Magnetic Interfaces and Nanostructures
Room 318 - Session MI1-MoA

Advanced Magnetic Materials in Low Dimensional Structures II

Moderator: Markus Donath, Muenster University, Germany

1:30pm **MI1-MoA-1 Bringing Materials-Specific Clarity to the Debate on Magnetism in RuO_2, *Bharat Jalan,*** University of Minnesota, USA **INVITED**

RuO_2, a rutile 4d-transition metal oxide, exhibits a unique crystal structure with both edge- and corner-sharing octahedra. This intrinsic anisotropy, when combined with strain engineering, provides a powerful avenue for tuning anisotropic electronic and optical properties. However, from a synthesis perspective, challenges such as variable Ru valence states, Ru/O stoichiometry control, anisotropic strain states, and structural defects can make it difficult to distinguish intrinsic properties from extrinsic effects in RuO_2 thin films – a classic trick in the pursuit of novel functionalities in quantum materials. In this talk, I will highlight our group's efforts in overcoming these synthesis challenges while demonstrating metallicity in epitaxial RuO_2 films down to the unit cell scale. Through a combination of advanced X-ray scattering, X-ray absorption spectroscopy, transmission electron microscopy, temperature-dependent transport, magneto-optical measurements, and density functional theory (DFT) calculations, we uncover robust magnetism in epitaxially strained RuO_2, consistent with an altermagnetic metallic phase [1-4]. Additionally, we reveal a novel polar phase in strained films with significant implications for electrical transport – an unexpected treat in the realm of functional oxides. I will discuss these findings in detail, emphasizing their sensitivity to material defects and structure – key ingredients that are often overlooked but crucial in determining emergent quantum phenomena.

Reference:

1. S. G. Jeong†, I. H. Choi†, S. Nair, L Buiarelli, B. Pourbahari, J. Y. Oh, N. Bassim, A. Seo, W. S. Choi, R. M. Fernandes, T. Birol, L. Zhao, J. S. Lee, and B. Jalan, **Altermagnetic polar metallic phase in ultra-thin epitaxially-strained RuO_2 films**, PNAS 123 (10) e2526641123 (2026) †Equal contribution
2. S. G. Jeong, I. H. Choi, S. Lee, J. Y. Oh, S. Nair, J. H. Lee, C. Kim, A. Seo, W. S. Choi, T. Low, J. S. Lee, and B. Jalan, **Anisotropic Strain Relaxation-Induced Directional Ultrafast Carrier Dynamics in RuO_2 Films**, Sci. Adv. 11, eadw7125 (2025)
3. S. G. Jeong, S. Lee, B. Lin, Z. Yang, I. H. Choi, J. Y Oh, S. Song, S. W. Lee, S. Nair, R. Choudhary, J. Parikh, S. Park, W. S. Choi, J. S. Lee, J. M. LeBeau, T. Low, and B. Jalan, **Metallicity and Anomalous Hall Effect in Epitaxially-Strained, Atomically-thin RuO_2 Films,** PNAS 122(24) e2500831122
4. S. G. Jeong, B. Y. X. Lin, M. Jin, I. H. Choi, S. Lee, Z. Yang, S. Nair, R. Choudhary, J. Parikh, A. Santhosh, M. Neurock, K. A. Stoerzinger, J. S. Lee, T. Low, Q. Tu, J. M. LeBeau, and B. Jalan,**Strain-Stabilized Interfacial Polarization Tunes Work Function Over 1 eV in RuO_2/TiO_2Heterostructures,** *Nat. Commun. 17, 2516 (2026)*

2:00pm **MI1-MoA-3 On the Sign of the Rashba Parameter in Image-Potential States*, Markus Donath,*** *Fabian Schöttke,* University of Münster, Germany*; Kaishu Kawaguchi,* University of Tokyo, Japan*; Kenta Kuroda,* Hiroshima University, Japan*; Peter Krüger, Thorsten Deilmann,* University of Münster, Germany*; Ayumi Harasawa, Shuntaro Tani, Yohei Kobayashi, Takeshi Kondo,* University of Tokyo, Japan

For spintronic devices, spin manipulation without external magnetic fields is highly desirable. At surfaces and two-dimensional materials, the spin degeneracy of electronic states can be lifted by the Rashba effect. The Rashba effect in surface states at high-*Z* materials is related to both the strong spin-orbit interaction in heavy atoms and the orbital angular momentum arising from the inversion-symmetry breaking at the surface. Image-potential surface states are simple model systems, where spin-dependent effects can be studied in view of spintronic applications. Our study on Bi_2Se_3 and Bi_2Te_3 showcases that the orbital angular momentum causes an intrinsically reversed Rashba parameter $\alpha_R \approx -100$ meV Å, i.e., a reversed spin splitting compared with the prototypical Rashba-split Au(111) crystal-induced surface state [1] or the image-potential state at Re(0001) [2]. The sign of α_R is decisive for controlling the absolute spin directions in view of spintronic devices. We present a consistent picture of spin-resolved experimental data from inverse photoemission and three-photon photoemission together with calculations from density-functional theory and many-body perturbation theory.

[1] M. Hoesch *et al.*, Phys. Rev. B **69**, 241401(R) (2004); S. N. P. Wissing *et al.*, New J. Phys. **15**, 105001 (2013).
[2] F. Schöttke *et al.*, Phys. Rev. B **105**, 155419 (2022).

2:15pm **MI1-MoA-4 High Magnetocrystalline Anisotropy-Driven Fuel Cell Electrocatalysis in PtPdFe Intermetallic Alloys***, Muhammad Irfansyah Maulana, **Jong-Sung Yu,*** DGIST, Republic of Korea

Ordered Pt-based intermetallic alloys are emerging as efficient oxygen reduction reaction (ORR) electrocatalysts in hydrogen fuel cells, outperforming their disordered counterparts. However, the intrinsic role of atomic ordering in governing ORR catalytic performance remains unclear. In this work, we report ferromagnetic PtPdFe ternary intermetallics with structurally ordered tetragonal $L1_0$ and cubic $L1_2$ phases (Figure 1a), each featuring distinct crystal structures and atomic arrangements. Our study highlights magnetocrystalline anisotropy as a key structure-dependent descriptor that governs ORR activity in these alloys. Electrochemical half- and single-cell tests reveal that $L1_0$-PtPdFe magnetic intermetallic catalysts (MICs) deliver higher ORR activity than their $L1_2$ counterparts (Figure 1b). Combined experimental and theoretical analyses attribute this enhancement to the unique tetragonal $L1_0$ structure, where strong 5d–3d orbital interactions along the c-axis induce ferromagnetic ordering and elevate magnetocrystalline anisotropy energy, thereby accelerating ORR kinetics. Furthermore, membrane electrode assemblies fabricated by $L1_0$-PtPdFe cathode MICs sustain fuel cell performance beyond the 2025 US Department of Energy stability targets under H_2–O_2, H_2–air, and H_2–N_2 conditions. These findings establish a new design principle for Pt-based intermetallic catalysts, demonstrating that magnetic anisotropy arising from ferromagnetic ordering can be strategically harnessed to optimize fuel cell performance.

Author Index

Bold page numbers indicate presenter

— D —
Deilmann, Thorsten: MI1-MoA-3, 1
Donath, Markus: MI1-MoA-3, **1**
— H —
Harasawa, Ayumi: MI1-MoA-3, 1
— J —
Jalan, Bharat: MI1-MoA-1, **1**
— K —
Kawaguchi, Kaishu: MI1-MoA-3, 1
Kobayashi, Yohei: MI1-MoA-3, 1
Kondo, Takeshi: MI1-MoA-3, 1
Krüger, Peter: MI1-MoA-3, 1
Kuroda, Kenta: MI1-MoA-3, 1
— M —
Maulana, Muhammad Irfansyah: MI1-MoA-4, 1
— S —
Schöttke, Fabian: MI1-MoA-3, 1
— T —
Tani, Shuntaro: MI1-MoA-3, 1
— Y —
Yu, Jong-Sung: MI1-MoA-4, **1**