Invited Talks

Oxide membranes of highly conducting transparent perovskites and tunable dielectrics: From fundamentals to applications

Lambert Alff, TU Darmstadt

L. Alff [1], A. Arzumanov [1], J. Cardoletti [1], J. Josenhans [1], P. Komissinskiy [1], B. Kunkel [1], Y. Ruan [1], H. Maune [2], M. Vakili [3], S. Preu [3]

[1] Advanced Thin Film Technology, Materials Science, TU Darmstadt, Darmstadt, D
[2] Microwave Engineering, Electrical Engineering and Information Technology, TU Darmstadt, D
[3] THz Devices and Systems, Electrical Engineering and Information Technology, TU Darmstadt, D

The recent development of methods to perform wafer transfer with oxide materials has the potential to become a game changing technology in oxide electronics. In contrast to van der Waals-bonded materials, oxides harbor an almost infinite amount of functionalities and allow transfer of membranes with controlled thickness from the unit cell-level to hundreds of nanometers. On the one hand, the emerging field of oxide membranes opens a new playground for the study of fundamental and potentially novel properties of the nano-objects themselves, including in particular strain studies and different (rotated) heterostructures. On the other hand, wafer transfer allows to overcome the challenge of combining highly crystalline functional oxide layers with semiconducting and metallic layers which cannot be grown in a conventional deposition process in one device.
Using membrane technology, we show here that some perovskite oxides can be grown coherently strained in the micrometer range - well beyond conventional limits of critical thickness [1]. The example is $SrMoO_3$, a highly conducting semitransparent oxide, that can be used as bottom electrode for varactors (tunable capacitors) based on $(Ba,Sr)TiO_3$. The key advantage is that for microwave applications extremely thick bottom electrodes are required for high-Q devices. Going towards functional devices, we show that membranes of oxide heterostructures can be transferred to Si wafers without significant loss of functional performance [2]. A future key challenge will be the transfer of oxides (in particular perovskites) as replacement for functional layers in realistic device heterostructures such as tunable microwave components and lasers. To give an outlook on the roadmap of oxide membranes, we show that specific two-dimensional defects along well-defined crystal planes which occur during membrane delamination might be useful for tailoring transferable membranes.

[1] Y. Ruan et al., Adv. Funct. Mater. 34, 2312508 (2024)
[2] Y. Ruan et al., IEEE Trans. Mater. Electron. Devices 2, 80 (2025).

The Quest for High Temperature Superconducting Nickelates

Ariando, National University of Singapore

[1] Department of Physics, National University of Singapore, Singapore

The discovery of superconductivity in the Ba-La-Cu-O system (the cuprate) at around 30 K marked a major breakthrough, spurring extensive exploration of oxide-based layered superconductors to achieve even higher critical temperatures (T_c) and to understand their electron pairing mechanisms. Until recently, evidence of Cooper pairing above 30 K in systems isostructural to the cuprates but without copper, under ambient pressure, and without lattice compression, had remained elusive despite observations of superconductivity in nickel oxide-based compounds (the nickelates). In this talk, I will present our efforts in designing and understanding higher-temperature superconducting nickelates. We demonstrate a new superconducting infinite-layer nickelate, with a Tc approaching 40 K under ambient pressure, realized in d9 hole-doped, late rare-earth nickel oxide (Sm-Eu-Ca)NiO_2 thin films with negligible lattice compression. This is supported by observations of a zero-resistance state above 31 K and the Meissner effect. The material can be synthesized with essentially no Ruddlesden–Popper-type structural defects, and it exhibits ultralow resistivity of approximately 0.01 mΩ·cm and a residual resistivity ratio of up to 10. Using resonant inelastic x-ray scattering, we observe dispersive paramagnonic excitations in both optimally and overdoped (Sm-Eu-Ca)NiO_2 samples, supporting a spin-fluctuation-mediated pairing scenario. Notably, despite a two-fold enhancement of Tc in (Sm-Eu-Ca)NiO_2 nickelates compared to their Pr- or Nd-based counterparts, the effective exchange coupling strength is reduced by approximately 20%. This behavior contrasts with hole-doped cuprates, where magnetic interactions are positively correlated with Tc, highlighting key differences in their superconducting mechanisms. Our findings demonstrate the potential for achieving high-temperature superconductivity in strongly correlated d-electron metal oxides beyond copper, offering a promising platform for further investigation into the nature of high-temperature Cooper pairing.

Strain and electrical control of spin-excitations in multiferroic $BiFeO_3$

Valentina Bisogni, Brookhaven National Laboratory

T. Kim [1], V. Bhartiya [1], S. Fa n[1], J. Li [1], Y.Gu [1], K. Kisslinger [2], F. Camino [2], P. Raghuvanshi [3], V. Cooper [3], Y. Liu [4], Y. Nie [4], Z. Zhu [5], C.-Y. Kuo [6], M. P. M. Dean [7], J.-G. Park [8], S.-W. Cheong [9], J. Pelliciari [1], V. Bisogni [1]

[1] National Synchrotron Light Source II, Brookhaven National Laboratory, New York, USA
[2] Center for Functional Nanomaterials, Brookhaven National Laboratory, New York, USA
[3] Materials Sciences and Technology Division, Oak Ridge National Laboratory, Tennessee, USA
[4] National Laboratory of Solid State Microstructures, College of Engineering and Applied Science, Nanjing University, Nanjing, China
[5] Institute of Physics, Chinese Academy of Sciences, Beijing, China
[6] Department of Electrophysics, National Yang Ming Chiao Tung University (NYCU), Hsinchu, Taiwan
[7] Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory, New York, USA
[8] Center for Quantum Materials and Department of Physics and Astronomy, Seoul National University, Seoul, Korea
[9] Rutgers Center for Emergent Materials and Department of Physics and Astronomy, Rutgers University, New Jersey, USA

The promise of devices for applications based on quantum materials requires the possibility to control their functionalities. In this context, $BiFeO_3$, a room-temperature multiferroic has been extensively studied as it provides multiple handles, like magneto-electric and magneto-elastic coupling [1], to manipulate its properties. Although several studies have investigated the magnetic structure, ferroelectric polarization, photo-striction effect, under external stimuli -- e.g. strain [2], electric/magnetic field [3], or laser [4] -- the observation of the spin-excitations and therefore, the understanding of the exchange interactions, is hindered by the lack of experimental techniques sensitive to magnetism at the microscopic scale, and compatible with the above perturbations.
By using resonant inelastic X-ray scattering (RIXS) at the Fe L_3 edge, we investigated the spin-excitations in $BiFeO_3$ as a function of epitaxial strain and electric field, using an in-situ electrical setup [5]. The linear dichroism in the magnon intensity provides evidence of the emergence of different magnetic structures depending on the strain, also supported by atomic multiplet calculations. The magnon dispersion as a function of strain reveals the evolution of the exchange interactions both along the in-plane and the out-of-plane directions, as a direct response to the structural variations. These results are in full agreement with ab-initio calculations. Finally, we found that the ferroelectric polarization switch via electric field alters the magnon energy, bandwidth, and dichroism, providing insights on the unconventional nature of the magneto-electric coupling in $BiFeO_3$. Overall, by investigating the multiferroic $BiFeO_3$ under external stimuli with RIXS, we revealed unique information on the microscopic origin of the material functional properties.

[1] J.-G. Park, et al., J. Phys.: Condens. Matter 26, 433202 (2014)
[2] D. Sando et al., Nat. Mater. 12, 641 (2013)
[3] P. Rovillain et al., Nat. Mater. 9, 975 (2010)
[4] H. Wen et al., Phys. Rev. Lett. 110, 037601 (2013)
[5] Y. Gu et al., arXiv:2508.05796; V. Bhartiya et al., arXiv:2504.17871.

Electronic structure and magnetism in bilayer $La_3Ni_2O_7$

Kateryna Foyevtsova, University of Notre Dame

K. Foyevtsova [1,3,4], M. Jiang [2], I. Elfimov [3, 4] , and G. Sawatzky [3, 4]

[1] Department of Physics and Astronomy, University of Notre Dame , Notre Dame, IN, USA
[2] School of Physical Science and Technology, Soochow University, Suzhou, China
[3] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, Canada
[4] Stewart Blusson Quantum Matter Institute, University of British Columbia, Vancouver, BC, Canada

Ni-based superconductivity continues to intrigue the scientific community, now further fueled by the discovery of a superconducting state in pressurized Ruddlesden-Popper (RP) nickelates $La_3Ni_2O_7$ [1] and $La_4Ni_3O_{10}$ [2] as well as in strained thin films of $(La,Pr)_3Ni_2O_7$ [3]. Accurate knowledge of the electronic structure of these materials is key to understanding the origin and further exploring the potential of their superconductivity. Despite sharing certain similarities with the cuprates, some features of the crystal and electronic structure of the RP nickelates are unique and may play a profound role in their properties. These include a multilayer geometry (two NiO_2 layers in $La_3Ni_2O_7$), a high formal Ni oxidation state ($Ni^{2.5+}$ for $La_3Ni_2O_7$), and the presence of apical oxygens between the layers, which activate the Ni $3z^2$-r^2 orbitals leading to Hund's multiorbital physics as well as give rise to interlayer dimerization through molecular orbital splittings. These effects are at complex interplay, complicated further by strong electronic correlations.
In this talk, I will present a microscopic picture for the bilayer $La_3Ni_2O_7$ emerging from theoretical studies based on two complementary techniques: hybrid functional band structure calculations [4] and cluster exact diagonalization [5]. Our main conclusion is that, while Ni localized magnetic moments are strongly favoured, the precise magnetic configuration of the Ni-Ni dimers, as well as preferences for certain types of a long-range magnetic order, are strongly intertwined with the local distribution of oxygen holes. Furthermore, we consistently find that the ground state of $La_3Ni_2O_7$ hosts coexisting charge and spin density waves accompanied by Ni-O bond disproportionation - a phase which, according to recent experiments, competes with superconductivity at near-ambient pressures.

[1] H. Sun et al., Nature 621, 493 (2023)
[2] M. Zhang et al., Phys. Rev. X 15, 021005 (2025)
[3] G. Zhou et al., Nature 640, 641 (2025)
[4] K. Foyevtsova et al., arXiv:2507.08123 (2025)
[5] G. Jiang et al., SCIENCE CHINA Physics, Mechanics & Astronomy Vol. 68, Issue 9: 297411 (2025)

Ferroelectric-Control of Magnetotransport in Ruddlesden-Popper Strontium Iridates

Xia Hong, University of Nebraska-Lincoln

X. Hong [1, 2]

[1] Department of Physics and Astronomy, University of Nebraska-Lincoln, Lincoln, Nebraska, USA
[2] Nebraska Center for Materials and Nanoscience, University of Nebraska-Lincoln, Lincoln, Nebraska, USA

The Ruddlesden-Popper 5d iridates $Sr_{n+1}Ir_nO_{3n+1}$ represents a model system where the electronic and magnetic states can by systematically tuned by the competition between charge itinerancy, strong spin-orbit coupling, and onsite Coulomb energy. Voltage control of their electronic and magnetic properties is of extensive research interests for designing emergent quantum states and developing novel energy-efficient device applications, which is yet to be demonstrated.
This talk discusses the tuning of magnetotransport properties of ultrathin $Sr_{n+1}Ir_nO_{3n+1}$ (n = 1, 2, ∞) films via interfacial ferroelectric $PbZr_{0.2}Ti_{0.8}O_3$ (PZT). Nonvolatile polarization control of metal-insulator transition (MIT) has been achieved in $SrIrO_3$ and $Sr_3Ir_2O_7$. Bulk $SrIrO_3$ is a correlated semimetal. In the two-dimensional (2D) limit, $SrIrO_3$ thin films exhibit weak localization and weak antilocalization [1], which are modulated via PZT polarization reversal. Anomalous Hall effect and topological Hall effect are observed in PZT/$SrIrO_3$ close to the MIT, signaling emergent magnetism. $Sr_3Ir_2O_7$-based ferroelectric tunnel junctions exhibit enhanced electroresistance at room temperature, which can be attributed to the polarization induced MIT in the narrow band gap Mott insulator [2]. Compared with the bulk Mott insulator state of Sr_2IrO_4, the PZT/ Sr_2IrO_4 heterostructure shows transport characteristic of a 2D correlated metal [3], consistent with the interfacial charge transfer effect. The in-plane magnetoresistance and out-of-plane anisotropic magnetoresistance of the heterostructure shows distinct temperature and magnetic field dependences compared with those of single-layer Sr_2IrO_4, suggesting possible emergence of incipient ferromagnetism and polarization controlled magnetic anisotropy. These results shed new light on the intricate interplay of interface lattice coupling, charge doping, symmetry breaking, and magnetism in 5d iridates, presenting new avenues for exploring correlated phenomena and designing voltage-controlled functionalities in this intriguing material system.

[1] L. Zhang et al, APL Materials, 8, 051108 (2020).
[2] Y. Zhang et al, Applied Physics Letters, 125, 102904 (2024).
[3] Y. Zhang et al, Advanced Physics Research, Article No. 2400208 (2025).

Significant light-induced nonlinear polarization in $PbTiO_3/SrTiO_3$ superlattices

Wanzheng Hu, Boston University

Wanzheng Hu [1]

[1] Department of Physics, Boston University, 590 Commonwealth Avenue, Boston, 02215, Massachusetts, USA

Recent discoveries of various light-induced long-lived synthetic topological polar structures in $PbTiO_3/SrTiO_3$ superlattices highlight the power of structural and functional couplings in creating new ordered phases. Since the superlattices are on the verge of polarization reorganization, these materials may be exceptionally susceptible to dynamical lattice distortion under resonant phonon excitations. A synergy between materials design (superlattices) and light control (mid-infrared pumping) would create exciting opportunities to discover new quantum phases. Here I will present our recent work on various $PbTiO_3/SrTiO_3$ superlattices.

[1] Daniel A. Bustamante Lopez, Deepankar Sri Gyan, Xiaojiang Li, Vladimir A. Stoica, Sujit Das, Peter Meisenheimer, Akash Surampalli, Xianghan Xu, Aiden Ross, Long-Qing Chen, Sang-Wook Cheong, Lane W. Martin, Ramamoorthy Ramesh, Venkatraman Gopalan and Wanzheng Hu, submitted (2025).

Synergistic polar states by selective atomic gradients in perovskite oxides

Daesu Lee, Pohang University of Science and Technology

Daesu Lee [1]

[1] Department of Physics, Pohang University of Science and Technology (POSTECH), Pohang, Gyeongsangbuk-do, Korea

Materials that combine distinct properties within a single phase are of both fundamental and technological significance. However, it is challenging to harmoniously combine various properties, particularly since some physical properties are inherently mutually exclusive. The artificial integration of these mutually exclusive properties could lead to innovative physical phenomena and functionalities, unattainable from conventional approaches. In this talk, I will present a universal approach to induce strong bulk polarity that not only coexists with its originally incompatible properties, such as metallicity, but also synergistically enables exceptional functionalities. Through a combination of thin-film growth, atomic-scale structural analysis, and first-principles calculations, we show that A-site selective atomic gradients generate robust polar states in otherwise centrosymmetric perovskite oxides ABO_3. These polar states coexist with various preexisting properties, leading to bulk polar metallicity with tunable nonreciprocal transport, high-κ/low-loss dielectricity with an equivalent oxide thickness below 0.1 nm, and giant pyroelectricity. This strategy provides a general route to designing multifunctional materials with unusual coexisting and synergistic properties.

Atomic-Scale Imaging of Frequency-Dependent Phonon Anisotropy in Perovskite Oxides

Xiaoqing Pan, University of California, Irvine

Xiaoqing Pan

[1] Department of Materials Science and Engineering and Department of Physics and Astronomy, UC Irvine Materials Research Institute (IMRI), University of California, Irvine, CA 92697, USA

Direct visualization of vibrational anisotropy in individual phonon modes is essential for understanding a wide range of optical, thermal, and elastic phenomena in materials. Conventional optical and diffraction techniques, while useful, lack the spatial and energy resolution required to reveal site-specific vibrational details. In this talk, we will introduce a novel momentum-selective electron energy-loss spectroscopy (q-selective EELS) technique that enables element-specific imaging of frequency- and symmetry-dependent vibrational anisotropies with atomic resolution. Vibrational anisotropy is manifested as differing magnitudes of orthogonal atomic displacements—represented as thermal ellipsoids. Using centrosymmetric strontium titanate as a model system, we observed two distinct types of oxygen vibrations characterized by contrasting anisotropies: oblate ellipsoids below 60 meV and prolate ones above. In non-centrosymmetric barium titanate, our approach detects subtle distortions of oxygen octahedra by revealing unexpected modulations in q-selective signals between apical and equatorial oxygen sites near 55 meV. These features arise from broken inversion symmetry and may relate to ferroelectric polarization. The measured frequency-dependent vibrational anisotropies provide new insights into the dielectric and thermal behaviors governed by acoustic and optical phonons. This ability to visualize phonon eigenvectors at specific crystallographic sites with unprecedented spatial and energy resolution opens new avenues for investigating properties in complex materials.

Magnon Confinement in oxide heterostructures

R. Ramesh, University of California, Berkeley

R. Ramesh [1,2]

[1] University of California, Berkeley CA 94720
[2] Rice University, Houston, TX 77005

A few years ago, an intriguing new spin based logic-in-memory architecture, MESO, was described which used magnetoelectric multiferroics (ME) and spin-orbit (SO) metallic oxides as key building blocks. Over the past year, there have been some new developments in SOT based manipulation of magnets. Particularly, the role of epitaxy and atomically perfect interfaces with spin and/or orbital current enhanced oxides has been shown to significantly impact the spin-to-charge conversion (or vice versa). We are studying spin transport in La-BFO using a combination of NV imaging and spin Hall measurements. Over the past year, we have discovered the powerful role of magnon confinement as a pathway to enhance spin transport (and thus the spin-to-charge conversion efficiency) by over 100X[1]. This talk will give you a summary of our progress so far.

[1] S. Husain, M. Ramesh, et al., under review in Science(2025);

Flexoelectrically induced polar topologies in twisted oxide membranes

Jacobo Santamaria, Universidad Complutense

I. Tenreiro [1], V. Zamora [1], H. Aramberri [2], M. Cabero [3], G. Sánchez-Santolino [1], V. Rouco [1], A. Rivera [1], F. Mompean [4], M. Garcia-Hernandez [4], J. Íñiguez [2], C. Leon [1], J. Santamaria [1]

[1] GFMC. Dept. Fisica de Materiales. Facultad de Fisica. Universidad Complutense. 28040 Madrid
[2] Materials Research and Technology Department, Luxembourg Institute of Science and Technology (LIST), Avenue des Hauts-Fourneaux 5, L-4362 Esch/Alzette, Luxembourg.
[3] ICTS Centro Nacional de Microscopia Electrónica "Luis Brú" U. Complutense. 28040 Madrid
[4] Instituto de Ciencia de Materiales de Madrid ICMM-CSIC 28049 Cantoblanco. Spain

The recent realization of membranes of perovskite oxides, has enabled their assembly into twisted homo bilayers. In twisted $BaTiO_3$ membranes, these inhomogeneous strain patterns underlay the formation of an array of ferroelectric vortices driven by the flexoelectric coupling of polarization to strain gradients [1]. Surprisingly, the shear interaction developing at the interface, driven by the mostly incoherent atomic registry between the two twisted layers, propagate into the layers, relaxing over distances which can be as long as tens of nanometers. The decaying nonhomogeneous strain triggers profound changes in the polarization landscape which evolves from a pure rotational polarization pattern with alternating ferroelectric vortices and antivortices to a superposition of a vortex lattice and a homogeneous polarization component. Yet, flexoelectricity is a universal phenomenon which may render polar landscapes in non-ferroelectric materials. Here we report a flexoelectrically induced polar topology in twisted membranes of $SrTiO_3$, a paraelectric centrosymmetric material. The polar landscape triggered by twisting is also supported by machine learned force fields based on first-principles calculations. We further show that the strain and polarization patterns in top and bottom layers are correlated in a way which breaks inversion and mirror symmetries thus unlocking a chirality degree of freedom.

[1] G. Sanchez-Santolino et al. Nature 626, 529 (2024)

Altermagnetism: from Spin Symmetries to Oxide Multiferroics

Libor Šmejkal, Max Plank Institute for the Physics of Complex Systems

Libor Šmejkal [1,2,3]

[1] Max Plank Institute for the Physics of Complex Systems, 01187 Dresden, Germany
[2] Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany
[3] Institute of Physics, Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

Since the 1930s, magnets have been classified into two main branches: ferromagnets and antiferromagnets. Recently, we have identified a third fundamental branch: altermagnets (see Figure) [1,2]. Altermagnetism is characterized by a compensated d-, g-, or i-wave alternating spin order, which distinguishes it from ferromagnets and antiferromagnets. The discovery of the altermagnetic class emerged from our systematic classification of crystallographic spin groups [1], which is analogous to the well-established frameworks used in superconductivity, superfluidity, and the Standard Model.

In this talk, we will outline our decade-long journey leading to the discovery of altermagnets, including the prediction[3] and experimental observation[4] of the anomalous Hall effect and unconventional electronic structure in compensated collinear magnets. We will also present our systematic classification, which—beyond even partial-wave altermagnets—recently revealed a new class of odd partial-wave magnets [5].

Furthermore, we will showcase experimental evidence supporting altermagnetism, including its distinct signatures in photoemission spectra [6] and nanoscale mapping [7]. Finally, we will explore emerging research directions exploiting unique altermagnetic effects unavailable in ferromagnets and antiferromagnets. These include altermagnetic spintronics [8], magnonics [9], two-dimensional magnetism [10], and multiferroics [11]. The possibility of altermagnetism in a wide range of materials, ranging from metals to insulators [1], is promising for potential applications both within and beyond solid-state physics, including ultrafast and low-power nanoelectronics.

[1] PRX 12, 031042 (2022).
[2] https://www.economist.com/science-and-technology/2024/01/24/scientists-have-found-a-new-kind-of-magnetic-material, https://www.science.org/content/article/researchers-discover-new-kind-magnetism
[3] Science Adv. 6, 23 (2020), PNAS 118 42 (2021),
[4] Nature Electronics 5, 735 (2022), Nature Commun. 15, 4961 (2024).
[5] arXiv:2309.01607v3 (2024).
[6] Nature 626, 517 (2024), Nature Commun. 15, 2116 (2024), PRL 132, 036702 (2024).
[7] Nature 636, 348 (2024).
[8] PRX 12, 011028 (2022), arXiv:2503.12203 (2025).
[9] PRL 131, 256703 (2023), arXiv:2309.02355 (2023), arXiv:2411.19928 (2024).
[10] arXiv:2309.02355
[11] arXiv:2411.19928

Contributed Talks

Growth of Ruddlesden-Popper nickelate phases by molecular beam epitaxy

Stefania Baronio, University of British Columbia

S. Baronio [1,2], B. A. Davidson [1,2], A. Damascelli [1,2], K. Zou [1,2]

[1] Department of Physics & Astronomy, University of British Columbia, Vancouver, British Columbia, Canada
[2] Quantum Matter Institute, University of British Columbia, Vancouver, British Columbia, Canada

The discovery of superconductivity up to 80 K in $La_3Ni_2O_7$ [1] under high pressure has sparked research on Ruddlesden–Popper (RP) layered nickelates. A breakthrough in this field has been the observation of superconductivity at ambient pressure with transition temperatures up to 40 K, achieved through epitaxial strain engineering of thin films [2]. Molecular beam epitaxy (MBE) enables the stabilization of these complex phases through shuttered deposition of alternating LaO and NiO_2 layers, offering control over sequences that are difficult to achieve as pure phases in bulk crystals. The growth of high-quality RP thin films remains challenging. A precise calibration of La and Ni fluxes is required that yields the stoichiometry (“relative La:Ni calibration”), as well as the shutter time corresponding to deposition of a complete layer (“absolute dose calibration”) - the latter is critical to prevent mixed-phase intergrowth [3]. We propose an approach for growing high-quality $La_{n+1}Ni_nO_{3n+1}$ thin films by applying a universal method recently developed by our group, which interprets the intensity oscillations of the diffracted RHEED reflections to provide real-time control of film stoichiometry and surface termination [4]. By identifying B-site layer inversion in the intensity oscillations, the shuttering sequences that result in phase-pure RP nickelate films can be carefully designed, starting from La_2NiO_4 (n=1). The films are subsequently characterized ex situ by X-ray diffraction, low-temperature magnetoresistance, and other measurements.

[1] H. Sun et al., Signatures of superconductivity near 80 K in a nickelate under high pressure. Nature 621, 493–498 (2023)
[2] E. K. Ko et al. Signatures of ambient pressure superconductivity in thin film La3Ni2O7. Nature 638, 935–940 (2025)
[3] G. A. Pan et al., Synthesis and electronic properties of Ndn+1NinO3n+1 Ruddlesden-Popper nickelate thin films. Phys. Rev. Materials 6, 055003 (2022)
[4] B. A. Davidson et al., A universal method for in situ control of stoichiometry and termination of epitaxial perovskite films. Research Square: https:doi.org/10.21203/rs.3.rs-4380373/v1 (2024)

Control of Hall Resistivity Anomaly in $SrRuO_3$ Epitaxial Thin Films via Mo Doping

Rahma Dhani Prasetiyawati, Sungkyunkwan University

Rahma Dhani Prasetiyawati [1], Sehwan Song [2], Seyoung Kwon [2], Min Yeong Choi [3], Min Chul Choi [4], Woo Tack Lim [1], Tuson Park [1], Jae Hyuck Jang [3], Sungkyun Park [2], Se Young Park [4,5], Suyoun Lee [6,7], and Woo Seok Choi [1,*]

[1] Department of Physics, Sungkyunkwan University, Suwon 16419, Korea
[2] Department of Physics, Pusan National University, Busan 46241, Korea
[3] Research Center for Materials Analysis, Korea Basic Science Institute, Daejeon, 34133, Korea
[4] Department of Physics and Integrative Institute of Basic Sciences, Soongsil University, Seoul, 06978, South Korea
[5] Origin of Matter and Evolution of Galaxies (OMEG) Institute, Soongsil University, Seoul, 06978, South Korea
[6] Center for Neuromorphic Engineering, Korea Institute of Science and Technology, Seoul, 02792, Korea
[7] Division of Nano & Information Technology, Korea University of Science and Technology, Daejeon, 34316, Korea

Hall effect plays an important role in investigating the dynamics between charge and spin interactions. Hall effect includes the anomalous Hall effect (AHE) and topological Hall effect (THE), which are fundamental for the advancement of spin-orbit-torque electronics. $SrRuO_3$ (SRO) is a ferromagnetic 4d perovskite oxide widely studied for its exotic phenomena originating from the interplay between spin-orbit coupling and Berry curvature. Several SRO-based systems exhibit THE signature emerged as a hump anomaly in the Hall resistivity (ρ_{xy}) and associated with the presence of magnetic skyrmions.[1, 2] It is then important to understand the interdependency between spin and charge degrees of freedom enabling a definitive control of ρ_{xy} anomaly beneficial for spintronic applications.

In the present study, we observed a significant enhancement in the ρxy of SRO thin films by Mo-doping alongside the emergence and systematic control of the hump anomaly in the ρxy. Epitaxial $SrRu_{1-x}Mo_xO_3$ (SRMO, x = 0 – 0.5) thin films have been deposited by using pulsed laser epitaxy on (001) $SrTiO_3$ (STO) substrates. The incorporation of Mo affects not only the ρxy but also the magnetic ground state, increasing the Curie temperature to 149 K and governing the reversal temperature (TR) where the AHE sign changes.[3] Our results elucidate the origin of the hump anomaly while providing a practical route to enhance the AHE and maintain the ferromagnetism of SRO thin films, which is fundamental for improving the controllability of oxide-based spintronic devices.

[1] Matsuno, J., Ogawa, N., Yasuda, K., Kagawa, F., Koshibae, W., Nagaosa, N., Tokura, Y., & Kawasaki, M. (2016). Interface-driven topological Hall effect in SrRuO3-SrIrO3 bilayer. Science Advances, 2, e1600304.
[2] Wang, C. A., Chang, C.-H., Herklotz, A., Chen, C., Ganss F., Kentsch, U., Chen, D., Gao, X., Zeng, Y.-J., Hellwig, O., Helm, M., Gemming, S., Chu, Y.-H., & Zhou., S. (2020). Topological Hall Effect in Single Thick SrRuO3 Layers Induced by Defect Engineering. Advanced Electronic Materials, 6, 2000184.
[3] Prasetiyawati, R. D., Jeong, S. G., Park, C.-K., Song, S., Park, S., Park, T., & Choi, W. S. (2023). Tunable electron scattering mechanism in plasmonic SrMoO3 thin films. Current Applied Physics 53, 110-117.

Atomic reconstruction and chirality in twisted bilayer oxides

Nicolas Gauquelin, University of Antwerpen

N. Gauquelin [1], W. S. Hansen [2], A. De Backer [1], E. Dollekamp [2], J.M. García Lastra [2], T. Chennit [1], A. Annys [1], N. Vitaliti [2], J. Hidding [2], S. van Aert [1], J. Verbeeck [1], and N. Pryds [2]

[1] EMAT and Nanolight Center of Excellence, Department of Physics, University of Antwerpen, Groenenborgerlaan 171, 2020 Antwerpen, Belgium
[2] Department of Energy Conversion and Storage, Technical University of Denmark, Kongens, Lyngby 2800, Denmark

The integration of dissimilar materials in heterostructures has long been a cornerstone of modern materials science, with seminal examples including 2D materials and van der Waals stacks. Recently, new methods have been developed to realize ultrathin freestanding oxide films approaching the 2D limit.[1] This offers unique opportunities to explore the wide range of new functionalities of complex oxides and their interfaces. In these heterostructures, controlling the Moiré superlattice pattern, formed by the interaction of two twisted lattices, plays a key role in creating unique electronic, optical, magnetic, and mechanical properties that are absent in the individual materials or in traditional, non-twisted heterostructures.[2]
In this talk, I will demonstrate how careful sample preparation combined with the use of advanced Scanning Transmission Electron Microscopy (STEM) techniques, including various annular dark field (ADF) imaging and four-dimensional STEM (4DSTEM), can directly probe the local atomic arrangement of twisted bilayer oxides. This methodology has already been successfully applied to 2D materials[3] and heterostructures, and we are now applying it to transition metal oxide (TMO) membranes for the first time. Through careful simulations and correlation with Density Functional Theory (DFT) we also show the emergence of chiral distortions in twisted TMO layered interfaces of finite dimensions. In this framework, Moiré patterns created by layered TMO materials may also be linked to dislocation arrays, which can be studied and visualized through STEM imaging.

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Formation of one-dimensional electron chains with alternating spin along dislocations: A concept for superconductivity in $SrTiO_3$

Daniel Gueckelhorn, INRS-EMT

D. Gueckelhorn [1], M. Fernández-Serra [2], and A. Ruediger [1]

[1] Centre Énergie Matériaux Télécommunications, Institut National de la Recherche Scientifique, Varennes, Québec, Canada
[2] Institute for Advanced Computational Science, Stony Brook University, Stony Brook, New York, USA

In 1964, $SrTiO_3$ was reported to be a superconductor [1], which cannot be explained by the BCS paradigm. Consequently, many different theories arose within the last decades describing possible mechanisms leading to a superconducting state [2]. Hereby, all theories have one thing in common: They attribute superconductivity to the bulk.
We present a possible explanation where the superconductive state is not a bulk, but a defect property based on ab initio calculations. In $SrTiO_3$ various defects can occur, but dislocations are of particular interest. This type of defect is abundant in every $SrTiO_3$ sample with densities of 10^6 to 10^{12} cm^{-2} [3] forming networks through the whole crystal [4]. These dislocations are a hotspot for oxygen vacancies. This is supported by experimental findings [5] and our simulations where the oxygen vacancy formation enthalpy is as low as 5.27 eV compared to 6.78 eV in bulk $SrTiO_3$. In case of an oxygen-reduced dislocation, the formation of a chain of free electrons is expected along oxygen vacancies. We show that, indeed, we get a chain of electrons with alternating spin along dislocations. Following the Peierls instability the electron chain will dimerize, allowing the creation of bosonic quasiparticles.
The dimerization will open the door for new approaches to explain the superconductive state including the bipolaron theory which is currently mainly used for high-temperature superconductors [6].

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Emergent Orbital Correlations in Spin-Orbit Coupled Materials

Gervasi Herranz, Institute for Materials Science of Barcelona ICMAB-CSIC

A. S. Miñarro [1], M. Villa [1], S. Plana-Ruiz [2.3], J. Gázquez [1], G. Herranz [1]

[1] Institute of Materials Science of Barcelona (ICMAB-CSIC)
[2] Scientific & Technical Resources, Universitat Rovira i Virgili, Tarragona
[3] LENS-MIND, Department of Electronics and Biomedical Engineering, Universitat de Barcelona

Transition metal oxides with partially filled d-orbitals display a rich competition between spin-orbit coupling (SOC), electron interactions, and Jahn-Teller (JT) effects. This interplay gives rise to exotic phases, such as spin-orbit Mott insulators, spin liquids, and excitonic magnets. In 4d and 5d systems like iridates or ruthenates, strong SOC is often thought to suppress JT distortions and freeze orbital motion. However, recent studies challenge this view, showing that JT physics can survive dynamically, even when SOC is strong. Thus, local orbital dynamics can persist, shaping the physical properties of these systems, even when they are thought to be fully dominated by SOC.
Here, we present a unified framework that includes SOC, JT coupling, and electron hopping between sites in the lattice. We explore how spin-orbit-entangled systems respond to local perturbations, an essential aspect for interpreting experiments like resonant inelastic X-ray scattering (RIXS), which directly probe these excitations and are key to uncovering the underlying physics. We describe how short-range orbital fluctuations naturally emerge from local perturbations of the ground state, driven by virtual hopping and electron correlations, much like magnetic interactions in solids. We also highlight Mn^{3+} compounds, where JT effects dominate but SOC still plays an active role through JT-induced t_{2g}–e_g mixing [1–3]. These insights are essential for building a complete picture of strongly correlated materials, where local fluctuations play a decisive role in shaping their properties.

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Oxide ionic drift-diffusion transistors for human interactive neuromorphic computing

Hisashi Inoue, National Institute of Advanced Industrial Science and Technology

H. Inoue [1], H. Tamura [2,3], A. Kitoh [1], X. Chen [4], Z. Byambadorj [4], T. Yajima [5], Y. Hotta [6], T. Iizuka [4], G. Tanaka [3,7], and I. H. Inoue [1]

[1] National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan
[2] Graduate Schools for Law and Politics, The University of Tokyo, Tokyo, Japan
[3] International Research Center for Neurointelligence (IRCN), The University of Tokyo, Tokyo, Japan
[4] Systems Design Laboratory, School of Engineering, The University of Tokyo, Tokyo, Japan
[5] Graduate School of Information Science and Electrical Engineering, Kyushu University, Fukuoka, Japan
[6] Department of Engineering, University of Hyogo, Hyogo, Japan
[7] Department of Computer Science, Nagoya Institute of Technology, Nagoya, Japan

Oxide materials exhibit a wide range of properties that hold promise for electronic devices beyond conventional semiconductors. Many oxides conduct ions in addition to electrons through electric-field-driven drift-diffusion. The resulting multi-timescale nature is useful for human interactive neuromorphic computing that mimics the long-timescale dynamics of the biological nerve system. In contrast to modern machine learning built on computers running at GHz frequency, biological nerve systems achieve adaptive learning with low power at kHz frequencies. Emulating such long timescales in compact, low-power electronic devices remains a key challenge for edge computing. Using an oxide semiconductor $SrTiO_3$ as the channel material, we show by experiments that the transistor implements leaky-integration – the fundamental behavior of biological neurons – with the timescales of ~ 1 s comparable to biological nerve system and retaining performance over 10^8 cycles [1]. Oxygen vacancies around the transistor channel are found to migrate through drift-diffusion, modulating the drain currents with the applied gate voltage. Owing to the negligible energy dissipation of drift-diffusion, the transistor operates at an extremely low power of ~ 500 pW. Through numerical simulations of handwriting authentication, we also show how these transistors are assembled to solve real-world problems [2], emphasizing the importance of long temporal dynamics for real-time human interactive neuromorphic computing.

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Moiré Heterostructures in Ferroelectric $Hr_{0.5}Zr_{0.5}O_2/ZrO_2$ heterostructures

Daisuke Kan, The University of Osaka

Daisuke Kan [1], Yufan Shen [1], Kousuke Ooe [2,3], Dawei Zhang [4], Lingling Xie [1], Haoze Zhang [4], Shunsuke Kobayashi [3], Jan Seidel [4], Yuichi Shimakawa [1]

[1] Institute for Chemical Research, Kyoto University, Uji, Kyoto, Japan.
[2] School of Physics and Astronomy, Monash University, Clayton, VIC 3800, Australia.
[3] Nanostructures Research Laboratory, Japan Fine Ceramics Center, Nagoya, Aichi, 456-8587, Japan
[4] School of Materials Science and Engineering, UNSW Sydney, Sydney 2052, Australia

When structurally dissimilar materials are heterostructured, the structural mismatch must be accommodated at the interface, which results in unique atomic structures not seen in the constituent materials and changes in physical properties. In this study, we show that Moiré superlattices can form when the fluorite oxides $Hf_{0.5}Zr_{0.5}O_2$ (HZO) and ZrO_2 (ZO) whose single layers respectively possess polar and nonpolar metastable structures, are heterostructured. We found that the HZO/ZO heterostructures exhibit robust ferroelectricity with a remnant polarization comparable to a single layer of $Hf_{0.5}Zr_{0.5}O_2$ and an enhanced dielectric constant. Plan-view scanning transmission electron microscopy observations reveal that Moiré superlattices consist of polar orthorhombic lattices of both HZO and ZO, highlighting the key role of the HZO/ZO interfaces in stabilizing the ferroelectricity with negative capacitance in the HZO/ZO bilayer structures. Furthermore, we found that both the dielectric constant and polarization are increased by reducing the thickness of HZO and ZO layers in the stacked structures and enhancing the interfacial effects.

Large charge-to-spin conversion in high entropy perovskite oxides

Pat Kezer, University of Michigan

P. Kezer [1], S. Almishal [2], Shinjan Mandal [1], Xiao Zhang [1], Sim Gelin [3], Yuxuan Wang [1] Ismaila Dabo [3], Emmanouil Kioupakis [1], Jon-Paul Maria [2], John T. Heron [1]

[1] University of Michigan, Ann Arbor, Michigan USA 48109
[2] Pennsylvania State University, University Park, Pennsylvania USA 16802
[3] Carnegie Mellon University, Pittsburg, Pennsylvania USA 15213

The spin Hall effect (SHE) is a material property in which a charge current produces a transverse spin-polarized current. This coupling of spin and charge opens new pathways for future energy efficient logic and memory devices. While canonical spin Hall materials (Ta, W, Pt etc.) show significant spin-charge conversion efficiency, their low resistivity and oxide-integrability can hinder their integration into emerging technologies. Here, we will discuss the SHE and its associated figures of merit in conductive high-entropy oxides (HEOs). We will discuss the interplay of disorder and composition on the effect in $Sr_{0.95}((TiCrNbMo)_{(1-x)}/4W_x)O_3$. Second harmonic Hall and spin-torque ferromagnetic resonance were performed to probe the SHE. These methods indicate a large conversion efficiency of 60.8 and 66.1% for the equimolar (x=0.2) HEO thin-film, particularly compared to a non-disordered $SrNbO_3$ film (11%). We find that local distortions from cubic symmetry (despite having global cubic symmetry) in the presence of large spin-orbit coupling due to the W bands at the Fermi level lead to the boosted effect.

Observation of Mermin-Wagner behavior in $LaFeO_3/SrTiO_3$ and $LaFeO_3/LaAlO_3$ superlattices

Michal Kiaba, Northwestern University

M.Kiaba [1,2], A.Suter [3],A.Dubroka [2]

[1] Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Brno, Czech Republic
[2] Department of Materials Science and Engineering, Northwestern university, Evanston, Illinois, United states of America
[3] Laboratory for Muon-Spin Spectroscopy, Paul Scherrer Institute, Villigen PSI, Switzerland

Two-dimensional magnetic materials can host emergent magnetic behavior driven by enhanced spin fluctuations due to reduced dimensionality. According to the Mermin–Wagner theorem, long-range magnetic order is suppressed in ideal two-dimensional systems due to long wavelength spin fluctuations; however, its applicability to real, finite-size systems is actively investigated. Here, we study the magnetic properties across the dimensional crossover in oxide superlattices composed of ultrathin antiferromagnetic $LaFeO_3$ layers embedded between $SrTiO_3$ or $LaAlO_3$ spacers. Using pulsed laser deposition, we fabricated superlattices with 1–3 unit cells of $LaFeO_3$ separated by 5 unit cells of spacer material, repeated 10 times on TiO_3-terminated $SrTiO_3$ substrates. Low-energy muon spin rotation measurements reveal that $LaFeO_3$ layers with 2 and 3 unit cells exhibit a static antiferromagnetic ground state, while a single-unit-cell $LaFeO_3$ layer remains dynamically fluctuating down to 5 K, consistent with the Mermin–Wagner theorem's prediction. The nearly identical magnetic behavior observed in superlattices with different spacer materials underscores that the magnetic properties are governed predominantly by the dimensionality of the $LaFeO_3$ layers. These results, extending our previous study [1], demonstrate how dimensional control in oxide heterostructures can be used to engineer magnetic ground states.

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Tuning the d orbital occupancy in $LaCoO_3$ electrocatalysts by thin film interfacial engineering

Ellen Kiens, MESA+ Institute for Nanotechnology

E. M. Kiens [1], I. C. G. van den Bosch [1], O. Bisen [2], J. R. H. Ruiters [1], N. Gauquelin [3], A. Annys [3], E. van der Minne [1], M. Van Spronsen [4], J. Verbeeck [3], G. Mul [1], G. Koster [1], M. Risch [2], F. M. F. de Groot [5], B. Mei [1,6], and C. Baeumer [1,7]

[1] MESA+ Institute for Nanotechnology, Faculty of Science and Technology, University of Twente, 7500 AE Enschede, The Netherlands
[2] Nachwuchsgruppe Gestaltung des Sauerstoffentwicklungsmechanismus, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Hahn-Meitner-Platz 1, 14109 Berlin, Germany
[3] Electron Microscopy for Materials Science, University of Antwerp, Campus Groenenborger, Groenenborgerlaan 171, 2020 Antwerpen, Belgium
[4] Diamond Light Source, Harwell Science and Innovation Campus, Didcot, Oxfordshire OX11 0DE, United Kingdom
[5] Materials Chemistry and Catalysis, Debye Institute for Nanomaterials Science, Utrecht University, Universiteitsweg 99, 3584 CG Utrecht, The Netherlands
[6] Laboratory of Industrial Chemistry, Ruhr University Bochum, 44780 Bochum, Germany
[7] Peter Gruenberg Institute 7, Forschungszentrum Juelich GmbH, 52428 Juelich, Germany

The configuration and occupancy of the outer orbitals of transition metal oxides govern their physical properties. Tuning the d orbital occupancy by interfacial engineering allows for tailoring of structural, electronic, magnetic and (electro)catalytic properties. In electrocatalysis, the occupation of these orbitals has been identified as a descriptor for the performance in catalysing the oxygen evolution reaction, the limiting half-reaction in electrochemical water splitting [1]. During electrocatalysis, the transition metal typically serves as the active site, where electrons are transferred between reaction intermediates and the transition metal.
In this work, we use epitaxial heterostructures as model systems to tune the Co d orbital occupation in ultrathin $LaCoO_3$ films and demonstrate how interfacial engineering affects their electrocatalytic performance. First, we study the effect of interfacial engineering on the Co valence and spin state using X-ray absorption spectroscopy combined with charge transfer multiplet calculations. Our results show that the Co d orbital occupation can be tuned from a partial Co^{2+} oxidation state to a partial Co^{4+} oxidation state. Second, we investigate how the Co electronic state evolves during electrocatalysis. Operando X-ray absorption spectroscopy reveals that the evolution of the Co electronic state with applied potential varies distinctly for different subsurfaces. Understanding the complex interplay between surface and subsurface layers is fundamental to improving the performance of perovskite oxide electrocatalysts.

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Electrostatically defined quantum dots in ZnO heterostructures

Yusuke Kozuka, National Institute for Materials Science

K. Noro [1,2,3], M. Shinozaki [3,4], Y. Kozuka [3,4], K. Matsumura [1,2], Y. Fujiwara [1,2], T. Kumasaka [4], A. Tsukazaki [5], M. Kawasaki [5,6], T. Otsuka [1,2,3,4,6,7]

[1] Research Institute of Electrical Communication, Tohoku University, Aoba-ku, Sendai, Japan
[2] Department of Electronic Engineering, Graduate School of Engineering, Tohoku University, Aoba-ku, Sendai, Japan
[3] Research Center for Materials Nanoarchitechtonics (MANA), National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, Japan
[4] WPI Advanced Institute for Materials Research, Tohoku University, Aoba-ku, Sendai, Japan
[5] Department of Applied Physics and Quantum-Phase Electronics Center (QPEC), University of Tokyo, Bunkyo-ku, Tokyo, Japan
[6] Center for Emergent Matter Science, RIKEN, Wako, Saitama, Japan
[7] Center for Science and Innovation in Spintronics, Tohoku University, Aoba-ku, Sendai, Japan

Electrostatically defined quantum dots in semiconductor heterostructures have provided fertile ground for testing the physics of 0D electrons. Various techniques to control and detect the quantum states of electrons in quantum dots are now applied towards realizing highly integrated quantum bits. Although GaAs heterostructures were initially used owing to the availability of high-quality heterostructures, Si is currently considered a promising material for quantum bits due to low-density nuclear spins, which minimizes the source of electron spin decoherence through hyperfine interaction. However, the presence of multiple valleys in Si is suggested as another source of decoherence via a spin-valley coupling [1].

Here, we show a first demonstration of electrostatically defined quantum dots using a ZnO heterostructure [2]. ZnO has a low nuclear spin density, as well as a weak spin-orbit interaction, similar to Si, and therefore, a long spin coherence is expected [3]. Additionally, ZnO is a wide-gap direct semiconductor with a single valley, being an ideal platform for semiconductor qubits. Recently, a growth technique to fabricate ZnO heterostructures hosting high-mobility electrons has been established [4]. By taking advantage of this technique, we have developed a reliable microfabrication process to electrostatically form quantum dots. Further advancements in fabrication technologies such as multilayer gate structures or integration of micromagnets will make ZnO quantum dots a major material system for semiconductor qubits.

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Unconventional superconductivity in nickelate thin films

Sangjae Lee, Yale University

S. Lee [1], D. Vu [1], H. Lee [2], D. Nicoletti [2], W. Wei [1], Z. Jin [3], M. Buzzi [2], Y. He [1], S. Ismail-Beigi [1], F. Walker [1], A. Cavalleri [2], C. Ahn [1]

[1] Department of Applied Physics, Yale University, New Haven, Connecticut, USA
[2] Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany
[3] Department of Physics, Yale University, New Haven, Connecticut, USA

Infinite-layer nickelates represent a new class of superconductors with electronic parallels to high-Tc cuprates. In this talk, I will present experimental evidence that rare-earth substitution in $Nd_xEu_xNiO_2$ (NENO) thin films leads to markedly unconventional superconductivity. By combining magnetotransport with terahertz spectroscopy on in situ Al reduced thin films, we reveal a large superconducting gap and anisotropic upper critical fields (Hc2) that exceed the Pauli limit, pointing to strong coupling superconductivity. Notably, we observe reentrant superconductivity under high magnetic fields (~20 T), which we interpret to be a result of the Jaccarino-Peter effect, a magnetic exchange-driven mechanism not previously reported in other nickelates. These unconventional superconducting properties highlight a novel role of Eu magnetism in the superconducting state. Together, these findings suggest that magnetic rare-earth substitution provides a new way for tuning electronic correlations in infinite layer nickelates, distinct from conventional charge doping or pressure approaches.

Stabilizing Low-Valence Nickel via Charge Transfer in MBE-Grown Oxide Films

Fengmiao Li, University of Science and Technology of China

Fengmiao Li [1,2,3], Ilya Elfimov [1,2], Daisuke Takegami [4], Sheng-Huai Chen [4], Chun-Fu Chang [4], Clemens Hochstädter [2], Rebecca Pons [1,2,5], Simon Godin [1,2], Bruce Davidson [1,2], Eva Benckiser [5], George Sawatzky [1,2], Ke Zou [1,2] and Hao Tjeng [4]

[1] Department of Physics & Astronomy, University of British Columbia, Vancouver, British Columbia, V6T 1Z1 Canada.
2Quantum Matter Institute, University of British Columbia, Vancouver, British Columbia, V6T 1Z4 Canada.
3School of Emerging Technology, The University of Science and Technology of China, Hefei, Anhui, 230026, China
4Max Planck Institute for Chemical Physics of Solids, Nothnitzer Straße 40, 01187 Dresden, Germany
5Max-Planck-Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

Recent breakthroughs in the discovery of superconductivity in nickel oxides—including infinite-layer epitaxial films [1] and Ruddlesden-Popper (RP) bulk phases [2–4]—have sparked tremendous interest in exploring nickel with variable oxidation states. However, the inherent instability of nickel when its oxidation state deviates from the strongly preferred 2+ poses significant challenges in obtaining high-quality crystals in the first place [5].

To address this issue, we have developed a purposely designed experimental approach utilizing charge transfer. We demonstrate that Ni in low-work-function metallic thin films can be driven to a valence state much lower than 2+. This advancement enables in-depth experimental studies on the nature of Ni 3d electrons and their intricate interactions with surrounding itinerant electrons. Our work presents a clean and effective method for synthesizing quantum materials containing low-valence nickel.

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Molecular-beam epitaxy of $SrMoO_3$ films with record low electrical resistivity

Anna Park, Cornell University

Anna S. Park [1,2], Vivek Anil [3], Matthew R. Barone [1,2], Brendan D. Faeth [2], Evan Krysko [1,2], Maya Ramesh [1], Tobias Schwaigert [1,2], Kyle M. Shen [3,4], Darrell G. Schlom [1,2,4,5]

[1] Department of Materials Science and Engineering, Cornell University, Ithaca, New York 14853, USA
[2] Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM), Cornell University, Ithaca, New York 14853
[3] Department of Physics, Laboratory of Atomic and Solid State Physics, Cornell University, Ithaca, New York 14853, USA
[4] Kavli Institute at Cornell for Nanoscale Science, Ithaca, New York 14853, USA
[5] Leibniz-Institut für Kristallzüchtung, Max-Born-Str. 2, 12489 Berlin, Germany

$SrMoO_3$ (SMO) is the most conductive perovskite oxide known with a reported room-temperature resistivity of ~5.1 μΩ·cm, about 40 times more conductive than $SrRuO_3$. This makes it an attractive material as a bottom electrode for perovskite heterostructures. SMO is also transparent in the visible spectrum, making it of interest as a transparent conducting oxide due to its 17x higher conductivity than the most conducting indium tin oxide. Importantly, the properties of oxide conductors depend strongly on composition, where off-stoichiometry can increase the room-temperature resistivity and dramatically decrease the residual resistivity ratio (ρ(300 K)/ρ(4 K)). This disorder is presumably responsible for the factor of 5 difference between the lowest room-temperature resistivity values obtained to date for SMO films compared to the best SMO bulk crystals. Here we report the properties of SMO thin films grown via molecular-beam epitaxy in an adsorption-controlled regime of substrate temperatures above 1100 °C, accessible by CO2 laser heating, in which SrO becomes volatile. The resulting phase-pure epitaxial SMO thin films are characterized by narrow rocking curves, room-temperature resistivities significantly lower than all prior epitaxial SMO films (<17 μΩ cm), and residual resistivity ratios better even than the best SMO single crystals reported to date. In situ angle-resolved photoemission measurements of these SMO films reveal remarkably sharp quasiparticles, allowing us to resolve subtle features in the spectra, such as band folding that arises from orthorhombic distortions.

Novel magnetic Ni-N-Ni centers in N-substituted NiO

George A. Sawatzky, University of British Columbia

George A. Sawatzky [1]

[1] University of British Columbia, Vancouver, British Columbia, Canada

Building on the concept of creating individual magnetic centers, we investigate the local electronic structure and magnetic ordering in nickel oxide (NiO) induced by substituting oxygen (O) atoms with nitrogen (N). Each nitrogen atom introduces an N 2p hole that strongly interacts with the electrons of a neighboring nickel (Ni) cation, with the resulting exchange interaction dominating the native superexchange mechanism. This interaction gives rise to the formation of Ni–N–Ni units composed of five coupled spins, which are decoupled from the long-range antiferromagnetic (AFM) order of the NiO lattice and exhibit degenerate spin states. We study these defect centers using density functional theory and validate their presence through high-resolution spectroscopy measurements on N-substituted NiO thin films grown by molecular beam epitaxy. This magnetic defect design presents a new platform for exploring quantum functionalities in strongly correlated oxides, with potential applications in quantum sensing and spin-qubit architectures.

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Density Wave Ordering in the Bilayer Nickelate Superconductor $La_3Ni_2O_7$

Kyle Shen, Cornell University

K.M. Shen [1], C.T. Parzyck [1], Y. Wu [1], D.G. Schlom [1], and D.G. Hawthorn [2]

[1] Departments of Physics and Materials Science and Engineering, Cornell University, Ithaca NY 14853, USA
[2] Department of Physics, University of Waterloo, Waterloo ON, Canada

The discovery of high-temperature superconductivity in $La_3Ni_2O_7$ has motivated the investigation of parent or competing phases which could shed light on the underlying pairing interaction and phase diagram. Here, we employ resonant elastic and inelastic soft x-ray scattering and polarimetry on MBE-grown thin films of bilayer $La_3Ni_2O_7$ to reveal the existing of a spin density wave (SDW) which forms unidirectional diagonal spin stripes with moments lying within the NiO_2 plane and perpendicular to the SDW wavevector. These stripes form anisotropic domains with shorter correlation lengths perpendicular versus parallel to the SDW wavevector, revealing nanoscale rotational and translational symmetry breaking analogous to the cuprate and Fe-based superconductors [1]. In addition, we also investigate another polymorph of $La_3Ni_2O_7$, a repeating monolayer-trilayer structure (so-called "1313") and compare the magnetic excitations and ordering between the two polymorphs.

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Zero-strain metal-insulator transition for ultrafast switching and ultimate endurance

Junwoo Son, Seoul National University

Y. Park [1], H. Sim [1], S. Lee [2], W.-W. Park [3], J. Hwang [4], P. Hur [1], Y. Lee [2], D. K. Lee [2], K. Song [5], J. Lee [4], O.-H. Kwon [3], S.-Y. Choi [1], J. Son [2]

[1] Department of Materials Science and Engineering, POSTECH, Pohang, South Korea
[2] Department of Materials Science and Engineering, Seoul National University, Seoul, South Korea
[3] Department of Chemistry, Ulsan National Institute of Science and Technology, Ulsan, South Korea
[4] Department of Physics, Pusan National University, Busan, South Korea
[5] Materials Characterization Center, Korea Institute of Materials Science, Changwon, South Korea

The coupled electronic and structural transitions in metal-insulator transition (MIT) hinder ultrafast switching and ultimate endurance. Decoupling these transitions and achieving a zero-strain electronic MIT can overcome the fundamental limitations of MIT in solid materials. Here, we demonstrate that iso-valent Ti dopants in supercooled VO_2 epitaxial films cause MIT with minimal hysteresis without changing unit-cell volume and crystal symmetry. The Ti dopants in the VO_2 lattice locally alter the configuration of V-V pairs, where the long-range ordering in V-V pairs is disrupted, and the nano-domains of V-V dimers are formed. Strikingly, these local V-V dimers persist even above the electronic transition temperature (TMI), facilitating the zero-strain electronic MIT with nanoscale structural heterogeneity. The geometrically compatible interface between insulating and metallic phases drastically enhances switching speed and endurance during electrically and optically driven zero-strain MIT. This discovery offers a fresh perspective on the scientific understanding of MIT and the improved functionality in terms of device speed and reliability by decoupling electronic and structural transitions.

Colossal and tunable dielectric tunability in domain-engineered ferroelectric thin films

Jonathan E Spanier, Drexel University

J. E. Spanier [1]

[1] Department of Mechanical Engineering & Mechanics, Department of Physics, Department of Electrical & Computer Engineering, Department of Materials Science and Engineering, Drexel University, Philadelphia PA 19104-2875, USA

Realization of tunable materials that are multifunctional and maintain high performance in dynamically changing environments is a fundamental goal of science and engineering. Tunable dielectrics form the basis of a wide variety of communication and sensing devices and require breakthrough performance improvement to enable next-generation technologies. Using phenomenological modeling, film growth, and characterization, we show that devices consisting of domain-wall-rich ferroelectric films close to a polar-domain-variant phase boundary exhibit colossal dielectric tunability of 100:1 (99%) at a voltage (electric field) of ~15 V (750 kV/cm), resulting in a tunability-quality factor product figure of merit that rises to nearly 10^5, two orders of magnitude higher than the best previous reported values. Remarkably, varying the amplitude of alternating-current bias enables modulation of this tunability by 50%, owing to domain-wall motion. These results suggest that domain engineering is a powerful approach for achieving unprecedented modulation of functional properties in ferroelectric films.

Mechanism of the Enhanced Ferromagnetism in a $La_{2/3}Sr_{1/3}MnO_3$ Membrane studied by Synchrotron Radiation Spectroscopy

Takahito Takeda, The University of Tokyo

Takahito Takeda [1], Takuma Arai [2], Daigo Matsubara [2], Kohei Yamagami [3], Le Duc Anh [2,4], Masaaki Tanaka [2,4], Masaki Kobayashi [2,4], and Shinobu Ohya [2,4]

[1] Department of Chemical System Engineering, The University of Tokyo
[2]Department of Electrical Engineering and Information Systems, The University of Tokyo
[3]Japan Synchrotron Radiation Research Institute
[4]Center for Spintronics Research Network, The University of Tokyo

$La_{2/3}Sr_{1/3}MnO_3$ (LSMO) is a promising material for spintronic applications due to its high Curie temperature (T_C) above 300 K and half-metallicity. However, in LSMO-based devices, ferromagnetism and conductivity are degraded by the formation of interfacial dead layers. Epitaxial lift-off using a water-soluble buffer layer, such as $Sr_4Al_2O_7$ (SAO), has emerged as an effective method to mitigate this issue, enhancing magnetization and T_c [1,2]. Nevertheless, its underling detailed origin remains unclear. In this study, we grew a LSMO/SAO heterostructure on a STO substrate via molecular beam epitaxy and subsequently transferred the LSMO film onto a p-type Si substrate by dissolving the SAO layer. The LSMO membrane exhibited enhanced ferromagnetism with a magnetic moment of 3.2 μB/Mn and T_C = 323 K compared to 2.0 μB/Mn and T_C = 312 K in the as-grown film. Our X-ray magnetic circular dichroism analysis revealed that the orbital magnetic moment of Mn in the membrane is ~3 times larger than that in the as-grown film. Furthermore, we found that epitaxial lift-off reduces the anisotropy of the orbital magnetic moments between the [001] and [100] directions. This enhancement is attributed to increased itineracy of the Mn 3*d* electrons, which is observed in our resonant photoemission spectroscopy (RPES) experiments [3], providing a plausible explanation for the improved ferromagnetism.

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Realisation of Field-Effect Transistor with a Freestanding $SrTiO_3$ Channel

Kosuke Tanaka, National Institute of Advanced Industrial Science and Technology

K. Tanaka [1,2], H. Inoue [1], A. Kitoh [1], M. Tamura [2], and I. H. Inoue [1,2]

[1] National Institute of Advanced Industrial Science and technology (AIST), Tsukuba 305-8565, Japan
[2] Department of Physics and Astronomy, Tokyo University of Science, Noda 278-8510, Japan

Strontium titanate ($SrTiO_3$, STO), an oxide semiconductor, exhibits diverse functionalities such as two-dimensional electron systems, ionic conduction, and ferroelectricity, beneficial for next-generation electronics through integration with CMOS technology. Recent advances using water-soluble sacrificial layers [1] allow freestanding oxide films to be transferred onto various substrates without high-temperature processes, promising for incorporation into CMOS platforms. Pursuing this approach, we report for the first time the fabrication and operation of a freestanding STO-FET — a field-effect transistor employing a freestanding STO film as the channel.
To fabricate the freestanding film, an epitaxial bilayer of STO/$Sr_4Al_2O_7$ was grown on an STO substrate by pulsed laser deposition. The sacrificial $Sr_4Al_2O_7$ layer was selectively removed by water immersion, resulting in the release of the STO film, which was subsequently transferred onto a Si/SiO_2 substrate. By optimizing the transfer process and using lattice-matched $Sr_4Al_2O_7$, an STO freestanding film crack-free over 100-µm-square was successfully obtained. Subsequently, a bilayer of Parylene C and HfO_2 was deposited as the gate insulator for the fabrication of the freestanding STO-FET. A low gate leakage ($I_G < 0.1$ nA) and a high on/off ratio (> 1000) were confirmed by I–V measurements, indicating strong carrier modulation even in a fully freestanding channel [2]. These results open pathways for ultra-low-power devices, including neuron-inspired elements compatible with CMOS circuits.

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Resonant MEMS based on $La_{2/3}Sr_{1/3}MnO_3$ suspended double-clamped microbridges for uncooled bolometer applications.

Gaia Tarsi, Normandie University

G. Tarsi [1], F. van der Laan [2,3], N. Manca [4], V. Pierron [1], L. Catalini [2,3], J. Blond [1], B. Guillet [1], S. Flament [1], Z. Wang [5], D.G. Schlom [5], D. Marrè [4,6], L. Pellegrino [4], L. Méchin [1]

[1] Normandie University, UNICAEN, ENSICAEN, CNRS GREYC, 14000 Caen, France.
[2] QSTeM, Testbed for Mechanical Quantum Sensing, 2628 XJ Delft, The Netherlands F, Science Park 104, 1098XG Amsterdam, The Netherlands.
[3] Center for Nanophotonics, AMOLF, Science Park 104, 1098XG Amsterdam, The Netherlands.
[4] CNR-SPIN, C.so F. M. Perrone, 24, Genova 16152, Italy.
[5] Department of Materials Science and Engineering, Cornell Univ., Ithaca, New York 14853-1501, USA.
[6] Dipartimento di Fisica - Universitá degli Studi di Genova, Via Dodecaneso, 33, Genova 16146, Italy.

In resonant bolometers, the power of incident radiation is measured through a frequency shift of the mechanical resonance of a suspended structure. In this work, $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) double-clamped microbridges were fabricated by UV laser lithography, Ion Beam Etching, and Reactive Ion Etching in SF_6 plasma [1]. These devices are realized from multilayered heterostructures made of LSMO (45 nm)/$CaTiO_3$/$SrTiO_3$ (20 nm) on silicon substrates. The $CaTiO_3$ thickness was varied from 0 to 14 nm to compensate epitaxial strain, improving fabrication yield and frequency reproducibility. Resonant frequencies were measured on 594 microbridges (5 µm wide, 50–250 µm long) using two setups: optical lever with piezo-driven excitation and interferometric readout with thermal noise actuation. All microbridges followed the string resonator model [2], enabling stress extraction above 550 MPa with excellent fabrication yield. Quality factors above 10^5 were measured in the best devices [3]. The temperature dependence of the resonance frequency of a 250 µm-long bridge was measured from 0 to 100 °C by heating the sample using a Peltier cell, showing linear behavior. Finally, a 2 µm laser spot (wavelength = 1510 nm, 0–100 µW) was employed to measure the bolometric responsivity $R = (1/f_0)(df/dP)$ of a 250 µm-long bridge. Values of R as high as 7×10^3 W^{-1} were achieved at room temperature, showing a one order of magnitude improvement over GaAs-based devices [4], confirming the potential of epitaxial oxides for infrared detection.

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Magnetic field driven re-entrant superconductivity in infinite layer nickelates

Lucia Varbaro, University of Geneva

Lucia Varbaro [1], Lukas Korosec [1], Chih-Ying Hsu [1,2], Marc Gabay [3], Duncan T.L. Alexander [2], Jean-Marc Triscone [1]

[1] DQMP, University of Geneva, Geneva, Switzerland
[2] Electron Spectrometry and Microscopy Laboratory (LSME), Institute of Physics (IPHYS), Ecole Polytechnique Fédérale
de Lausanne (EPFL), Lausanne, Switzerland
[3] Laboratoire de Physique des Solides, Université Paris-Saclay, CNRS UMR 8502, Orsay, France

We explore the synthesis and emergent electronic behavior of infinite-layer nickelate thin films (112 phase), focusing on $Nd_xEu_xNiO_2$ (NENO) and $Sm_{1-2x}Nd_xEu_xNiO_2$ (SNENO) solid solutions. The infinite layer superconducting phase is obtained from perovskite nickelates via a topotactic reduction, as demonstrated by D. Li [1] using CaH_2 or NaH to selectively remove apical oxygens and induce a square planar NiO_2 coordination. Following the solid-state route proposed by W. Wei [2,3], we deposit metallic aluminum onto a perovskite film and use the reaction $2Al + 3NdNiO_3 \rightarrow Al_2O_3 + 3NdNiO_2$ to obtain the 112 phase. All thin films were synthesized via RF off-axis magnetron sputtering, with the aluminum layer deposited in situ on-axis.
Using high-quality 113 nickelate films and heterostructures [4-6], the 112 NENO and SNENO phases on LSAT and $NdGaO_3$ (NGO) substrates respectively were successfully obtained. The interplay between the field response of the Eu^{2+}, Nd^{3+} and Sm^{3+} magnetic ions and superconductivity in these infinite-layer systems was investigated.
The lower-T_c samples display a striking re-entrant superconducting behavior and distinct superconducting domes in the H_{c2}-T_c magnetic phase diagram are observed, consistent with the Jaccarino–Peter effect [7] linked to the negative exchange field between the magnetic rare earth ions and electron spins. The presented Hall effect data can be successfully modeled by including an anomalous Hall term proportional to the spin paramagnetic response of the aforementioned magnetic ions.

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Scalable Fabrication of Functional Fe_3O_4 Nanodots on Nb:$SrTiO_3$ Substrates

Yifan Xu, Forschungszentrum Jülich

Y. Xu [1,2], C. Bednarski-Meinke [2], Y.-P. Liu [3], E. Wang [3], A. Qdemat [2], P. Yuan [3], L. M. Vogl [4], P. Schöffmann [5], C. Yin [1,2], G. Dehm [4], F. Gunkel [3], R. Dittmann [3], O. Petracic [2,1], and M. H. Hamed [6,2]

[1] Faculty of Mathematics and Natural Sciences, Heinrich Heine Universität Düsseldorf, Düsseldorf, Germany
[2] Jülich Centre for Neutron Science (JCNS-2) and JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany
[3] Peter Grünberg Institute (PGI-7), Forschungszentrum Jülich GmbH, Jülich, Germany
[4] Max Planck Institute for Sustainable Materials, Düsseldorf, Germany
[5] Synchrotron SOLEIL, L'Orme des Merisiers, Saint-Aubin, France
[6] Faculty of Science, Helwan University, Cairo, Egypt

Iron oxide heterostructures are promising for future electronic and spintronic applications. Scaling these systems down to the nanoscale opens new opportunities to study size effects and interfacial phenomena in confined geometries. However, achieving well-ordered nanostructures while retaining key material properties remains a challenge. In this work, we demonstrate a bottom-up approach for creating highly ordered Fe_3O_4 nanodot arrays of different sizes of 30 nm and 70 nm on Nb-doped $SrTiO_3$ substrates. The fabrication combines pulsed laser deposition (PLD) with commercially available anodic aluminum oxide (AAO) templates, enabling lateral confinement into nanodots with diameters as small as 30 nm. Structural characterization using X-ray diffraction (XRD), scanning transmission electron microscopy (STEM), and grazing-incidence small-angle X-ray scattering (GISAXS) confirms good crystallinity and long-range ordering of the nanodot arrays. Magnetic measurements reveal that the Verwey transition is preserved, indicating that the nanodots maintain the stoichiometry and magnetic behavior of continuous films. Moreover, conductive atomic force microscopy (cAFM) reveals room-temperature bipolar resistive switching at the single-dot level. This scalable method enables reliable downscaling of functional oxide systems while preserving their key structural, magnetic, and electrical characteristics. It provides a platform to explore redox-active interfaces and switching phenomena in spatially confined geometries, and can be readily extended to other complex oxide materials.

Ultrafast spin dynamics and spin-glass behavior with/without strained $Y_3Fe_5O_{12}$ (YIG) thin films characterized by time-resolved magneto-optic Faraday effect (TR-MOFE)

Dongxun Yang, The University of Tokyo

Dongxun Yang [1], Md Shamim Sarker [2], Hiroyasu Yamahara [1], Munetoshi Seki [1,2], Hitoshi Tabata [1,2]

[1] Department of Bioengineering, Graduate School of Engineering, The University of Tokyo, Tokyo, Japan
[2] Department of Electrical Engineering and Information Systems, Graduate School of Engineering, The University of Tokyo, Tokyo, Japan

Yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG) is a widely studied magnetic insulator, renowned for its exceptional magnetization characteristics and low damping. Recent advances in doping and interface strain engineering have enabled YIG thin films to exhibit spin glass behavior at room temperature, presenting exciting opportunities for neuromorphic computing applications. However, characterizing the local spin dynamics and spin glass phase in YIG remains a challenge due to limitations in conventional excitation and detection techniques. In this study, we employ time-resolved magneto-optic Faraday effect (TR-MOFE) measurements to probe the nano-pico-second time scale spin dynamics of YIG thin films grown on GGG ($Gd_3Ga_5O_{12}$) and YAG ($Y_3Al_5O_{12}$) substrates. The TR-MOFE system enables us to resolve key magnetic properties such as ultrafast demagnetization, spin precession, and damping behavior under both in-plane and out-of-plane external magnetic fields. Using the Kittel model and damped oscillator analysis, we extract ferromagnetic resonance parameters and evaluate magnetic anisotropy. Moreover, we investigate the magnetic field-induced transition to the spin glass phase in YIG/YAG heterostructures. Our results provide new insights into the ultrafast magnetization processes in YIG thin films, offering valuable information for the development of next-generation spintronic and neuromorphic devices.

Poster Presentations

Deposition and characterization of spinel IGZO thin films with increased indium contents

Evangelos Agiannis, KU Leuven

E. Agiannis [1,2], H.F.W. Dekkers [2], M. Agati [2], A. Delabie [2,1]

[1] Department of chemistry, KU Leuven, Celestijnenlaan 200F, Leuven 3001, Belgium
[2] Imec, Kapeldreef 75, Leuven 3001, Belgium

Indium gallium zinc oxide (IGZO) is a n-type semiconducting oxide, characterized by its wide band gap, the absence of mobile holes and the low deposition temperature of its amorphous phase. Due to these characteristics, it has attracted a lot of attention for various applications, ranging from optical displays to 3D memory elements. Spinel IGZO is a metastable phase represented by space group $Fd\bar{3}m$ (227). When compared to amorphous IGZO, it is predicted to be less sensitive to oxygen vacancy formation due to its more uniform oxygen bonding [1], making it electrically more stable. Increasing the indium concentration of spinel IGZO is expected to cause an improvement of its carrier mobility due to the enhanced overlap of the 5s orbitals that originate from indium atoms [2,3]. Spinel indium zinc oxide (IZO) has been studied by density function theory simulations [4], but its growth in significant quantities has not yet been established.
In this study, we discuss the deposition of polycrystalline spinel IGZO films with increased indium contents by employing co-sputtering from multiple targets, positioned around a substrate with a polycrystalline spinel gallium zinc oxide template. It was found that the bombardment with O^- during sputtering enhanced the growth into the spinel structure. By optimizing the deposition conditions, it was possible to deposit films with indications of spinel IZO crystallites, providing the opportunity for a high mobility and electrically stable semiconducting oxide for flexible and/or transparent electronics.

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$Cu/SiO_2/Pt$ Atomic Switches Operable at Cryogenic Temperatures

Ryuichiro Arayama, Waseda University

R. Arayama [1,2], T. Tsuruoka [2], K. Terabe [2], T. Watanabe [1], and Y. Kozuka [1,2,3]

[1] School of Advanced Science and Engineering, Waseda University, Shinjuku-ku, Tokyo, Japan
[2] Research Center for Materials Nanoarchitechtonics, National Institute for Materials Science, Tsukuba, Ibaraki, Japan
[3] WPI Advanced Institute for Materials Research, Tohoku University, Sendai, Miyagi, Japan

In recent years, research and development of quantum computers have advanced rapidly. A significant challenge in quantum computers operating at cryogenic temperatures is the increasing number of coaxial cables used to transmit microwaves within cryostats, which leads to limitations in both space and cooling capacity. This study aims to address this issue by developing atomic switches potentially capable of operating at cryogenic temperatures. An atomic switch is a device that turns resistance on and off by reversibly formation and dissolution of nanoscale metallic filaments, based on the migration of metal ions [1,2]. While switching phenomena in metal-insulator-metal structures have been reported previously [3-6], demonstrations of atomic switching at low temperatures are still limited. In this work, we fabricated atomic switches with a $Cu/SiO_2/Pt$ layered structure and investigated their switching behavior from room temperature down to cryogenic temperatures. We confirmed successful switching operation even at 4 K. Although successful operation at cryogenic temperatures has been achieved, several challenges remain, including stable switching repeatability and relatively high on resistance values.

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Tuning phase-change and metal-insulator transitions in VO_2 for metasurfaces and memristors

Ariando, National University of Singapore

Saurav Prakash [1], Xing Gao [1], Qi Gang Yap [1], Prakash Pitchappa [2], A. Ariando [1]

[1] Department of Physics, National University of Singapore, Singapore 117551
2 Institute of Microelectronics (IME), Agency for Science, Technology and Research (A*STAR), Singapore 138634

Vanadium dioxide (VO_2) is a phase-change material that exhibits a well-known metal-insulator transition, making it a promising candidate for next-generation electronic devices. Its relatively low transition temperature offers significant potential for emerging applications, including neuromorphic computing and terahertz (THz) devices for future wireless communication, sensing, and non-destructive imaging technologies. Metasurfaces, with their diverse functionalities, compactness, and simplified fabrication compared to traditional 3D structures, have emerged as a transformative solution. However, conventional metasurfaces are limited by in-plane mirror symmetry and restricted degrees of freedom, which constrain their capabilities for advanced chiral response, beamforming, and reconfiguration. Achieving dynamic tunability has thus become a major focus of research. Among various strategies, integrating VO_2 has proven effective due to its insulator-to-metal phase transition at 67°C, which induces significant changes in conductivity and permittivity. Yet, the simultaneous variation of these properties can pose challenges for certain applications.

In this work, we fabricate and characterize tungsten-doped VO_2 single bridge devices to reduce the switching voltage and power requirements. With tungsten doping, we achieve up to an 84% reduction in switching voltage and a 44% reduction in power at 3% tungsten concentration, compared to undoped VO_2 bridges. To evaluate practical utility, these doped devices are incorporated into oscillator circuits, demonstrating reliable switching behavior on par with undoped VO_2 devices. This represents a significant advancement for VO_2-based electronics, particularly for neuromorphic computing where low-power, high-speed switching is essential for emulating synaptic behavior in high-performance systems. Additionally, we present a robust and scalable platform for multifunctional THz metadevices based on electrically actuated resonators, capable of dramatic reconfiguration between planar and 3D geometries by harnessing the VO_2 phase transition. Our approach achieves tunable responses through structural changes in the resonators rather than relying solely on the intrinsic material properties of VO_2. We demonstrate this platform with 3D split ring resonators, employing two complementary mechanisms: folding induced by stress mismatch for non-volatile state design and unfolding triggered by strain during VO_2 phase transition for volatile reconfiguration. This broad structural reconfiguration enables resonance mode switching, highly tunable magnetic and electric polarizabilities, and increased frequency agility. Consequently, these VO_2-integrated metadevices offer electrical reconfigurability, multifunctionality, spectral scalability, and adaptability, making them highly attractive for emerging 6G applications such as reconfigurable intelligent surfaces, holographic beam formers, and spatial light modulators.

About the Quantum Phenomena of Oxide Thin Films on Vicinal Substrates

Nicolas Bonmassar, University of Stuttgart

N. Bonmassar [1]

[1] Department for Materials Physics, Institute for Materials Sciences, University of Stuttgart, Stuttgart, Germany

I will report on the recent findings on the utilization of offcut/vicinal substrates by facilitating atomic precision layer-by-layer growth in both in-plane and out-of-plane directions. This objective is realized through the implementation of *in situ* monitoring of the oscillations of the reflected high-energy electron diffraction (RHEED) patterns. The efficacy of this method is illustrated by the observation of interfacial ferromagnetism in a bidirectionally grown superlattice of alternating $LaMnO_3$ and $SrMnO_3$ layers. [1] This superlattice functions as a model system, thereby demonstrating the method's versatility. By employing a variety of scanning transmission electron microscopy techniques, sheet resistance measurements, and magnetometry we characterized our samples. Next, the approach is applied to the growth of superconducting $La_{1.84}Sr_{0.16}CuO_4$ thin films grown in ozone atmosphere on various offcut substrates. The anisotropic critical current is found to arise from two distinct mechanisms induced by the substrate geometry.

Building on this capability for atomically precise growth on offcut substrates, we are currently exploring the potential of controlled substrate offcut angles and step morphologies for the creation of highly ordered nanostructured channels for gas sensing, as measured by electric resistivity. In this configuration, the growth of ultrathin metal-oxide films (e.g., WO_3) with a high number of step-edges is guided by offcut substrates, thereby enhancing the sensitivity to changes in electric resistance.

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Oxygen vacancy driven resistive switching in $SrTiO_3$/Si(001) heterostructures due to an electronic mechanism

Sam Cantrell, Texas State University

Patrick Kollias [1], Ryan Cottier [1], John Miracle [2], Samuel Cantrell [2], and Nikoleta Theodoropoulou [1,2]

[1] Department of Physics, Texas State University, San Marcos, Texas 78666, USA
[2] Materials Science Engineering and Commercialization Program, Texas State University, San Marcos, Texas 78666, USA

Resistive switching (RS) has been extensively studied for its potential applications in non-volatile memory and neuromorphic devices. RS in oxides is closely linked to the presence of oxygen vacancies, which play a crucial role in its underlying mechanism. One of the most widely explored RS mechanisms involves the migration of oxygen ions within the oxide. We investigate the RS behavior of strontium titanate ($SrTiO_3$) thin films grown directly on Si(001) substrates using oxide molecular beam epitaxy. Structural characterization confirms that the $SrTiO_3$/Si interface remains atomically sharp and that there is no SiO at the interface. We examine the dependence of the RS behavior on the oxygen vacancy concentration and substrate type using conductive Atomic Force Microscopy (c-AFM). We demonstrate that the hysteresis observed in the I–V characteristics of $SrTiO_3$/Si heterojunctions is driven by oxygen vacancy migration. We find that the concentration of oxygen vacancies in $SrTiO_3$ is the primary determinant of the RS behavior. We simulate the band bending at the heterostructure using COMSOL, successfully reproducing the salient I–V characteristics observed experimentally. Our model considers only electronic effects and incorporates a layer of oxygen vacancies that drifts under an applied voltage. We demonstrate that both the conduction-band offset between Si and $SrTiO_3$, and the oxygen vacancy distribution are critical in determining RS behavior and reproducing the experimental I–V characteristics. [1]

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Oxide Piezoelectric Films on Flexible Glass

Juliette Cardoletti, Technische Universität Darmstadt

J. Cardoletti [1], L. Song [1], A.-M. Philippe [2], S. Girod [1], B. Malic [3], E. Defay [1,4], and S. Glinsek [1]

[1] Smart Materials Unit, Luxembourg Institute of Science and Technology, Belvaux, Luxembourg
[2] Advanced Analysis and Support Unit, Luxembourg Institute of Science and Technology, Belvaux, Luxembourg
[3] Electronic Ceramics Department, Jožef Stefan Institute, Ljubljana, Slovenia
[4] Department of Physics and Materials Science, University of Luxembourg, Belvaux, Luxembourg

With the rise of wearable electronics, flexible substrates are quickly becoming a key factor of integration. One of their major drawbacks is a relatively low maximum processing temperature, below the crystallization temperature of numerous oxide thin films. Yet, enabling piezoelectric thin films deposition on flexible substrates is the key to numerous applications, including in the medical field.

With its large piezoelectric coefficient and transparency, lead zirconate titanate (PZT) is widely used in industry and an obvious candidate for integration on glass. Its crystallization on thick, rigid glass [1] has already been demonstrated using flash lamp annealing but there is no report of piezoelectrics crystallized directly on thin, flexible glass.

Flash lamp annealing is a powerful tool to thermally treat samples through the absorption of broad-spectrum light. Its integration in a sol-gel process allows treatment of large area oxide thin films on temperature-sensitive substrates, which is particularly suited for industrial applications. Yet, the large amount of energy it delivers in a minimal time frame proves challenging for thin, flexible glass.

In this work, we demonstrate crystallization and macroscopic ferroelectric properties of PZT thin films grown directly on thin and flexible glasses, including alumina-borosilicate and borosilicate, through flash lamp annealing. The achieved films crystallize in perovskite phase and they exhibit an in-plane permittivity of 340 with dielectric losses below 5 % and a maximum polarization larger than 20 μCcm^{-2}.

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Microstructures of $BaTiO_3$ films grown on LSAT and $SrTiO_3$ by molecular beam epitaxy

Yupeng Chen, The University of British Columbia

Y. Chen [1,2], B. Davidson [1,2], X. Xin [2,3], L. Chrostowski [2.3], K. Zou [1,2]

[1] Department of Physics & Astronomy, University of British Columbia, Vancouver, British Columbia, Canada
[2] Quantum Matter Institute, University of British Columbia, Vancouver, British Columbia, Canada
[3] Department of Electrical and Computer Engineering, University of British Columbia, Vancouver, British Columbia, Canada

Barium titanate ($BaTiO_3$) is a ferroelectric material with a Curie temperature near 400 K, widely used in electronic and photonic applications. Recent studies have revealed that $BaTiO_3$ exhibits a Pockels coefficient significantly higher than that of conventional electro-optic materials such as lithium niobate, making it a promising candidate for next-generation electro-optic modulators and quantum photonic devices. Realizing high-quality $BaTiO_3$ thin films with well-controlled microstructure is therefore critical. In this work, we investigate the microstructural differences of $BaTiO_3$ films grown on $SrTiO_3$ and LSAT substrates using oxide molecular beam epitaxy. Structural characterization confirms high crystallinity. X-ray diffraction and reciprocal space mapping reveal clear substrate-dependent variations in lattice parameters and in the relative proportions of a- and c- domains, which we attribute primarily to the larger lattice mismatch between $BaTiO_3$ and LSAT. This study offers a strategy for controlling the extrinsic microstructure of $BaTiO_3$ thin films through substrate selection.

Controlling Oxygen Vacancies for Enhanced TER and Linear Synaptic weight in $Hf_{0.7}Zr_{0.3}O_2/La_{0.7}Sr_{0.3}MnO_3$Heterostructure

Taekjib Choi, Sejong University

H. Lee [1], H. Chung [1], D. H. Ryu [1], M. Lee [1], J. Lee [1], and T. Choi [1]

[1] Department of Nanotechnology & Advanced Materials Engineering, Sejong University, Seoul 05006, Republic of Korea

Ferroelectric tunnel junctions (FTJs) are promising candidates for artificial synapses due to their inherent non-volatility and analog resistive switching behavior. However, achieving both high tunneling electroresistance (TER) and linear synaptic weight updates remains challenging. In this study, Pt/$Hf_{0.7}Zr_{0.3}O_2$ (HZO)/$La_{0.7}Sr_{0.3}MnO_3$ (LSMO) heterostructures were fabricated by pulsed laser deposition, followed by in-situ annealing under low oxygen partial pressure to intentionally introduce oxygen vacancies in the LSMO bottom electrode. Electrical measurements revealed that oxygen-deficient LSMO promotes enhanced vacancy migration under bias, resulting in strong interfacial resistance modulation and increased TER. Moreover, vacancy-induced pinning sites in the HZO layer facilitated gradual and symmetric polarization switching, which is crucial for linear synaptic updates. Piezoresponse force microscopy confirmed domain control and reversible switching across the heterointerface. Numerical simulations using experimental parameters achieved 94.8 % recognition accuracy on the MNIST dataset, demonstrating the potential of the device for neuromorphic computing. These results underscore interface defect engineering as a viable route to optimize memory and synaptic behavior in FTJ-based systems .

Pulsed Laser Deposition of Rare Earth Perovskite Nickelates for Metal Insulator Transition Spatial Resolution

Laszlo Cline, Northwestern University

L. Cline [1], M. Kiaba [1], A. Kaplan [1], A. Devincenti [1], and J. Fowlie [1]

[1] Department of Materials Science and Engineering, Northwestern University, Evanston, IL, USA

Rare-earth perovskite nickelates ($RNiO_3$) are known for their metal to insulator transition (MIT) [1]. Due to strong coupling of lattice and charge degrees of freedom, $RNiO_3$ exhibit a MIT concurrent with a structural transition from orthorhombic to monoclinic below their transition temperature (TMI). These transition temperatures, dictated by the Ni-O-Ni bond angle, can be adjusted using epitaxial strain [2]. Recent studies have leveraged local probes to spatially resolve MIT evolution in $NdNiO_3$ [3, 4]. MIT spatial resolution enables the visualization of potential phase coexistence near TMI, a hallmark of first order behavior, as well as giving insight into nucleation and growth mechanisms and the interplay of order and disorder.
The goal of this project is to extend spatially resolved studies to RNOs where the MIT behavior is not conventionally first order. To achieve this, we optimize thin film growth by pulsed laser deposition (PLD). Preliminary measurements with spatial resolution will be presented.

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Layering control during the growth of Ruddlesden-Popper phases

Bruce Davidson, UBC/QMI

B. A. Davidson [1], S. Baronio [1] and K. Zou [1,2]

[1] Quantum Matter Institute, Univ. of British Columbia, 2355 East Mall, Vancouver BC V6T 1Z4
[2] Dept. of Physics and Astronomy, Univ. of British Columbia, 6224 Agricultural Road, Vancouver BC V6T 1Z1

In this work we describe layering control during thin-film growth of different polymorphs of Ruddlesden-Popper (RP) phases. The layered structure of the RP phases can be stabilized using "shuttered" growth approach based on alternating delivery of cations [1]. Growth of many transition-metal perovskite phases shows a B-site layer inversion mechanism that is readily seen in the intensity oscillations in the diffracted electron reflections [2]. Shuttered growth of RP phases allows stabilization of phase-pure films of high-order (up to n=50) that are not possible in bulk single crystals [3]. Following the discovery of high-temperature superconductivity in the n=2 RP phase of nickelates, renewed attention was focused on two different polymorphs of the n=2 phase, denoted "2-2-2-2" for the known n=2 phase and "1-3-1-3" for alternating n=1 and n=3 blocks that have the same global $A_3B_2O_7$ stoichiometry. We present layering recipes that take into account layer-inversion and allow precise formation of different polymorphs for RP phases of titanates, manganites and nickelates, as confirmed by X-ray diffraction.

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Pathways for growth and stabilization of nickelate superconducting phase

Antoine Devincenti, Northwestern University

A. Devincenti [1], M. Kiaba [1], L. Cline [1], A. Kaplan [1] and J. Fowlie [1]

[1] Materials Science & Engineering, Northwestern University, Evanston, Illinois, United States

The controlled growth and stabilization of transition metal oxides (TMOs) are crucial to studying their intrinsic electronic properties, including superconducting phases.
In 2023, Sun et al reported superconductivity in Ruddlesden-Popper $La_3Ni_2O_7$ under strong hydrostatic pressure [1]. Ko and Yu et al. have recently reported stabilization of $La_3Ni_2O_7$ thin films via epitaxial strain using compressive $SrLaAlO_4$ (SLAO) substrate, enabling the existence of the superconducting phase at ambient pressure [2]. Finer control of stability, stoichiometry and crystallinity of this superconducting phase is necessary to better understand its underlying nature. Direct and indirect reaction pathways are investigated to synthesize thin films of $La_3Ni_2O_7$. The direct, or conventional, method is to grow $La_3Ni_2O_7$ via pulsed laser deposition (PLD). Such a method requires precise control of the temperature and oxygen partial pressure. The quality of the substrate plays a crucial role in achieving defect-free thin films. Therefore, annealing conditions are optimized to produce favorable substrate termination that ensure controlled film growth. While working on improving $La_3Ni_2O_7$ film quality via the direct method, an indirect method is investigated to achieve its synthesis. The indirect method uses soft chemistry to synthesize $La_3Ni_2O_7$ by post-processing the perovskite $LaNiO_3$ phase, also grown by PLD.
Both direct and indirect methods are investigated in this work and preliminary results will be discussed.

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Controlling proton migration in oxide heterostructures by interfacial chemical potential mismatch

Sota Fuji, Kyoto University

S. Fuji [1], L. Xie [1], R. Aso [2], T. Majima [3], Y. Shimakawa [1], D. Kan [1]

[1] Institute for Chemical Research, Kyoto University, Kyoto, Japan
[2] Department of Applied Quantum Physics and Nuclear Engineering, Kyusyu University, Fukuoka, Japan
[3] Department of Nuclear Engineering, Kyoto University, Kyoto, Japan

Controlling proton accumulation and migration in oxides is important for exploring their functional properties. In this study, we show that electrochemical protonation and proton diffusion in rutile-structured VO_2 epitaxial films with the (001) orientation can be controlled by capping them with TiO_2 epitaxial films. Quantitative evaluation of protons by elastic recoil detection analysis (ERDA) revealed that when protons were electrochemically injected into the TiO_2-capped VO_2 films in transistor structures with gate layers of Nafion membranes at 100 ºC, the injected protons passed through the TiO_2 cap layer and were accumulated in the VO_2 films. Furthermore, the accumulated protons remained and were confined in the VO_2 films even after the protonated TiO_2-capped VO_2 films were annealed at 100 ºC. These observations imply that the chemical potential mismatch at the TiO_2/VO_2 interface impacts on the proton accumulation and migration in VO_2. In this presentation, we will present details of electrochemical (de-)protonation of TiO_2-capped VO_2 and discuss the influence of the interfacial chemical potential mismatch on the proton accumulation and migration in VO_2.

Electric Field-Driven Rashba Spin-Orbit Fields in Al/$Sr_{1-x}Ca_xTiO_3$ interfaces

Janine Gückelhorn, Institut de Ciència de Materials de Barcelona (ICMAB-CSIC)

J. Gückelhorn [1], S. Plana-Ruiz [2, 3], G. Singh [1], S. Estandia [1], R. Guzman [1], F. Gallego [4], LM Vicente-Arche [4], M. Bibes [4], J. Gázquez [1], and G. Herranz [1]

[1] Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Campus de la UAB, Bellaterra, Spain.
[2] Scientific & Technical Resources, Universitat Rovira i Virgili, Tarragona, Spain.
[3] LENS-MIND, Department of Electronics and Biomedical Engineering, Universitat de Barcelona, Barcelona, Spain.
[4] Laboratoire Albert Fert, CNRS, Thales, Université Paris Saclay, Palaiseau, France.

Two-dimensional electron gases (2DEGs) at oxide interfaces, such as $SrTiO_3$ (STO)/$LaAlO_3$ or STO/Al, exhibit strong Rashba spin-orbit coupling (SOC), yet the microscopic mechanisms underlying this effect remain under debate. First principles density-functional-theory calculations suggests that Rashba interactions tend to be stronger in materials which are easier to polarize, distinguishing between orbital and lattice polarization induced by the interfacial electric field arising from broken inversion symmetry as origin of the Rashba effects [1].
Here, we investigate 2DEGs at Al/Ca-doped STO interfaces, where Ca substitution induces ferroelectricity and enhances the material's polarizability. We have varied the carrier density using electrostatic gating of the 2DEG and systematically analyzed the Rashba spin-orbit fields via weak-localization in magnetotransport. The results unambiguously demonstrate that Ca doping leads to a substantial increase in the Rashba coefficient compared to undoped STO. Performing four-dimensional scanning transmission electron microscopy (4D-STEM), we find that this enhancement correlates with a significant increase in the internal electric field of the 2DEG, while lattice displacements remain negligible across all Ca concentrations [2]. This shines further light on the Rashba SOC origin and highlights polarizability as a key control parameter for SOC in oxide 2DEGs.

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Oxide interfaces, Neuromorphic architecture, Synapses, Spintronics, Spin to charge conversion

Anshu Gupta, Denmark Technical University

A. Gupta [1, 2], A. Vashist [1], S. Chakraverty [1]

[1] 1 Quantum Materials and Devices Unit, Institute of Nano Science and Technology, Mohali, India.
[2] Current address: Department of Energy Conversion and Storage, Technical University of Denmark Kgs. Lyngby, 2800, Denmark.

Neuromorphic electronics, inspired by the complexity of the biological brain, hold promise for revolutionizing information technology by enabling more efficient computing paradigms [1]. Here, we investigate the potential of oxide heterostructure in serving as artificial synapses for neuromorphic computational networks. Our artificial synapse is based on the two-dimensional electron gas (2DEG) within the oxide heterostructure EuO–$KTaO_3$ (KTO), which exhibits optoelectronic properties essential for emulating key cognitive functions such as sensory perception, learning, and memory. In this study [2], we demonstrate how the EuO–KTO interface 2DEG may switch between volatile to nonvolatile resistive states through combined stimulation of a gate voltage and an optical signal. This optical simulation-induced switchability contrasts with the compliance current method otherwise for memristors. Our single artificial synaptic device not only accurately replicates the short- and long-term plasticity seen in biological synapses on scale of 0.05s to 509 s respectively but also performs logic gate operations, enhancing its versatility and functionality.

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Probing Interfacial Phonon-Mediated Superconductivity in Oxide Heterostructures Near Quantum Criticality

Roger Guzman, Institute of Materials Science of Barcelona

R. Guzman [1,2], M. Pruneda [3,4], J. P. Nery [3,5], M. Xu [2], Aowen Li [2], N. Wittemeier [4], Ang Li [2], G. Singh [4], N. Bergeal [6], A. Kalaboukhov [7], G. Herranz [4], J. Gazquez [4], and W. Zhou [2]

[1] Institute of Materials Science of Barcelona (ICMAB-CSIC), Bellaterra, Barcelona, Spain.
[2] School of Physical Sciences, University of Chinese Academy of Sciences, Beijing, China.
[3] Nanomaterials and Nanotechnology Research Center (CINN), CSIC-UNIOVI, El Entrego, Asturias, Spain.
[4] Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST, Bellaterra, Barcelona, Spain.
[5] Nanomat Group, QMAT Research Unit, and European Theoretical Spectroscopy Facility, Université de Liège, B-4000 Liège, Belgium
[6] Laboratoire de Physique et d'Etude des Matériaux, ESPCI Paris, Université PSL, CNRS, Sorbonne Université, Paris, France.
[7] Department of Microtechnology and Nanoscience - MC2, Chalmers University of Technology, Gothenburg, Sweden

The $LaAlO_3/SrTiO_3$ (LAO/STO) interface, known for its tunable 2D electron gas (2DEG), Rashba spin-orbit coupling, and proximity to a ferroelectric quantum critical point, is a key platform for studying low-dimensional superconductivity [1-3]. Yet, despite substantial theoretical interest in the quantum critical origin of the pairing interaction [4], direct evidence connecting interfacial phonon dynamics with electronic pairing mechanisms has remained elusive. In this study, we use monochromated, momentum-resolved vibrational electron energy loss spectroscopy [5] in scanning transmission electron microscopy, combined with ab initio calculations, to directly probe the lattice dynamics across LAO/STO interfaces with systematically varied carrier densities spanning the superconducting phase diagram. We observe that the emergence of superconductivity correlates with interfacial lattice polarization and the appearance of new high-frequency, localized phonon modes, which are highly sensitive to carrier concentration. Among the interfacial modes, we find that phonons comprising transversal vibrations of apical oxygens –which inherently break inversion symmetry– exhibit the strongest electron-phonon coupling. Our findings provide compelling experimental evidence that superconductivity at oxide interfaces arises from a fundamentally different microscopic mechanism than in the bulk, mediated by interfacial phonons near ferroelectric quantum criticality, with direct implications in other quantum paraelectrics such as KTaO3 and Ca-doped SrTiO3.

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Growth-controlled normal state anisotropic transport at two-dimensional $LaAlO_3/KTaO_3$ interfaces

Gervasi Herranz, Institute for Materials Science of Barcelona ICMAB-CSIC

Fereshteh Masoudinia [1], Roger Guzmán [1], Jordi Fraxedas [2], Jaume Gázquez [1], Gervasi Herranz [1], Gyanendra Singh [1]

[1] Institute of Materials Science of Barcelona (ICMAB-CSIC)
[2] Catalan Institute of Nanoscience and Nanotechnology (ICN2)

A recent breakthrough in interface physics is the observation of two-dimensional superconductivity in electron gases formed at (111)-oriented $KTaO_3$ interfaces. The superconducting transition temperature in this system reaches up to 2.2 K, nearly an order of magnitude higher than that observed in conventional $LaAlO_3/SrTiO_3$ interfaces. Additionally, a spontaneous in-plane transport anisotropy emerges below the onset of superconductivity, suggesting the formation of a distinct stripe-like phase [1]. The origin of this anisotropic superconducting transport remains unclear, as no similar behavior is observed in the normal state, emphasizing the need for a systematic investigation of growth parameters and their impact on fundamental properties.
In this study, we present a comprehensive investigation of normal-state anisotropic transport in (111)-oriented $LaAlO_3/KTaO_3$ interfaces as a function of growth temperature. The temperature dependence of the sheet resistance and its modulation by gate voltage reveal a significant variation in anisotropic transport behavior. Furthermore, transmission electron microscopy reveals stripe-like regions with an enhanced concentration of oxygen vacancies. These findings indicate that the formation of stripe-like features is strongly influenced by growth temperature and likely originates from oxygen vacancy-induced stripe-like patterns.

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Enhanced Spin Berry Curvature by Oxygen Octahedral Rotation Enabling Thickness-Dependent Single-Layer Spin-Orbit Torque Magnetization Switching in Wely Oxide $SrRuO_3$

Hiroto Horiuchi, The University of Tokyo

H. Horiuchi [1], Y. Araki [2], Y. K. Wakabayashi [3], J. Ieda [2], M. Yamanouchi [4], Y. Sato [5], S. Kaneta-Takada [1], Y. Taniyasu [3], H. Yamamoto [3], Y. Krockenberger [3], M. Tanaka [1,6,7], and S. Ohya [1,6,7]

[1] Department of Electrical Engineering and Information Systems, The University of Tokyo, Bunkyo-ku, Tokyo, Japan
[2] Advanced Science Research Center, Japan Atomic Energy Agency, Tokai-mura, Ibaraki, Japan
[3] NTT Basic Research Laboratories, NTT Corporation, Atsugi-shi, Kanagawa, Japan
[4] Division of Electronics for Informatics, Graduate School of Information Science and Technology, Hokkaido University, Sapporo-shi, Hokkaido, Japan
[5] Research and Education Institute for Semiconductors and Informatics, Kumamoto University, Chuo-ku, Kumamoto, Japan
[6] Center for Spintronics Research Network (CSRN), The University of Tokyo, Bunkyo-ku, Tokyo, Japan
[7] Institute for Nano Quantum Information Electronics, The University of Tokyo, Bunkyo-ku, Tokyo, Japan

Spin Berry curvature (SBC) is crucial in generating novel spintronics functionalities, such as spin-orbit torques (SOTs). Breaking the crystalline inversion symmetry is expected to significantly enhance SBC, and thus, the intrinsic spin Hall effect (SHE) in ferromagnets. However, this strategy is not applied to devices; typical SOT magnetization switching is realized using ferromagnet/heavy-metal bilayers. Here, we demonstrate SOT partial magnetization switching in a single-layer Weyl oxide $SrRuO_3$ (SRO) with various thicknesses, which we have epitaxially grown on a $SrTiO_3$ (001) substrate using machine-learning-assisted molecular-beam epitaxy [1], with a small current density of ~3.1 MA cm^{-2} [2]. This value is one order of magnitude smaller than that needed for SOT switching using bilayer systems. Although our SRO film has a seemingly perfect, defect-free lattice, detailed structural analysis revealed subtle oxygen octahedral rotations (OORs) of ~5° near the interface. SRO exhibits linear band crossings in the symmetric bulk state [3]. Our tight-binding calculations indicate that a strong SBC is induced around small gaps generated at band crossings by the synergy of inherent spin-orbit coupling and band inversion due to the OOR. Consequently, a substantial intrinsic SHE arises near the interface, enabling efficient magnetization reversal. The results indicate that a minute atomic displacement can induce large intrinsic SOTs. This work was partly supported by Grants-in-Aid for Scientific Research, JST CREST, JST ERATO, and Spintronics Research Network of Japan (Spin-RNJ).

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Microwave varactor using Pt/$SrTiO_3$ Schottky junctions

Kenta Itoh, Waseda University

Kenta Itoh [1,2], Akitomi Shirachi [2,3,4], Motoya Shinozaki [2,5], Shoichi Sato [5], Takeshi Kumasa-ka [5], Tomohiro Otsuka [3,4,5,6,7], Takanobu Watanabe [1] and Yusuke Kozuka [1,2,5]

[1] Faculty of Science and Engineering, Waseda University,
[2] Research Center for Materials Nanoarchitechtonics (MANA), National Institute for Material Science (NIMS), Tsukuba, Ibaraki, Japan
[3] Research Institute of Electrical Communication,Tohoku University, Sendai, Miyagi, Japan
[4] Department of Electronic Engineering, Graduate School of Engineering, Tohoku University, Sendai, Miyagi, Japan
[5] WPI Advanced Institute for Materials Research, Tohoku University, Sendai, Miyagi, Japan
[6] Center for Science and Innovation in Spintronics, Tohoku University, Sendai, Miyagi, Japan
[7] RIKEN Center for Emergent Matter Science, Wako, Saitama, Japan

Radio-frequency reflectometry is an effective technique for fast and sensitive readout of quantum states, where resistance or capacitance is measured by the reflection signal of the microwave in an LC resonant circuit [1,2]. In this scheme, finely tuning the resonance frequency and impedance matching is a crucial step to realize sufficient sensitivity. However, parasitic capacitance causes these parameters to deviate from their designed values, leading to reduced measurement accuracy. To compensate for the parasitic effect and adjust the resonator properties, bulk $SrTiO_3$ has recently been proposed as an effective varactor (variable capacitor) [3,4]. However, a large voltage of about tens of volts is necessary to operate the $SrTiO_3$ varactor, which is not ideal for practical use.
In this work, we have developed Pt/Nb-doped $SrTiO_3$ Schottky junctions that work at low temperatures with relatively small voltages. The device is fabricated by sputtering Pt onto a 0.01wt% Nb: $SrTiO_3$ (001) substrate. Using a Pt/Nb-doped $SrTiO_3$ Schottky junction as the capacitor, we form an LC resonant circuit and measure the frequency dependence of the reflection characteristics of the resonant circuit using a vector network analyzer. A DC bias is applied via bias tees to modulate the varactor capacitance. As a result, the resonance frequency varies with the relatively small applied voltage below 10 V. This study demonstrates, for the first time, a microwave varactor based on an oxide Schottky junction, showing promise for quantum measurements at cryogenic temperatures.

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Synthesis and electrochemical evaluation of multilayer graphene-coated SiO_2 composites with enhanced capacitance and cycling stability

JInjoo Jung, Kyungpook National University

J. Jung [1], C.-D. Kim[2], J. Oh[2], H. Pae[2], K. T. Kang[3], S.B. Kang[4], Y. Jo[2]

[1] KNU G-LAMP Project Group, KNU-Institute of Basic Sciences, College of Natural Sciences, Kyungpook National University, Daegu 41566, South Korea
[2] Department of Physics, Kyungpook National University, Daegu 41566, South Korea
[3] Department of Physics, KNU G-LAMP Project Group, Kyungpook National University, Daegu 41566, Korea.
[4] Research and Development Center, Korea Carbon Industry Promotion Agency, Deokjin-gu, Jeollabuk-Do 54853, South Korea

Silicon-based materials, such as Si, SiC, and SiO_x, have been extensively investigated as electrode materials for M/NEMS and energy storage devices, primarily storing charge through the electric double-layer mechanism but commonly exhibiting poor electrical conductivity. In this study, we synthesized a graphite-coated SiO_2 compositie (GCSC) by covering SiO_2 particles with multilayer graphene (MLG) through thermal chemical vapor deposition. The GCSC consists of SiO_2 particles coated with MLG having a thickness of approximately 6 nm, with an interlayer spacing of about 0.34 nm between the graphene layers. The Raman spectra with an Id/Ig ratio of 1.83 indicate the presence of a significant disorder in the MLG. The synthesized GCSC was tested as a supercapacitor material after being treated with HNO3 to improve its wettability in electrolytes. At 200 mV s^{-1}, the GCSC electrode achieved a specific capacitance of 44.9 F g^{-1}, retaining approximately 63.6% of its initial value of 70.2 F g^{-1} measured at 0.5 mV s^{-1}. Electrochemical evaluation demonstrated outstanding stability of the GCSC electrode, retaining 99% of its initial capacitance after 5000 charge–discharge cycles at 3 A g^{-1} in a 1M H_2SO_4 electrolyte. These results show the potential of the GCSC as a cost-effective and high-performance electrode material for supercapacitors, with promising potential for energy storage applications.

Real-time Investigation of Topotactic Phase Transition of Strontium Ferrite Thin Films

Kyeong Tae Kang, Kyungpook National University

K. T. Kang [1]

[1] Department of Physics, KNU G-LAMP Project Group, Kyungpook National University, Daegu 41566, Korea

Understanding the dynamics of the oxygen sublattice during topotactic transformations in transition metal oxides (TMOs) is crucial for unlocking their functional potential in energy and electronic applications. $SrFeO_x$ (SFO_x), with its multivalent Fe states and layered framework, serves as a model system to explore these transformations. Using in situ atomic-resolution electron microscopy, we scrutinized the intricate atomic-scale dynamics involved in the transformation of SFO_x. We identified that the transformation from PV-SFO to BM-SFO is governed through oxygen diffusion through FeO_4 chains, driven by an interstitial mechanism, which induces the emergence of a hyper-stoichiometric intermediate phase at the moving boundary [1]. We extended this by revealing that the further reduction of oxygen from BM-SFO to IL-SFO proceeds via anisotropic oxygen release, guided by lattice reorientation that aligns oxygen vacancy channels. Cooperative ionic displacements facilitated a dimensional transition in oxygen coordination from 3D to 2D, accompanied by transient metastable states [2].
Building on these insights, we now integrate operando techniques such as transport, XRD, Raman spectroscopy, and XPS to monitor the same transformation in real time at macroscopic scales [3,4], confirming the presence of a hidden mechanism during the redox-driven phase transition. This multimodal operando approach bridges atomic-scale dynamics and bulk properties, offering a comprehensive framework for controlling topotactic phase behavior in complex oxides.

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Low-Temperature Phase Transition of N-doped VO_2 Thin Films Grown on Synthetic Mica and Quartz Substrates

Taisei Kano, Kyoto Institute of Technology

T. Kano [1], and H. Nishinaka [2]

[1] Department of Electronics, Kyoto Institute of Technology, Kyoto, Japan.
[2] Faculty of Electrical Engineering and Electronics, Kyoto Institute of Technology, Kyoto, Japan.

Vanadium dioxide (VO_2) has attracted considerable research interest after Morin reported its metal-insulator transition (MIT) in 1959 [1]. This MIT involves abrupt changes in resistivity and infrared transmittance, accompanied by a structural change from monoclinic to rutile. Due to this unique behavior, VO_2 has become promising for thermochromic smart windows. However, its relatively high MIT temperature (~67 °C) remains a critical limitation for passive switching applications. Lattice strain and metal doping at vanadium sites (e.g., W, Mo) have proven effective in reducing the MIT temperature [2,3]. In contrast, doping at oxygen sites remains underexplored. In this study, nitrogen-doped VO_2 thin films were grown on synthetic mica and quartz substrates using mistCVD, a technique previously applied for nitrogen incorporation in oxide films [4].

Initially, N-doped VO_2 films were deposited on synthetic mica substrates with a SnO_2 buffer layer. XRD confirmed oriented growth and suggested nitrogen incorporation at oxygen sites. Films grown at 425 °C exhibited an MIT near 29.5 °C, approximately 20 °C lower than that of prior reports [5], indicating enhanced suitability for smart window applications.

Subsequently, N-doped VO_2 films were grown on amorphous quartz substrates using a rutile SnO_2 buffer layer. GIXRD revealed the formation of polycrystalline VO_2 between 450 and 525 °C. The MIT temperature was reduced to 32.3°C when grown at 450°C; however, this reduction was not observed at higher temperatures, underscoring the importance of low-temperature growth.

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Synthesis and Stability of $BaFeO_3$ via Pulsed Laser Deposition

Aliya Kaplan, Northwestern University

A. Kaplan [1], M. Kiaba [1], A. Devincenti [1], L. Cline [1], and J. Fowlie [1]

[1] Materials Science and Engineering, Northwestern University, Evanston, Illinois, United States

$BaFeO_3$, a centrosymmetric perovskite lacking magnetic frustration, demonstrates spiral magnetism when in polycrystalline powder form [1]. This result has not been replicated in $BaFeO_3$ thin films, possibly due to the challenge of oxygen stability – specifically, the instability of Fe^{4+} relative to the more stable Fe^$^{3+}$ state. Multiple papers on the synthesis of $BaFeO_3$ thin films report an in-plane lattice parameter larger than that of the bulk material, suggesting the presence of oxygen vacancies [2-4]. Most recently, one group [5] reported films with a bulk-equivalent in-plane lattice parameter, but did not observe the spiral magnetism reported in the bulk material. Since no oxygen-retention method was reported to have been used, it is possible that oxygen off-stoichiometry prevents a consensus on the nature of spiral magnetism in $BaFeO_3$. Several strategies exist to mitigate oxygen loss, including post-annealing [6] and inclusion of a capping layer [7]. To extend the reliable period of time for characterization of $BaFeO_3$, this work seeks to optimize the synthesis and stability of $BaFeO_3$ thin films.

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Analog Switching of $SrCoO_x$ Memristors with Various Thicknesses and Substrate Orientations

Minseong Kim, Kyungpook National University

M. Kim [1], Y. Kim [2], H. Bong [1], Y. Kim [1,5], Y. So [1,5],
J. Oh [3], W. S. Choi [3], D. Kwon [4],
J. Woo [2], K. T. Kang [1,5]

[1] Department of Physics, Kyungpook National University, Daegu 41566, Korea

[2] School of Electronics Engineering, Kyungpook National University, Daegu 41566, Korea

[3] Department of Physics, Sungkyunkwan University, Suwon 16419, Korea

[4] Center for Energy Materials Research, Korea Institute of Science and Technology, Seoul 02792, Korea

[5] Department of Physics, KNU G-LAMP Project Group, Kyungpook National University, Daegu 41566, Korea

The reversible topotactic phase transition between insulating brownmillerite $SrCoO_{2.5}$ (BM-SCO) and metallic perovskite $SrCoO_3$ (P-SCO) offers a robust platform for achieving analog memory resistive switching. This oxygen stoichiometry-driven structural transition enables the engineering of oxygen vacancy channels (OVCs), which act as tunable ion transport pathways within the lattice. Such functionality is particularly promising for analog memory technologies, where gradual resistance modulation—rather than abrupt switching—is essential for neuromorphic computing. In this study, we present a comprehensive analysis of the memristive behavior of W/BM-SCO//Nb:$SrTiO_3$ heterostructures, in which the orientation and effective length of the OVCs are tuned by varying film thickness and substrate crystallographic orientation, (110) and (111). The resistive switching characteristics were examined through systematic current–voltage (I-V) measurements. Unlike conventional memristors that require a high-voltage electroforming step, our devices operate without such an additional voltage application, owing to the presence of well-aligned, pre-existing OVCs in the BM-SCO lattice that serve as predefined pathways for oxygen ion migration. The devices exhibit stable and reversible transitions between high-resistance and low-resistance states, along with reproducible multi-level switching under continuous voltage sweeps, demonstrating their suitability for next-generation analog memory devices.

Epitaxial strained induced Zircon-scheelite phase transformation in YVO4 thin films

Youngdo Kim, Yale University

Hanlin Tang [1], Hanshi Li [2], Shuhang Pan [3], Youngdo Kim [1], Frederick J. Walker [1], Charles H, Ahn [1,2,3]

[1] Department of Applied Physics, Yale University, New Haven, Connecticut 06520, USA
[2] Department of Mechanical Engineering and Materials Science, Yale University, New Haven, Connecticut 06520, USA
[3] Department of Physics, Yale University, New Haven, Connecticut 06520, USA

Quantum transducers that convert microwave photons into optical photons are important components of quantum networks. High efficiency quantum transducers require transduction medium have strong optical and microwave light coupling, as well as low noise operating environment. Yb^{3+}: YVO_4 emerges as competitive candidate for transduction application. Previous research on bulk Yb^{3+}: YVO_4 shows that the current limit on the transduction efficiency is the re-absorption of the outgoing optical signal by the host crystal [1]. The re-absorption effect can be reduced by controlling the thickness of the host crystal. The optimal thickness of YVO_4 is ~ 1μm by theoretical calculation, which cannot be achieved in bulk crystals. An alternative approach is to grow YVO_4 thin films as the host.

In this talk, we will discuss the methods growing YVO_4 thin films on YVO_4 substrates and sapphire substrates using Molecular Beam Epitaxy. The surface quality has been significantly improved in homoepitaxial thin films compared to bare substrates. For heteroepitaxial growth on sapphire substrates. We discovered interface strain-controlled Zircon-Scheelite phase transition of YVO_4 thin films by introducing a buffer oxide layer. To study the domain structures of YVO_4 thin films grown on sapphire substrates, we also did plane-view 4D STEM and obtained the 2D mapping of the domain distribution, which is consistent with what we observed in AFM and RHEED.

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Orientation-dependent surface chemistry and transition dynamics in $SrFeO_x$ films

Yunzyne Kim, Kyungpook National University

Y. Kim [1,2], H. Kim [1,2], H. Bong [1], S. Song [3], B. Jeong [4], J. -S. Bae [4], W. S. Choi [5], S. Park [3], D. Lee [2,5], and K. T. Kang [1,2]

[1] Department of Physics, Kyungpook National University, Daegu, Korea
[2] KNU G-LAMP Project Group, Kyungpook National University, Daegu, Korea
[3] Department of Physics, Pusan National University, Busan, Korea
[4] Korea Basic Science Institute, Daejeon, Korea
[5] Department of Physics, Sungkyunkwan University, Suwon, Korea

The topotactic phase transition from insulating brownmillerite $SrFeO_{2.5}$ (BM-SFO) to metallic perovskite $SrFeO_3$ is of interest for energy and sensing applications. This transition is enabled by ordered oxygen vacancy channels (OVCs), which facilitate oxygen ion migration. While prior studies addressed structural and electronic roles of OVCs, their influence on surface states during the transition remains unexplored. Given that the surface plays a critical role as the interface for oxygen exchange, understanding surface chemical evolution is essential for unraveling mechanisms that govern electronic properties, catalytic performance, and material stability.

We examined the surface chemistry of BM-SFO films with different OVC orientations during the transition using ambient-pressure X-ray photoelectron spectroscopy (AP-XPS). To control OVC orientation, (001)-oriented LSAT and STO substrates were used to create vertically (*v*-OVCs) and horizontally (*h*-OVCs) aligned channels. *In-situ* XRD and resistance measurements showed lower transition barriers in *v*-OVC films. AP-XPS tracked surface chemical changes, including SrO and unoccupied O 2*p* states near the Fermi level. A pronounced increase in the surface SrO was observed in *v*-OVC films, correlated with enhanced oxygen exchange. We discuss how the OVC orientation affects surface chemistry, conductivity, and the energy barrier for the transition, offering insights into the relationship between surface states and functional behavior of SFO films.

Current status of ARPES beamline BL06U at NanoTerasu

Miho Kitamura, National Institutes for Quantum Science and Technology (QST)

M. Kitamura [1], H. Iwasawa [1], F. Nishino [1], N. Inami [1], T. Takeuchi [1], T. Imazono [1], Y. Ohtsubo [1], J. Miyawaki [1], K. Yamamoto [1], K. Inaba [1], A. Agui [1], T. Nakatani [1], K. Fujii [1], H. Kimura [1], and K. Horiba [1]

[1] NanoTerasu Center, National Institutes for Quantum Science and Technology (QST), Sendai, Miyagi, Japan

The beamline BL06U is one of the public beamlines at NanoTerasu, a 3-GeV high-brilliance synchrotron radiation facility at Tohoku, Japan. This beamline is designed for an angle-resolved photoemission spectroscopy (ARPES) beamline to utilize micro-focused and nano-focused beams. ARPES is one of the most powerful experimental techniques for directly determining the band structure of solid surfaces. Especially, spatially resolved ARPES measurements using a focused beam have recently attracted considerable attention due to the importance of micro/nanoscale characterization of electronic structures in exotic quantum materials, including functional oxides. It is also helpful for studying inhomogeneous samples, hard-to-cleave samples, and tiny single crystals.

BL06U provides brilliant soft x-rays with various polarizations (linear horizontal, linear vertical, and left- and right-circular) in the 50–1,000 eV energy range. Two distinct operational modes—a high-energy-resolution (HR) mode (EΔE >50,000 @50eV) for HR-ARPES and a low-divergence mode optimized for high-flux nano-ARPES—can be selected by adjusting a collimated plane grating monochromator [1]. It has two switchable branches: one is currently under construction for nano-ARPES experiments utilizing nano-focusing mirror optics, and the other has been open for users since March 2025 as a micro-ARPES station, where versatile ARPES experiments with a spot size of 10 μm are possible. In the presentation, we will introduce the detailed optical design and the current status of this ARPES beamline BL06U.

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Exploring the Electronic Structure and Magnetic Properties of Epitaxially Strained Cubic Perovskite $BaRuO_3$ Thin Films

Evan Krysko, Cornell University

E. Krysko [1,2], A. S. Park [1,2]*, B. D. Faeth [1,2], B. Burganov [3], H. Paik [1,2], P. Malinowski [3], C. J. Mowers [3], X. Huang [3], D. Sotir [1,2], M. Barone [1,2], J. M. A. Loock [2], L. Qui [2], K. M. Shen [3,4], D. G. Schlom [1,2,4,5]

[1] Department of Materials Science and Engineering, Cornell University, Ithaca, New York 14853, USA
[2] Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM), Cornell University, Ithaca, New York 14853, USA
[3] Department of Physics, Cornell University, Ithaca, New York 14853, USA
[4] Kavli Institute at Cornell for Nanoscale Science, Ithaca, New York 14853, USA
[5] Leibniz-Institut für Kristallzüchtung, Max-Born-Straße 2, 12489 Berlin, Germany

Perovskite ruthenates such as $SrRuO_3$ and $CaRuO_3$ have been studied extensively for their exciting electronic and magnetic properties and have provided great platforms to study correlated electron systems. The cubic perovskite (3C) $BaRuO_3$ could also provide insight into such systems, especially with its simpler electronic structure when compared to those of orthorhombic $SrRuO_3$ and $CaRuO_3$. Nonetheless, 3C $BaRuO_3$ has been far less explored due to the necessity of high pressure to synthesize it in bulk (180,000 atm) and competition during growth from other polymorphs (4H, 6H, and 9R). Here we use a combination of ozone-assisted molecular-beam epitaxy (MBE) and in situ angle-resolved photoemission spectroscopy (ARPES) to study the electronic and magnetic properties of 3C $BaRuO_3$ under varying degrees of biaxial strain. We demonstrate an adsorption-controlled growth regime that allows for the growth of commensurately-strained films with enhanced residual resistivity ratios compared to previously reported thin films grown by pulsed-laser deposition. First-ever ARPES measurements on these 3C $BaRuO_3$ thin films reveal saddle points in close proximity to the Fermi level. A detailed accounting of the fermiology and possible signatures of magnetic ordering as a function of applied biaxial strain and temperature will be discussed.

Electronic Phase Transitions in VO_2/W:VO_2 $(110)_R$ Bilayers Studied by Soft-X-ray Photoemission Spectroscopy

Hiroshi Kumigashira, Tohoku University

S. Inoue [1], D. Shiga [1,2], R. Hayasaka [1], T. Tirasutt [1], S. Watanabe [1], N. Hasegawa [1], K. Ozawa [2], and H. Kumigashira [1,2]

[1] Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University, Sendai 980–8577, Japan
[2] Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK), Tsukuba 305–0801, Japan

VO_2 is one of the promising candidates as a channel material for future Mott transistors since it exhibits an abrupt metal-insulator transition (MIT) near room temperature accompanied by the V-V dimerization along the $[001]_R$ direction. Recently, it has been reported that bilayers composed of a VO_2 $(001)_R$ layer and an electron-doped $V_{1-x}W_xO_2$ (W:VO_2) $(001)_R$ layer with a lower MIT temperature (T_{MIT}) exhibit an interface-induced collective MIT [1,2]. To understand the origin of this collective phenomenon, it is crucial to obtain information on the orientation dependence of the phenomenon in the bilayers. In this study, we investigated the changes in the electronic structure of VO_2/W:VO_2 $(110)_R$ bilayers wherein the one-dimensional V-V chains are parallel to the interface using soft x-ray photoemission spectroscopy (SXPES). Thanks to the surface sensitivity of SXPES, we determined the changes in the electronic structure and V-V dimerization in each constituent layer separately [3,4]. The selective observation reveals that the temperature dependence of the upper VO_2 layer in the $(110)_R$ bilayers is almost identical to that of VO_2 $(110)_R$ films. This behavior seems to be different from the case of interface-induced collective phase transition in $(001)_R$ bilayers [4]. These results strongly suggest that the electronic phase transitions occur independently in each layer of the $(110)_R$ bilayers.

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Investigation of long-range in-plane polarization order in Bi_2WO_6 thin films

Yong-Jun Kwon, KAIST

Y.-J. Kwon [1,2], J. Lee [1,2], H. Bang [1,2], M. Kang [1,2], J. Kim [1,2], and C.-H. Yang [1,2,*]

[1] Department of Physics, KAIST, Daejeon, 34141, Republic of Korea
[2] Center for Lattice Defectronics, KAIST, Daejeon, 34141, Republic of Korea

Topological polar textures in ferroelectric oxide thin films—nontrivial order-parameter configurations known as quasi-particles—are characterized by their integer winding numbers. Analogous to magnetic skyrmions, these structures promise topologically protected, nanoscale elements for next-generation memory devices [1]. Among layered ferroelectrics, Bi_2WO_6 thin films intrinsically host polar vortices with ±1 winding numbers [2–4], yet direct visualization and efficient detection of their in-plane domain distributions remain challenging [5]. Here, we grow epitaxial Bi_2WO_6 films on $La_{0.7}Sr_{0.3}MnO_3$ bottom electrodes under controlled tensile or compressive strain via pulsed-laser deposition. Atomic force microscopy reveals extended in-plane domain networks on twinned $NdAlO_3$(001) substrates, while X-ray diffraction confirms the film's pure Aurivillius phase. Guided by contemporary theoretical models [6], we propose a strain- and substrate-driven mechanism for domain formation. Crucially, we demonstrate that specific Raman-active modes serve as optical fingerprints for polar domains, enabling rapid, noninvasive detection compared to conventional piezoresponse force microscopy or transmission electron microscopy. Our findings establish a versatile platform for engineered ferroelectric topological textures and their integration into high-density memory architectures.

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Interfacial Engineering of TiO_2 to Stabilize the Ferroelectric Phase in Ultrathin $Hf_{0.5}Zr_{0.5}O_2$ Films

Juhyeong Lee, Sejong University

J. Lee [1], D. H. Ryu [1], M. Lee [1], M. S. Choi [1], and T. Choi [1]

[1] Department of Nanotechnology & Advanced Materials Engineering, Sejong University, Seoul, Republic of Korea

Hafnium-based ferroelectrics have garnered significant attention owing to their stable remanent polarization at reduced thicknesses, CMOS compatibility, and excellent scalability, making them promising candidates for next-generation non-volatile memory. Nonetheless, stabilizing the ferroelectric orthorhombic phase (o-phase, $Pca2_1$) of ultrathin $Hf_{0.5}Zr_{0.5}O_2$ (HZO) remains a critical challenge, primarily due to its metastable nature and the dominant influence of surface and interfacial energies that favor the formation of non-ferroelectric monoclinic or tetragonal phases. In this work, a bottom sub-nanometer TiO_2 interfacial layer was incorporated to enhance the ferroelectric properties of HZO by lowering the energy barrier associated with o-phase formation. In addition, the TiO_2 interfacial layer acts as an oxygen reservoir that stabilizes the local oxygen environment during the initial crystallization of HZO. Consequently, this structure attains robust ferroelectricity at a thickness of 6 nm, demonstrating its potential for scalable non-volatile memory applications.

Enhanced Energy Storage in Anti-Ferroelectric Capacitors Enabled by Atomic-scale Stacking of HfO_2–ZrO_2 Superlattices

Myeongyun Lee, Sejong University

M. Lee [1], D. H. Ryu [1], H. Chung [1], J. Lee [1], M. S. Choi [1], D. Hong [1], and T. Choi [1]

[1] Department of Nanotechnology & Advanced Materials Engineering, Sejong University, Seoul, Republic of Korea

Hafnia-based anti-ferroelectrics (AFEs) are promising for next-generation energy storage due to their superior endurance, recoverable energy density, and scalability. In contrast to conventional atomic layer deposition (ALD) super-cycle methods, periodically stacked HfO_2/ZrO_2 superlattices promote the formation of orthorhombic ($Pca2_1$) and tetragonal ($P4_2/nmc$) phases, effectively enhancing anti-ferroelectric behavior. This enhancement is attributed to local strain, which promotes phase stabilization, and to suppressed oxygen vacancy diffusion in HfO_2 layers with higher migration barriers compared to ZrO_2. In this study, ultrathin $Hf_{1-x}Zr_xO_2$ films (<10 nm) with a superlattice structure were fabricated by an ALD process, followed by TiN electrode deposition and post-metallization annealing for crystallization. This artificial heterostructure enables atomic-scale control of composition and strain, improving phase stability and promoting field-induced phase transition. Compared to hafnia-based AFE thin films, these engineered structures exhibit significantly higher recoverable energy density (>50 J/cm^3) and improved cycling endurance, with energy efficiency exceeding 65 %. These results demonstrate the potential of nanoscale superlattice engineering for high-performance AFE capacitors in advanced energy storage systems.

Epitaxial thin films of spinel-type $MgFe_2O_4$ for photoelectrochemical water splitting by visible light

Sangbin Lee, The University of Tokyo

S. Lee [1], D. Yang [2], H. Tabata [1],[2],[3], M. Seki [1],[3]

[1] Department of Electrical Engineering and Information Systems, Graduate School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
[2]Department of Bioengineering, Graduate School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
[3]Center for Spintronics Research Network, Graduate School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

Photoelectrochemical (PEC) water splitting is a promising method which converts sunlight directly into storable hydrogen fuel [1]. Hematite α-Fe_2O_3 is one of the most promising candidates for the PEC water splitting by visible light owing to its low cost, small bandgap energy (2.1 eV), high chemical stability and environmental friendliness [2]. However, the efficiency of hematite-based photoanodes is severely limited by the ultrafast recombination of photo-excited electron–hole pairs [3]. Here we focused on the spinel type $MgFe_2O_4$ (MFO) as an earth-abundant alternative material. Epitaxial MFO thin films were grown using pulsed-laser deposition (PLD). The conductive La-doped $BaSnO_3$ (LBSO) thin film deposited on $SrTiO_3$ (001) substrates was used as a transparent bottom electrode layer. The bandgap energy of the MFO film was 2.3 eV. The photocurrent density and incident-photon to current efficiency (IPCE) of MFO films were significantly larger than those of hematite photoanodes under visible-light irradiation. Furthermore, time-resolved spectroscopy measurements revealed that a lifetime of photocarriers in MFO ($\tau \approx 2.8$ ps) is remarkably longer than that in hematite. These findings prove epitaxial MFO as a promising, earth-abundant alternative to hematite for next-generation oxide photoelectrodes.

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Anisotropic magnetoresistive sensors based on epitaxial $La_{0.7}Sr_{0.3}MnO_3$ thin films

Laurence Mechin, CNRS-GREYC

R. Solis Léon [1,2], T. Tagiyev [1], L. Enger [1], S. K. Chaluvadi [3], V. Polewczyky [3], A. Y. Petrov [3], G. Vinai [3], L. Braglia [3], J. M. Diez [2], V. Pierron [1], P. Torelli [3], P. Orgiani [3], S. Flament [1], B. Guillet [1], P. Perna [2], L. Méchin [1]

[1] Normandie University, UNICAEN, ENSICAEN, CNRS GREYC, 14000 Caen, France
[2] IMDEA-Nanociencia, 28049 Madrid, Spain
[3] Istituto Officina dei Materiali (IOM)–CNR, Laboratorio TASC, I-34149 Trieste, Italy

We previously fabricated anisotropic magnetoresistive (AMR) sensors using half-metallic $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) thin films, which is ferromagnetic up to 350 K and has low intrinsic noise at low frequencies. The LSMO films were etched in Wheatstone bridge configuration, and the magnetic easy axis was induced by using 4° vicinal $SrTiO_3$ substrates through step-induced uniaxial anisotropy. Magnetotransport and noise characterization were performed, which give detectivity (defined as the ratio of the noise voltage spectral density by the device sensitivity) of around 1.4 $nT·Hz^{-1/2}$−1/2 at 1 Hz and 240 $pT·Hz^{-1/2}$−1/2 at 1 kHz at T=310 K, which corresponds to human body temperature [1, 2].
In this work we will discuss ways of improving the performance of these AMR sensors either by changing the Sr doping in the $La_{1-x}Sr_xMnO_3$ thin films or by the addition of a ferromagnetic flux concentrator. The latter amplifies the magnetic flux density seen by the sensor and thus enhance its sensitivity. These high-performance LSMO AMR sensors with demonstrated detectivity below 1 $nT·Hz^{-1/2}$−1/2 could find applications in magnetophysiological measurements such as those produced by action potential propagation in muscles and in neurons [3, 4].

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Colossal Interfacial Response at Room Temperature in Super-Orbital-Splitting-Type Interfacial Multiferroics: A Theoretical and Experimental Study

Hiroshi Naganuma, Nagoya University

H. Naganuma [1], K. Nawa [2], T. Ichinose [2], K. Amemiya [3], T. Shiraishi [4], Y. Sato [4], T. Fukushima [2]

[1] Nagoya University, Nagoya, Japan
[2] AIST, Tsukuba, Japan
[3] KEK-IMSS, Tsukuba, Japan
[4] Kumamoto University, Kumamoto, Japan

Magnetoelectric (ME) interactions in multiferroic materials attract interest due to their potential for ultra-low-power, non-volatile memory and bio-sensing applications. However, their use is limited by low transition temperatures and weak magnetoelectric coupling at room temperature. Achieving strong ME effects above room temperature remains a major challenge. In our previous report [1] magnetization of Fe was enhanced by Ru capping on $BiFeO_3$, indicating the potential of the capping layer to enhance the magnetization of $BiFeO_3$.
In this study, we report a novel interfacial multiferroic system exhibiting a colossal magnetoelectric response at room temperature. This effect appears at the interface between ferroelectric $BiFeO_3$ and a metallic Co overlayer. Structural and spectroscopic analyses reveal a ~1 nm-thick interfacial layer. X-ray Magnetic Circular Dichroism (XMCD) measurements at KEK-PF show a strong interfacial magnetic moment, electrically controlled by the ferroelectric polarization of $BiFeO_3$.
First-principles calculations using Fugaku reproduce the XMCD spectra and reveal that oxygen vacancies and partial Fe–Co substitution drive a unique electronic reconstruction. Despite these changes, the interface remains insulating, suggesting an unconventional "super-orbital-splitting" orbital configuration.
Our results highlight how interfacial engineering can induce emergent multiferroic behavior not found in bulk materials, paving the way for room-temperature, tunable magnetoelectric devices through atomic-scale oxide-metal interface control.

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Electronic Structure of Correlated Layered Ruthenates: Insights from ARPES and DFT

Prosper Ngabonziza, Louisiana State University

P. Ngabonziza [1],[2], S. Sajeev [1], B. D. Faeth [3],[10], E. Krysko [3],[10], M. R. Barone [3],[10], A. P. Nono Tchiomo [1], N. Wadehra [3], G. Gebreyesus [4], J. D. Denlinger [5], A. V. Fedorov [5], G. Cao [6], J. W. Allen [7], R. M. Martin [8] and D. G. Schlom [3],[9]

[1] Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA
[2] Department of Physics, University of Johannesburg, P.O. Box 524 Auckland Park 2006, Johannesburg, South Africa
[3] Department of Material Science and Engineering, Cornell University, Ithaca, New York 14853, USA
[4] Department of Physics, College of Basic and Applied Sciences, University of Ghana, Ghana
[5] Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
[6] Department of Physics, University of Colorado at Boulder, Boulder, Colorado 80309, USA
[7] Randall Laboratory of Physics, University of Michigan, Ann Arbor, Michigan 48109, USA
[8] Department of Applied Physics, Stanford University, Stanford, California 94305, USA
[9] Kavli Institute at Cornell for Nanoscale Science, Ithaca, New York 14853, USA
[10] Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM), Cornell University, Ithaca, New York 14853, USA

In this talk, I will present our recent ARPES and DFT studies of layered ruthenates, focusing on $Sr_4Ru_3O_{10}$ single crystals and epitaxial $Sr_3Ru_2O_7$ thin films. For $Sr_4Ru_3O_{10}$, spin- and angle-resolved ARPES reveals distinct spin-polarized Fermi surfaces [1]: electron-like minority spin bands near the zone center and hole-like majority spin bands at the corners. Two narrow features ~30 meV below the Fermi level include a nearly 100% spin-polarized van Hove singularity at low temperature. These show strong temperature-dependent coherence-incoherence crossover, consistent with Hund metal behavior. Spin-polarized DFT identifies specific orbital and layer contributions, suggesting outer-layer-driven metamagnetism.

For $Sr_3Ru_2O_7$ thin films, we will report on the first ARPES study of their low-energy band structure under varying strain, using films grown on different oxide substrates [2]. In-situ ARPES reveals a complex Fermi surface and multiple narrow bands within a few meV of the Fermi level. Strain tuning modifies dispersions and induces features near van Hove singularities, favorable for magnetic instabilities. Comparisons with DFT highlight key strain-driven changes in orbital character and band splitting.

Together, these studies show how spin polarization, epitaxial strain, and reduced dimensionality shape the correlated electronic states in layered ruthenates.

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Magnetization Enhancement in Ultrathin $ErFeO_3$ Epitaxial Films via Interfacial Octahedral Rotation

Jin Young Oh, Sungkyunkwan University

Jin Young Oh [1], Yaolong Xing [2], Seung Gyo Jeong [3], Sehwan Song [4], Woo-suk Noh [5], Valeria Lauter [6], Sungkyun Park [4], Sang Ho Oh [2], Woo Seok Choi [1]

[1] Department of Physics, Sungkyunkwan University, Suwon, South Korea
[2] Department of Energy Engineering, Korea Institute of Energy Technology, Naju, South Korea
[3] Department of Chemical Engineering and Materials Science, University of Minnesota, Minnesota,USA
[4] Department of Physics, Pusan National University, Busan, South Korea
[5] MPPC-CPM, Max Planck POSTECH Korea Research Initiative, Pohang, South Korea
[6] Spallation Neutron Source, Oak Ridge National Laboratory, Tennessee, USA

In its bulk form, orthoferrite $ErFeO_3$ (EFO) is known to have rich magnetic phase transitions: A canted antiferromagnetic phase, spin reorientation, and long-range ordering of Er^{3+} moments. The magnetic transitions are driven by exchange interactions mediated via spin-orbit coupling among Er^{3+} and Fe^{3+} ions [1-3]. To explore the influence of atomic structure to this complex magnetic system, we fabricated epitaxial EFO thin films (2–50 unit cells) on cubic $SrTiO_3$ (STO) (001) substrates by pulsed laser epitaxy and characterized those films using magnetic property measurement system (MPMS). The MPMS measurements reveal a substantial increase in room-temperature magnetization as the film thickness decreases, peaking at ~2 nm with much higher value than bulk [4]. In addition, scanning transmission electron microscopy (STEM) was performed on ~2.3 nm and ~12.9 nm thick films. STEM analyses indicate that near the STO interface, the oxygen octahedral rotation (OOR) of EFO is suppressed from ~20° to ~0° within a 2-unit-cell layer region due to the large lattice mismatch between EFO and STO. In the 2.3(12.9)-nm-thick film, this region constitute ~30%(~5%) of the total layers. This suggests that the influence of interfacial OOR on magnetic moment is larger in thinner film. Polarized neutron reflectivity simulation result supports this localized magnetic moment at interface. These findings confirm that the magnetic properties are tuned by OOR, an essential structural parameter, and this effect is maximized in ultrathin films where the interfacial structure is dominant.

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Cubic Perovskite Oxides Beyond 4.19 Å

Yoon Seok Oh , UNIST

Y.S. Oh [1], and H.W. Lee [1]

[1] Department of Physics, Ulsan National Institute of Science and Technology, Ulsan, South Korea

Among cubic perovskite oxides, $BaZrO_3$ possesses the largest lattice parameter of 4.19 Å. Such a large lattice parameter enables the application of substantial tensile strain to overlying perovskite films, allowing us to grow epitaxial films that were unattainable on prevalent perovskite substrates [1]. Nevertheless, for certain intriguing perovskite oxides, such as superconducting $Ba(Bi,Sb)O_3$ (4.3 – 4.5 Å), even $BaZrO_3$ is insufficient to achieve high-quality epitaxial films because the residual mismatch still hampers epitaxy. To overcome this limitation, we have explored routes to push the $BaZrO_3$ lattice parameter beyond 4.19 Å. In this poster, we present experimental results highlighting how lattice expansion can be driven and phase transitions induced in the $BaZrO_3$ system.

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Formation of Superconducting 2D Electron Gas at $MgO/KTaO_3$-(111) Interfaces

Chun Sum Brian Pang, University of British Columbia

Chun Sum Brian Pang [1,2], Bruce A. Davidson [1,2], Fengmiao Li [1,2], Mohamed Oudah [1,2], Peter Moen [1,2], Steef Smit [1,2], Cissy T. Suen [1,2], Simon Godin [1,2], Sergey A. Gorovikov [3], Marta Zonno [3], Sergey Zhdanovich [1,2], Giorgio Levy [1,2], Matteo Michiardi [1,2], Alannah M. Hallas [1,2], Andrea Damascelli [1,2], and Ke Zou [1,2]

[1] Quantum Matter Institute, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada
[2] Department of Physics & Astronomy, University of British Columbia, Vancouver, BC, V6T 1Z1, Canada
[3] Canadian Light Source, Inc., 44 Innovation Boulevard, Saskatoon, SK, S7N 2V3, Canada

Two-dimensional electron gases (2DEGs) at $KTaO_3$ surfaces have garnered considerable attention due to their efficient spin-charge conversion and the recent discovery of superconductivity. In this work, we present a method to induce superconducting 2DEGs on $KTaO_3$-(111) surfaces by Mg-assisted surface reduction using molecular-beam epitaxy (MBE), with superconductivity confirmed through transport measurements. By *in situ* soft X-ray photoemission spectroscopy (XPS) and angle-resolved photoemission spectroscopy (ARPES), the low-energy band structure and surface chemistry of the 2DEGs are directly examined without a capping layer. XPS reveals the emergence of reduced Ta oxidation states, while ARPES measurements identify a parabolic conduction band (~150 meV bandwidth) and sub-band formation arising from quantum confinement, consistent with a two-dimensional electronic system. This approach offers a simple and direct route to realize superconducting 2DEGs on $KTaO_3$ surfaces.

Curvature-induced polar structures in oxide membranes

David Pesquera, Catalan Institute of Nanoscience and Nanotechnology, ICN2

David Pesquera [1], Hiroko Yokota [2], Martí Checa [3], Kumara Cordero [1], Gustau Catalán [1], Felip Santdiumenge [4]

[1] Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST, Campus UAB, Bellaterra, Barcelona, Catalonia, 08193 Spain
[2] School of Materials and Chemical Technology, Tokyo Institute of Technology, 4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8501, Japan
[3] Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[4] ICREA-Catalan Institution for Research and Advanced Studies, Passeig Lluïs Companys, Barcelona, Catalonia, Spain
[5] Institut de Ciéncia de Materials de Barcelona-CSIC, Campus de la UAB, 08193 Bellaterra, Catalonia, Spain

Structural distortions in oxide thin films can be engineered via epitaxial strain, typically applied in planar directions. However, introducing controlled strain gradients often requires film inhomogeneities—such as compositional variations or relaxation—and the films remain clamped to their substrates. Freestanding oxide membranes [1], in contrast, can be strained more deeply [2], shaped into 3D morphologies with designed curvature, and thus host intrinsic strain gradients. This opens new avenues for structural and functional design in complex oxides.
I present two examples where curvature drives polar phenomena in oxide membranes:
• Buckling-induced strain hierarchies: In $BaTiO_3$, mechanical wrinkling creates a complex strain field that stabilizes a two-tier domain structure: mesoscale a/c domain bundles aligned with wrinkle curvature, and nanoscale a_2 domains arising from in-plane lattice misorientation [3].
• Rolling-induced polar metals: Controlled membrane rolling generates constant curvature, inducing polar distortions even in centrosymmetric materials. I show that microscale helical structures of $SrRuO_3$—a nominally nonpolar metal—develop spontaneous polarization, realizing a polar metallic state.
I will discuss how such curvilinear geometries in oxide membranes enable new functionalities relevant for piezoelectrics, flexible devices, and spintronics.

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Towards Room-Temperature Oxide Electronics: Sharp Metal to Insulator transition in $Nd_{0.7}Y_{0.3}NiO_3$ Thin Films

Sophia Sahoo, University Of Twente

S. Sahoo [1], G. Rijnders [1], G. Koster [1]

[1] MESA+ Institute for Nanotechnology, University of Twente, 7500 AE Enschede, The Netherlands

The study of metal–insulator transitions (MIT) in strongly correlated rare-earth nickelates presents promising avenues for tailoring material functionalities relevant to a broad spectrum of technological applications [1, 2]. In this work, we systematically investigate the effect of oxygen partial pressure (OPP) on the MIT characteristics of $Nd_{0.7}Y_{0.3}NiO_3$ (NYNO) thin films epitaxially grown on single-crystalline $LaAlO_3$ (100) substrates.

We prepared two epitaxial (NYNO) (8 nm thick) thin films at a substrate temperature of 650 °C under different OPP of 0.2 mbar and 0.4 mbar. From the temperature-dependent resistivity, the film grown under 0.4 mbar OPP exhibits a MIT around 295 K whereas the film grown at 0.2 mbar OPP displays a sharp MIT at a significantly higher temperature of 347 K. Notably, the transition is also considerably sharper in the 0.2 mbar sample as compared to the film grown at 0.4 mbar OPP.

After realizing an MIT above room temperature (RT) in the NYNO film, our next objective is to investigate its photo-induced dynamics using an ultrafast femtosecond laser to trigger the Insulator-to-Metal Transition (IMT) and probe the symmetry changes by monitoring the higher harmonics. This will allow us to fundamentally understand the coupling between the electronic and structural degrees of freedom and the realization of a sharp and tunable MIT above RT underscores the potential of NYNO films for next-generation 'Mottronics' and its integration into oxide electronic devices.

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Electronic structure of $SrNbO_3$ thin films using soft X-ray momentum microscopy

Michael Sing, U Würzburg

P. Sadhukhan [1], M. Spring [1], C. Schmitt [1], D. Biswas [2], J. Liu [2], T.-L. Lee [2], L. Dudy [3], M. Kamp [1], M. Sing [1], and R. Claessen [1]

[1] Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, 97074 Würzburg, Germany
[2] Diamond Light Source Ltd., Didcot, United Kingdom
[3] SOLEIL Synchrotron, 91190 Saint-Aubin, France

The realization of quantum materials with both electron correlations and topological properties is currently under active investigation. In this context, 4d transition metal oxides offer a good balance between e-e correlations and spin-orbit coupling. Recently, a topological band structure was predicted for tetragonal $SrNbO_3$ (SNO) [1], featuring high mobility and linear magnetoresistance [2,3]. The understanding of its band structure is still not well established experimentally. In fact, the synthesis of pristine SNO thin films is challenging due to the metastable nature of the Nb^{4+} cation with a d^1 configuration. Here, we probe the 3D band structure of stoichiometric SNO thin films on $DyScO_3(110)$ using photon energy and polarization-dependent soft X-ray photoelectron spectroscopy with the momentum microscope of beamline I09 at Diamond Light Source, UK. While the Fermi surface contours and band dispersions show overall good agreement with density-functional theory calculations, waterfall-type spectral weight between 1-2.5 eV at the Γ points has no counterpart in theory. We discuss its origin in terms of e-e correlations and coupling to lattice degrees of freedom.

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Influence of surface Sr segregation on the topotactic phase transition in $SrFeO_{3-x}$ thin films

Yerin So, Kyungpook National University

Y. So [1,2], M. Kim [1], H. Kim [1,2], Y. Kim [1,2], J. Oh [3], S. Kwon [4], J. -S. Bae [5], W. S. Choi [3], S. Park [4], D. Lee [2,6], and K. T. Kang [1,2]

[1] Department of Physics, Kyungpook National University, Daegu, Korea
[2] KNU G-LAMP Project Group, Kyungpook National University, Daegu, Korea
[3] Department of Physics, Sungkyunkwan University, Suwon, Korea
[4] Department of Physics, Pusan National University, Busan, Korea
[5] Korea Basic Science Institute, Busan, Korea
[6] Department of Physics Education, Kyungpook National University, Daegu, Korea

The topotactic phase transition between the insulating brownmillerite $SrFeO_{2.5}$ (BM-SFO) and the metallic perovskite $SrFeO_3$ (PV-SFO) has attracted considerable attention due to its potential use in memristors and solid oxide fuel cells. The process is driven by the incorporation of O^{2-} ions from the surface into the bulk, making surface reactions a critical factor. Surface Sr segregation is a form of *A*-site cation enrichment that is frequently observed in perovskite-based oxides and is known to be related to the strain state of the film. However, the impact of surface Sr segregation on the oxygen reduction reaction remains controversial, with conflicting reports suggesting that it can either enhance or inhibit its activity.

In this study, we aim to investigate how strain-induced surface Sr segregation affects the topotactic phase transition by controlling the strain state through film thickness. BM-SFO films of 20 and 60 nm thickness were grown on (001)-oriented $SrTiO_3$ substrates using pulsed laser deposition. Resistance measurements showed that the 20 nm film exhibited enhanced reactivity during the topotactic phase transition at 400 ºC. Reciprocal space mapping measurements showed that the 60 nm film had a relaxed strain state compared to the 20 nm film. Angle-resolved X-ray photoelectron spectroscopy showed that the 20 nm film had more surface SrO than the 60 nm film. This work provides insight into how strain-induced surface Sr segregation affects the reactivity of topotactic phase transitions.

Engineering Quantum Phenomena and Electronic Structures on Oxide Interfaces

Byungmin Sohn, SungKyunKwan University (SKKU)

Byungmin Sohn [1]

[1] Department of Physics, Sungkyunkwan University, Suwon 16419, Republic of Korea

Interfaces and surfaces of quantum materials have gained significance due to their utility as scalable and controllable platforms for manipulating physical properties such as superconductivity, multiferroicity, and topological states of matter. For decades, researchers have explored manipulating interfaces/surfaces in these materials through thin-film growth techniques. However, studying the surfaces/interfaces of quantum materials often poses experimental challenges. In this talk, I explore controlled electronic structures and novel phenomena using angle-resolved photoemission spectroscopy (ARPES) and oxide thin-film growth methods.

Epitaxially Stabilized van der Waals Oxide: 2H-NbO_2

Takuto Soma, Institute of Science Tokyo

Takuto Soma [1], Aya Sato [1], Hiroshi Kumigashira [2], Kohei Yoshimatsu [2], Akira Ohtomo [1]

[1] Department of Chemical Science and Engineering, Institute of Science Tokyo, Tokyo, Japan
[2] Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University, Sendai, Japan

Two-dimensional (2D) materials have garnered significant attention as next-generation materials, synthesized through the exfoliation of van der Waals (vdW) compounds. In contrast, transition-metal (TM) oxides represent strongly correlated electron systems that exhibit emergent properties such as superconductivity and metal-insulator transitions. However, their application in the 2D materials research field is limited due to the rarity of their vdW crystal structures [1]. This study addresses this gap by focusing on the layered niobate $LiNbO_2$. Although 2H-type structure is common in vdW TM dichalcogenides like MoS_2, it is rare in ionic oxides and only appears in $LiNbO_2$, which is composed of 2H-type NbO_2^- layers with Li^+ intercalants [2,3]. We propose a synthesis method for the vdW 2H-type TM dioxide 2H-NbO_2, utilizing a thin-film chemistry approach that begins with $LiNbO_2$ thin-films [4]. By integrating epitaxially stabilized thin films having nanoscale thickness with a solvothermal oxidation reaction, we successfully deintercalated Li^+ beyond the bulk limit while preserving the single-crystal structure. The synthesized 2H-NbO_2 with Nb^{4+} ($4d^1$) was found to be a correlated insulator with a half-filled single band. Furthermore, the electronic phases of the $Li_{1-x}NbO_2$ system exhibited a superconductivity with quantum critical behaviors [5], similar to those observed in cuprates and Moiré superlattices. Our findings suggest that "strongly correlated vdW oxides" could provide a pathway for introducing Mott physics into 2D systems, bridging both research field.

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Modulation of anomalous Hall effect in $SrRuO_3$ thin films via strain engineering

Min Jae Son, Kyungpook National University

M. J. Son [1,2], J. H. Kim [1,2], H. Kim [2,3], D. Lee [2,3], Y. Jo [1,2], and K. T. Kang [1,2]

[1] Department of Physics, Kyungpook National University, Daegu 41566, Korea
[2] Department of Physics, KNU G-LAMP Project Group, Kyungpook National University, Daegu 41566, Korea
[3] Department of Physics Education, Kyungpook National University, Daegu 41566, Korea

$SrRuO_3$ (SRO) is a conducting perovskite oxide that serves as a prototypical platform for investigating spin--orbit coupling--driven transport phenomena, including the anomalous Hall effect (AHE). These properties are known to be susceptible to lattice strain, film dimensionality, and interfacial structure. Among these parameters, interfacial strain has emerged as a particularly effective means for tuning magnetotransport behavior. In this study, we examine how interfacial strain modulation influences the AHE response in epitaxial SRO thin films. The films were fabricated on $SrTiO_3$ substrates by pulsed laser deposition, incorporating $SrCoO_{2.5}$ (SCO) buffer layers with systematically varied thickness. Although SCO does not directly contribute to the transport behavior, it functions effectively as a strain-tuning buffer layer, influencing the structure of the SRO layer, e.g., the shape of the octahedron. Strain states, confirmed by high-resolution X-ray diffraction and reciprocal space mapping, were found to correlate with distinct changes in the AHE response of SRO as a function of SCO buffer layer thickness. These results demonstrate that interfacial strain plays a pivotal role in modulating spin--orbit--driven magnetotransport, offering a viable route for tuning the anomalous Hall effect in complex oxide thin films.

Oxide membranes: a new platform for emergent quantum effects like charge transfer and Mott transitions

Merit Spring, Julius-Maximilians-Universität Würzburg

Merit Spring [1], Varun Harbola [2], Deepnarayan Biswas [3], Tien-Lin Lee [3], Jochen Mannhart [2], Michael Sing [1] and Ralph Claessen [1]

[1] Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, 97074 Würzburg, Germany
[2] Max Planck Institute for Solid State Research Heisenbergstr. 1, 70569 Stuttgart, Germany
[3] Diamond Light Source Ldt. Harwell Science and Innovation Campus, Didcot, Oxfordshire OX11 0DE, UK

Freestanding oxide membranes have recently emerged as a versatile platform for the design and control of novel electronic phases, either in their intrinsic form or via the formation of interfaces with broken symmetries [1]. In a heterostructure consisting of a $SrTiO_3$ (STO) membrane with fourfold symmetry and an Al_2O_3 (sapphire) substrate exhibiting threefold interfacial symmetry, electron energy-loss spectroscopy (EELS) in scanning transmission electron microscopy (STEM) revealed indications of charge transfer into the Ti 3d states of the STO membrane [2]. The microscopic mechanism underlying this electron transfer, however, remains unresolved.
To gain further insight, we investigated the evolution of the Ti^{3+} spectral weight using hard x-ray photoelectron spectroscopy and compared the experimental results to theoretical simulations across a range of membrane thicknesses, down to the ultra-thin limit of 2 unit cells of STO.
Another membrane material in application is $LaTiO_3$, attracting significant interest due to its Mott insulating behaviour [3]. We established the fabrication of membranes to integrate them into a strain device. This offers a promising route toward reversible control of the Mott transition and may pave the way for the active manipulation of correlated phase transitions in other freestanding oxide membrane systems by strain.

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CO_2 laser heating for advanced applications in PLD processes

Wolfgang Stein, SURFACE systems+technology GmbH+Co KG

W. Stein [1], A. P. Nono Tchiomo [2], Marc Pohlmann [1], S. Sajeev [2], Neethu Leyo [2], P. Ngabonziza [2,3]

[1] SURFACE systems+technology GmbH+Co KG,Rheinstr.7,Hueckelhoven,Germany
[2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA
[3]Department of Physics, University of Johannesburg, P.O. Box 524 Auckland Park 2006, Johannesburg, South Africa

SURFACE builds more than 30 years PLD and LMBE systems and has over 10 years of experience designing CO_2 laser heaters for these systems. Unlike our standard (NIR) diode laser heater of our LMBE systems, which require clamping or silver paste bonding of substrates to a metal carrier due to poor absorption in perovskite-based materials, CO_2 lasers enable direct heating of NIR-transparent oxide substrates thanks to strong absorption at the 10.6 μm wavelength. This allows substrate temperatures exceeding 1600 °C, limited only by the substrate itself, opening new possibilities for high-temperature processing. However, CO_2 lasers require optical shaping to transform the inherently Gaussian beam profile into a homogeneous flat-top heating spot. SURFACE has developed specialized optical systems and geometrically matched ceramic holders that ensure uniform heating and compatibility with in-situ diagnostics like RHEED and ellipsometry—even with moving substrates during PLD processes.

These high temperatures also enable precise in situ surface termination of oxide substrates. Specifically for materials like $SrTiO_3$(001), CO_2 laser-assisted thermal annealing offers a reproducible and cleaner alternative to conventional ex-situ chemical etching. We demonstrate that SURFACE's CO_2 laser system allows controlled surface reconstructions and terminations directly before deposition, significantly enhancing epitaxial growth quality. This approach is now generally applicable across a range of oxide substrates, offering a powerful tool for advanced oxide film engineering.

Inelastic ion-phonon interaction and multilevel ionic conduction in Ca-doped $BiFeO_3$

Jeonghun Suh, Korea Advanced Institute of Science and Technology

Jeonghun Suh [1,2], Heung-Sik Park [1,2], Ji Soo Lim [1,2], Boram Kim [1], Ho-Hyun Nahm [1], Seongjae Cho [1], Jong Sook Lee [3], Myung-Ho Bae [4,5], Yong-Hyun Kim [1], and Chan-Ho Yang* [1,2,5]

[1] Department of Physics, Korea Advanced Institute of Science and Technology, Yuseong-gu, Daejeon 34141, Republic of Korea
[2] Center for Lattice Defectronics, Korea Advanced Institute of Science and Technology, Yuseong-gu, Daejeon 34141, Republic of Korea
[3] School of Materials Science and Engineering, Chonnam National University, Gwangju 61186, Republic of Korea
[4] Korea Research Institute of Standards and Science, Yuseong-gu, Daejeon 34113, Republic of Korea
[5] KAIST Graduate School of Quantum Science and Technology, Korea Advanced Institute of Science and Technology, Yuseong-gu, Daejeon 34141, Republic of Korea

We report unconventional ionic transport behavior in Ca-doped $BiFeO_3$ thin films, characterized by enhanced ionic mobility at low electric fields and discrete, multilevel conductivity states modulated by the applied voltage. These effects are attributed to inelastic scattering between migrating oxygen vacancies and optical phonons. Real-time electrocoloration imaging [1, 2] under applied bias reveals that the ionic mobility exceeds Ohmic predictions at low fields and saturates at high fields, suggesting a field-dependent scattering mechanism. Electrochemical impedance spectroscopy measurements [2, 3] show voltage-dependent ionic conductivity with distinct plateaus, which correlate with the Raman-active phonon modes. This correlation enables the extraction of a characteristic inelastic scattering length. Furthermore, by varying the device channel length, we observe a crossover from quasi-ballistic to diffusive ionic transport, consistent with the proposed ion-phonon scattering scenario. The transport behavior is further explained by the survival probability model, where the field-driven motion of vacancies is modulated by resonant phonon scattering events. Our results establish a microscopic mechanism for inelastic ion-phonon interactions in oxide materials and demonstrate that ionic conductivity can be tuned through both electric field and structural design of the transport channel.

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Enhanced nonreciprocal conduction at a polar-magnetic interface of $GdTiO_3/EuTiO_3$

Kei S. Takahashi, Kanazawa University

K. S. Takahashi [1, 2], N. Takahara [2, 3], N. Nagaosa [2, 4], M. Kawasaki [2, 3], and Y. Tokura [2, 3, 5]

[1] Department of Physics, Kanazawa University, Kanazawa, Japan
[2] RIKEN Center for Emergent Matter Science (CEMS), Wako, Japan
[3] Department of Applied Physics and Quantum-Phase Electronics Center (QPEC), University of Tokyo, Tokyo, Japan
[4] RIKEN Fundamental Quantum Science Program (FQSP), Wako, Japan
[5] Tokyo College, University of Tokyo, Tokyo 113-8656, Japan

Oxide heterostructures provide excellent playgrounds to investigate novel transport phenomena emerging at interfaces due to the broken inversion symmetry in stark contrast to constituent compounds. Here, we fabricate $GdTiO_3/EuTiO_3$ heterostructures, where two-dimensional electron system emerges due to Ti^{3+}/Ti^{4+} valence-mismatch interface in the background of large magnetic moment from half-filled 4f electrons on Gd^{3+} and Eu^{2+} ions. Therefore, this system can be regarded as a magnetic counterpart of well-known valence mismatch interface $LaAlO_3/SrTiO_3$ or $LaTiO_3/SrTiO_3$. Reflecting the coexistence of electric polarization and magnetism at the interface, nonreciprocal transport properties are observed with singular dependencies on temperature and magnetic field originating from the scattering by chiral magnons. We discovered that, despite the extremely small Rashba band splitting, the nonreciprocal resistance is surprisingly large, presenting a promising route to the materials design of polar-magnetic metals composed of transition metal oxides.

Impact of Growth Method on Structural and Electronic Properties of Nb:Bi_2WO_6 Thin Films for pn Junction Applications

Ichiro Takakuwa, Tokyo University of Science

I. Takakuwa [1,2], R. Seino [1,2], S. Suzuki [2], K. Nishio [2], S. Asanuma [3], Y. Nemoto [4], Y. Nishimiya [4], Y. Higashi [5], T. Ito [5], and M. Minohara [1]

[1] Global Research and Development Center for Business by Quantum-AI technology (G-QuAT), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan
[2] Department of Materials Science and Technology, Tokyo University of Science, Katsushika, Tokyo, Japan
[3] Semiconductor Frontier Research Center, AIST, Tsukuba, Ibaraki, Japan
[4] Electron Microscopy Unit, National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, Japan
[5] Department of Electronics and Manufacturing Core Electronics Technology Research Institute, AIST, Tsukuba, Ibaraki, Japan

The development of p-type wide-bandgap oxide semiconductors is crucial for realizing high-breakdown voltage power devices [1]. We have previously demonstrated p-type conductivity and carrier density modulation via intentional doping into Bi_2WO_6 (BWO) bulk materials [2]. To extend this toward practical applications, optimizing thin-film growth processes is essential, particularly in selecting appropriate growth methods. In this study, we investigated the growth of Nb-doped BWO (Nb:BWO) thin films using two different techniques: pulsed laser deposition (PLD) and solid-phase epitaxy (SPE). X-ray diffraction analyses confirmed that crystalline Nb:BWO films were successfully obtained by both methods. However, compositional and electronic characterizations revealed distinct differences. X-ray fluorescence and photoemission spectroscopy (PES) indicated a significant bismuth deficiency in PLD-grown films, while SPE-grown films exhibited nearly ideal stoichiometry. Furthermore, PES spectra showed a defect state near the Fermi level in the PLD-grown film–a signature of Bi deficiency–which was absent in the SPE-grown film. Such defect states are expected to negatively affect device performance. Consistently, rectifying behavior in Nb:BWO/β-Ga_2O_3 heterojunctions was found to be significantly poorer in PLD-grown diode compared to those grown by SPE. These results indicate that SPE is a more suitable growth method for realizing high-quality p-type Nb:BWO films providing a promising pathway for oxide-based power device applications [3].

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In-plane anomalous Hall effect in ferromagnetic oxide films

Masaki Uchida, Institute of Science Tokyo

S. Nishihaya [1], Y. Matsuki [1], H. Kaminakamura [1], H. Sugeno [1], M.-C. Jiang [2,3], Y. Murakami [1], R. Arita [2,4], H. Ishizuka [1], and M. Uchida [1,5]

[1] Department of Physics, Institute of Science Tokyo, Japan
[2] RIKEN Center for Emergent Matter Science, Japan
[3] Department of Physics and Center for Theoretical Physics, National Taiwan University, Taiwan
[4] Department of Physics, the University of Tokyo, Japan
[5] Toyota Physical and Chemical Research Institute, Japan

The Hall effect typically manifests as a transverse voltage in response to an electric current under an out-of-plane magnetic field or spin magnetization. Recent theoretical studies have predicted that even in-plane magnetic field can induce an anomalous Hall effect, though experimental evidence has remained scarce. Notably, the recent observation of in-plane anomalous Hall effect (iAHE), emerging with threefold rotational symmetry in the principal plane, reveals an intrinsic mechanism that generates a Hall vector component perpendicular to the applied magnetic field [1]. This off-diagonal coupling between out-of-plane orbital magnetization and in-plane magnetic field, strictly dictated by crystal symmetry, opens new avenues for engineering unconventional Hall responses [2,3].

Oxide films offer a suitable platform for probing iAHE due to their well-controlled domain structures and the precision achievable in Hall measurements. Here we investigate iAHE in (111)-oriented ultrathin films of the prototypical ferromagnetic oxide $SrRuO_3$ [4], which possess in-plane easy axes of spin magnetization. These films exhibit a spontaneous iAHE at zero field, intrinsically coupled to the in-plane spin magnetization and tunable via its direction. Systematic angle-dependent measurements reveal complex Hall responses shaped by higher-order terms permitted under trigonal symmetry distortion. Our findings demonstrate the potential for versatile and controllable in-plane Hall functionalities with out-of-plane orbital ferromagnetism.

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Single monolayer ferromagnetic perovskite SrRuO3 with high conductivity and strong ferromagnetism

Yuki K. Wakabayashi, NTT Basic Research Laboratories

Yuki K. Wakabayashi [1], Masaki Kobayashi [2,3], Yoshiharu Krockenberger [1], Takahito Takeda [4], Kohei Yamagami [5], Hideki Yamamoto [1], and Yoshitaka Taniyasu [1]

[1] NTT Basic Research Laboratories, NTT Corporation, Japan
[2] Center for Spintronics Research Network, The University of Tokyo, Japan
[3] Department of Electrical Engineering and Information Systems, The University of Tokyo, Japan
[4] Graduate School of Advanced Science and Engineering, Hiroshima University, Japan
[5] Japan Synchrotron Radiation Research Institute (JASRI), Japan

Two-dimensional (2D) ferromagnetic metals have attracted attention as next-generation spintronics materials due to their potential for electric and magnetic field tunability by combining the advantages of 2D electron systems and ferromagnets. While van der Waals ferromagnets are chemically inert and stable in air, their limited scalability hinders device integration. Alternatively, ultrathin films derived from scalable three-dimensional ferromagnetic metals face challenges such as degradation into non-magnetic or insulating states upon air exposure. In this study, we employed machine learning-assisted molecular beam epitaxy [1,2] to grow a precisely controlled monolayer (1 ML) of 4d ferromagnetic Weyl oxide $SrRuO_3$ (SRO) on a $DyScO_3$ (110) substrate, capped with 2 ML of $SrTiO_3$ (STO) to suppress surface reactions. This structure exhibited robust ferromagnetism with a Curie temperature of ~154 K and metallic conductivity [3]. Cross-sectional scanning transmission electron microscopy and atomic force microscopy measurements confirmed the atomically flat structure of [2 ML STO/1 ML SRO/DSO], and magnetotransport showed clear ferromagnetic domain hysteresis below 130 K. Furthermore, X-ray absorption spectroscopy and X-ray magnetic circular dichroism measurements revealed spontaneous magnetization and strong orbital hybridization between Ru 4d and O 2p states, key to maintaining metallic ferromagnetism in 1 ML SRO. These results demonstrate a scalable route to stable 2D ferromagnetic metals suitable for spintronic applications.

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Orbital-resolved anisotropic electron pockets in electron-doped SrTiO3 observed by ARPES

Yuki K. Wakabayashi, NTT Basic Research Laboratories

Y. K. Wakabayashi [1], A. Munakata [2], Y. Taniyasu [1], and M. Kobayashi [2,3]

[1] NTT Basic Research Laboratories, NTT Corporation, Japan
[2] Department of Electrical Engineering and Information Systems, The University of Tokyo, Japan
[3] Center for Spintronics Research Network, The University of Tokyo, Japan

$SrTiO_3$ (STO) is a wide-bandgap semiconductor with high dielectric constant and chemical stability, making it a promising material for high-k dielectrics and photocatalysis, as well as a widely used substrate for oxide epitaxy [1,2]. STO is a d0 insulator with an O 2p valence band and an empty Ti 3d t2g conduction band. Upon light electron doping, conduction band electron pockets (EPs) emerge at the Γ point, but their direct and orbital-resolved observation has been lacking. Here, we report orbital-selective characterization of EP band dispersion in 1% Nb-doped STO single crystals by polarization-dependent angle-resolved photoemission spectroscopy (ARPES) [3]. Using linearly and circularly polarized light at KEK-PF BL28 under UHV and 12 K, we selectively probed dxz, dyz, and dxy orbital components based on dipole selection rules. The energy distribution curves near Γ showed a sharp quasiparticle peak at the Fermi level (EF) without any in-gap defect states, indicating intrinsic metallicity. The valence band maximum lies 3.85 eV below EF, and the conduction band minimum is 60 meV below EF, yielding a direct bandgap of 3.79 eV, in agreement with optical data [4]. High-resolution ARPES along Γ–X revealed two bands with effective masses m1 = 0.63m0 and m2 = 8.0m0, assigned to dxz and dyz orbitals, respectively. In the presentation, we will also compare these experimental values with theoretical predictions and reported effective masses of 2D electron gases at STO surfaces and interfaces. These results provide valuable guidance for oxide-based heterostructure design.

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Role of Ion Milling Angle in Determining Conducting and Insulating States on $SrTiO_3$ Surfaces

Yuki K. Wakabayashi, NTT Basic Research Laboratories

Y. K. Wakabayashi [1], Y. Krockenberger [1], K. Takiguchi [1], H. Yamamoto [1], and Y. Taniyasu [1]

[1] NTT Basic Research Laboratories, NTT Corporation, Japan

$SrTiO_3$ (STO) is a foundational material for oxide electronics due to its high dielectric constant (100–200) and high electron mobility [1,2]. It has also gained attention as an efficient photocatalyst for water splitting under ultraviolet irradiation [3]. For these applications, damage-free, high-precision microfabrication of STO is critically important. Ion milling is a widely used technique for high-resolution patterning in MEMS and magnetic tunnel junctions. However, in STO, ion milling often induces a conductive layer at the surface, transforming it from an insulator into a high-mobility 2D conductor. Thus, understanding and optimizing milling parameters to suppress such damage is vital. In this study, we systematically investigated the effect of ion milling angle θ on STO's post-milling surface conductivity and established conditions for maintaining surface insulating. Electrical transport properties were evaluated using the van der Pauw method. At beam voltage VB = 354 V and beam current IB = 106 mA, STO samples milled at θ = 5°–90° exhibited clear angular dependence: at θ ≤ 10°, the surface remained highly insulating (>50 MΩ), while at θ ≥ 15°, it became conductive with high mobility (μ = 5000–7000 cm^2/Vs at 2 K). Analysis based on Ar^+ ion penetration depth revealed that surface conduction emerges when the vertical penetration length exceeds the STO lattice constant (3.905 Å). These results indicate that shallow-angle milling suppresses damage to subsurface layers, offering a route for damage-free patterning of STO surfaces [4].

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Preparation of freestanding oxide films via $Sr_4Al_2O_7$ sacrificial layer and their quality assessment by lock-in thermography

Ao Wang, University of Science and Technology of China

A. Wang [1], J. Zhang [1], and L. Wang [1]

[1] Hefei National Research Center for Physical Sciences at Microscale, University of Science and Technology of China, Hefei, Anhui, China

Releasing epitaxial oxide films or heterostructures from substrate constraints not only enables integration with other low-dimensional systems but also stimulates intriguing functionalities. A key to fabricating large-scale freestanding oxide membranes lies in identifying a versatile, water-soluble sacrificial layer that is compatible with the epitaxial growth of high-quality oxide heterostructures. Here, we introduce a novel water-soluble sacrificial layer, "super-tetragonal" $Sr_4Al_2O_7$ (SAO_T). Its low-symmetry crystal structure enables superior capability to sustain epitaxial strain, allowing broad tunability of lattice constants. The resulting structural coherency and defect-free interface in perovskite ABO_3/SAO_T heterostructures effectively suppress crack formation during the water release of freestanding oxide membranes. We also propose a method to evaluate the quality of freestanding conductive oxide films using lock-in thermography (LIT). Compared to optical microscopy, this method can detect microcracks more efficiently. Additionally, large cracks and wrinkles also produce characteristic patterns in LIT images. Our study is of great significance for improving the quality of freestanding films and promoting their application in innovative devices.

Interfacial Engineering on the Structural Symmetry and Ferroelectricity of $Hf_{0.5}Zr_{0.5}O_2$-based heterostructures

Lingfei Wang, University of Science and Technology of China

Lingfei Wang [1]

[1] Hefei National Research Center for Physical Sciences at the Microscale, University of Science and Technology of China, Hefei 230026, China

Ferroelectric HfO_2-based thin films with fluorite structures exhibit outstanding nanoscale polarization stability, high compatibility with complementary metal-oxide-semiconductor (CMOS) processes, and low toxicity, making them a perfect match for the development of highly integrated, low-power information processing and storage devices. Consequently, this emerging ferroelectric system has attracted significant research interest from both academia and industry in recent years. However, the ferroelectric phase in HfO_2-based thin films is not thermodynamically stable, leading to the inevitable coexistence of ferroelectric and non-ferroelectric phases. This multiphase coexistence results in complex domain structures, as well as challenges such as wake-up effects, fatigue, and high coercive fields, which limit their potential for application in practical electronic devices. To address these challenges, we have constructed heterostructures of ABO_3 perovskite oxides and $Hf_{0.5}Zr_{0.5}O_2$ (HZO), and then employed various strain and interface engineering strategies to effectively engineering the structural symmetry of HZO films. These approaches have optimized the ferroelectric properties of epitaxial HZO films, improving their wake-up, fatigue, retention, and leakage current behavior, while achieving HZO ferroelectric films with uniform polarization orientation.

Spectral evidence of correlation-controlled metal-insulator transition in $Nd_{1-x}Sr_xNiO_3$ thin films

Rui Xu, University of Science and Technology of China

Rui Xu [1,2], Huan Ye [1], Yuzhe Wang [1,2], Jianghao Yao [1,2], Xianglin Li [1,2], Long Wei [5], Zhisheng Zhao [1,2], Sen Liao [1,2], Peng Li [1,2], Chihao Li [3], Rui Peng [3], Zhengtai Liu [4], Dawei Shen [5], Kai Chen [5], Yilin Wang [1,2], Lingfei Wang [1], Donglai Feng [1, 5], and Juan Jiang [1,2]

[1] Hefei National Research Center for Physical Sciences at Microscale and school of emergent technology, University of Science and Technology of China, Hefei, 230026, China
[2] Hefei National Laboratory, University of Science and Technology of China, Hefei 230088, China
[3] State Key Laboratory of Surface Physics, Department of Physics, and Advanced Materials Laboratory, Fudan University, Shanghai 200433, China
[4] Shanghai Synchrotron Radiation Facility, Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai, 201210, China
[5] National Synchrotron Radiation Laboratory and School of Nuclear Science and Technology, University of Science and Technology of China, Hefei, 230026, China

$NdNiO_3$, as a representative material in $RNiO_3$, has been investigated intensively. The metal-insulator transition (MIT) in $NdNiO_3$ thin film demonstrates exceptional tunability through epitaxial strain and carrier doping. Here, we synthesized high-quality $Nd_{1-x}Sr_xNiO_3$ thin films on $(La_{0.3}Sr_{0.7})(Al_{0.65}Ta_{0.35})O_3$ (LSAT) (001) and $SrTiO_3$ (STO) (001) substrates, and systematically investigated the effects of substrate strain and chemical doping on their low-energy electronic structures using angle-resolved photoemission spectroscopy (ARPES). Transport measurements reveal that Sr doping strongly suppresses the metal--insulator transition (MIT) temperature T_{MIT} on both substrates, with accelerated suppression in STO (001)-grown samples. Our ARPES results reveal that beyond a chemical potential shift, Sr doping significantly alters the effective mass, with a larger change observed in $Nd_{1-x}Sr_xNiO_3$/STO (001) than in LSAT-based films. These findings indicate that Sr doping, combined with epitaxial strain, alters the correlation strength and thereby modifies the MIT. Our results unravel the intricate interplay among multiple degrees of freedom in $Nd_{1-x}Sr_xNiO_3$ thin films, deepening the understanding of nickelate-based heterostructure design and engineering.

Driving epitaxially strained $BaFe_{12}O_{19}$ towards multiferroicity via phononic coupling

Zoe You, Cornell University

$BaFe_{12}O_{19}$ is an M-type hexaferrite with a strong ferromagnetic moment and high transition temperature. In addition to its outstanding magnetic properties, it has recently attracted significant attention as a quantum paraelectric. While quantum fluctuations suppress the formation of long-range ferroelectric order even at the lowest temperatures, theory suggests that sufficient strain can induce ferroelectric order at room temperature. In this work, we exploit nonlinear phonon-strain coupling to enhance the polar order of epitaxially strained $BaFe_{12}O_{19}$ thin film, pushing the system closer to a multiferroic state.