voltage and photocharge carrier density. These findings provide fundamental insight to light-induced piezoelectricity enhancement, offering its potential for multifunctional optoelectronic devices.

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SW2-3 | 마법각도 비틀린 이중층 그래핀에서 상호 연관된 위상에서의 양자 텍스처 시각화

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Creating flat bands by moire band engineering, magic-angle twisted bilayer graphene exhibit abundant emergent quantum phenomena such as correlated insulator, unconventional superconductors, and topological magnet phases [1-4].Strong interactions between electrons are believed to play a major role to form these quantum phases, yet the microscopic mechanisms remain poorly understood. To uncover the underlying fundamental physics of those correlated quantum phases, it is essential to identify the exact ground state wavefunction, for which a careful analysis of the real-space electronic structure may provide vital information. In this talk, I will discuss about our recent Scanning Tunneling Microscopy (STM) results that manifest atomic scale electronic textures of correlated phases originated from coherently interfering electronic states in different valleys [5]. I will also discuss our recent achievement in distinguishing the ground state of correlated insulating states in twisted bilayer graphene by using novel phase-sensitive analyzing technique enabling to extract key information of the many-body wavefunction from the atomic scale features.

keywords: Scanning Tunneling Microscopy, correlated insulator, twisted bilayer graphene

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SW2-4 | 뉴로모픽 컴퓨팅 구현을 위한 산화물 멤리스터 소재 및 소자 개발

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Memristive devices have become a promising candidate for energy-efficient and high-throughput unconventional computing, which is a key enabler for artificial intelligent systems in the big data and IoT era. The so-called neuromorphic computing can be implemented on a resistive neural network with memristive synapses and neurons. In this talk, I will first briefly introduce memristive devices. I will then discuss the promises and challenges, including uniformity issues, non-linearity, and 3d structure compatibility, of the memristive devices & arrays, and also some approaches to overcome such issues.[1-6] A few examples selected from our recent experimental demonstrations of the promising applications from next-generation memory to bio-system emulator, which utilize such memristors, are also introduced.[7-9]

Keywords: Memristor, Bio-inspired computing

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SW2-5 | Investigating crystal structures of functional oxides by using DFT calculations and TEM

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This presentation delves into two studies involving crystal phase analysis of functional oxides using density functional theory (DFT) and transmission electron microscopy (TEM). The first topic explores the strain effect on the ground-state crystal structure of Sr_2SnO_4 Ruddlesden-Popper (RP) oxides through DFT. RP oxides ($A_{n+1}B_nO_{3n+1}$), which consist of perovskite ABO_3 slabs with AO rock-salt layers inserted between them, can exhibit diverse crystal structures. Here, we examine the lattice dynamics of Sr_2SnO_4, n=1 RP strontium stannates and investigate the strain effects on the ground-state crystal structure by employing first-principles calculations and group theoretical symmetry analyses. Secondly, the identification of a specific phase of perovskite $SrSnO_3$ utilizing experimental TEM is discussed. By employing the bright-field mode in scanning TEM (STEM), the octahedral tilt and pertinent atomic displacements are captured. The structure is determined to be an orthorhombic Pnma phase with the $a^-a^-c^+$ Glazer notation. Careful analysis of the experimental results unveils the presence of grains exhibiting different orientations within the $SrSnO_3$ film, along with their distribution.

SW2-6 | A Diffusive Memristor with Reliable Reproducibility and Uniformity Enabled by UVO Surface Treatment.

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Active cation-based diffusive memristors featuring essentially volatile threshold switching have been proposed for novel applications, such as a selector in a one-selector-and-one-resistor structure and signal generators in neuromorphic computing. However, the high variability of the switching behavior, which results from the high electroforming voltage, external environmental conditions, and transition to the non-volatile switching mode in a high-current range, is considered a major impediment to such applications. Herein, for the first time, we developed a highly reliable threshold switching device immune to atmospheric changes based on an ultraviolet-ozone (UVO)-treated diffusive memristor consisting of Ag and SiO2 nanorods (NRs). UVO treatment forms a stable water reservoir on the surface of SiO2 NRs, facilitating the redox reaction and ion migration of Ag. Consequently, diffusive memristors possess reliable switching characteristics, including electroforming-free, repeatable, and consistent switching with resistance to changes in ambient conditions and compliance levels during operation. We demonstrated that our approach is suitable for various metal oxides and can be used in numerous applications.

SW2-7 | Chemi-Memristive Device for Mimicking an Artificial Olfactory System

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Technologies based on the fusion of gas sensors and neuromorphic computing to mimic the olfactory system have immense potential. However, the implementation of neuromorphic olfactory systems remains in a state of infancy because conventional gas sensors lack the necessary functions. Therefore, this study proposes a hysteretic "chemi-memristive gas sensor" based on oxygen vacancy chemi-memristive dynamics that differ from that of conventional gas sensors. After the memristive switching operation, the redox reaction with the external gas molecules is enhanced, resulting in the generation and elimination of oxygen vacancies that induce rapid current changes. In addition, the pre-generated oxygen vacancies enhance the post-sensing properties. Therefore, fast responses, short recovery times, and hysteretic gas response are achieved by the proposed sensor at room temperature. Based on the advantageous functionality of the sensor, device-level olfactory systems that can monitor the history of input gas stimuli are experimentally demonstrated as a potential application. Moreover, analog conductance modulation induced by oxidizing and reducing gases enables the conversion of external gas stimuli into synaptic weights and hence the realization of typical synaptic functionalities without an additional device or circuit. The proposed chemi-memristive device represents an advance in the bioinspired technology adopted in creating artificial intelligence systems.