## Magnetic Interfaces and Nanostructures
## Room 318 - Session MI-MoM

### Advanced Magnetic Materials in Low Dimensional Structures I

**Moderators: Dr. Valeria Lauter**, Oak Ridge National Laboratory, **Prof. Dr. Markus Donath**, Muenster University, Germany

10:00am **MI-MoM-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 $RuO_2/TiO_2$Heterostructures,** *Nat. Commun. 17, 2516 (2026)*


10:30am **MI-MoM-3 Compositionally Tunable Synthesis of High-Entropy Transition Metal Dichalcogenides Exhibiting Above-Room-Temperature Magnetism***, **Xiahua Zhong**, Chen Zhang,* University of Missouri-Columbia*; Zheng Gai, Huan Zhao,* Oak Ridge National Laboratory, USA*; Yingchao Yang,* University of Missouri-Columbia

As silicon-based electronics approach their physical limits, spintronics, leveraging electron spin rather than charge, offers a promising path for next-generation information technologies. Realizing this potential requires two-dimensional (2D) materials with robust and tunable room-temperature magnetism. Here, we report a two-step synthesis strategy for fabricating 2D high-entropy transition metal dichalcogenides (HE-TMDs) incorporating magnetic elements beyond conventional groups 4-6. High-entropy layered double hydroxides (HE-LDHs) are first synthesized via hydrothermal coprecipitation, enabling atomic-level mixing of diverse transition metals across groups 4-12. Subsequent chalcogenization yields 2D HE-TMDs while preserving homogeneous elemental distribution. This approach circumvents the constraints of high-temperature and vapor-phase methods, enabling the synthesis of compositionally complex and structurally controlled 2D magnets. Representative $V_{\alpha}Cr_{\beta}Fe_{\gamma}Co_{\delta}Ni_{1-\alpha-\beta-\gamma-\delta}S_{2-x}$ exhibits robust ferromagnetism above room temperature, demonstrating the potential of this high-entropy design strategy to expand the family of 2D magnetic materials for spintronic applications.

10:45am **MI-MoM-4 Anomalous Hall Effect in Antiferromagnetic Dirac Semimetal $EuCu_2Sb_2$***, **Souvik Sasmal**,* Argonne National Lab

Magnetic Dirac semimetals—where Dirac fermions are protected by combined crystalline and magnetic symmetries—remain experimentally rare, despite intense theoretical interest. In this work, we identify EuCu2Sb2 as a promising candidate hosting Dirac-like electronic states in proximity to magnetic order. Temperature-dependent transport and magnetization measurements reveal an A-type antiferromagnetic transition at 5.1 K, accompanied by anisotropic resistivity, spin reorientation, and weak anomalous Hall features. Angle-resolved photoemission spectroscopy (ARPES) reveals linear Dirac-like band crossings at the X point, already present in the paramagnetic phase. First-principles calculations support a topological band inversion near the Fermi level and confirm the origin of the Dirac dispersion. These findings establish EuCu2Sb2 as a rare material system that bridges topological band structure with localized magnetism, offering a platform to explore symmetry-protected Dirac states in correlated magnetic materials.

11:00am **MI-MoM-5 Revisiting Altermagnetism in RuO2 and Cr-doped RuO2 Epitaxial Films through THz Spectroscopy and Neutron Scattering***, David T. Plouff, Nawsher J. Parvez,* Department of Physics and Astronomy, University of Delaware*; Laura Scheuer,* Department of Physics and Astronomy, University of Delaware, Germany*; Shreya Shrestha,* Department of Physics and Astronomy, University of Delaware*; Weipeng Wu,* Department of Physics and Astronomy, University of Delaware, China*; subhash Bhatt,* University of Delaware*; Xinhao Wang,* University of Delaware, China*; Lars Gundlach, M. Benjamin Jungfleisch,* University of Delaware*; Xixiang Zhang,* King Abdulah University of Science and Technology, Saudi Arabia*; Adam A. Aczel,* Oak Ridge National Laboratory, USA*; Jonathan Gaudet,* National Institute for Science and Technology (NIST)*; **John Q. Xiao**,* University of Delaware **INVITED**

Altermagnetism has recently emerged as a potentially transformative concept in spintronics, offering the possibility of combining the ultrafast dynamics of antiferromagnets with spin-split electronic structures typically associated with ferromagnets. Among proposed candidates, rutile $RuO_2$ has attracted intense attention because of predictions of unconventional spin transport. However, despite intense activity, the existence of an intrinsic altermagnetic order in $RuO_2$ remains highly controversial.

In this talk, we will present our systematic experimental investigation of epitaxial $RuO_2$ and $Ru_{1-x}Cr_xO_2$ thin films using terahertz and neutron-scattering measurements. Time-domain THz spectroscopy measurements on $RuO_2$ reveal that previously reported spintronic signatures can be consistently explained by conventional mechanism, including inverse spin Hall effects and anisotropic electronic conductivity associated with the rutile crystal structure, without invoking altermagnetic order. Motivated by theoretical predictions that hole doping may stabilize an altermagnetic state, we further probed magnetic state in $Ru_{1-x}Cr_xO_2$ thin films by using neutron scattering techniques.Our measurements show no evidence of long-range magnetic ordering down to 10 K in $Ru_{0.8}Cr_{0.2}O_2$ thin films, placing important experimental constraints on current theoretical models of altermagnetism in rutile oxides.

Beyond resolving the magnetic ground state, our work also reveals a new THz emission mechanism originating from the interplay between spintronic THz generation and anisotropic electronic transport in $RuO_2$. This hybrid mechanism enables magnetic-field tuning of the polarization ellipticity of emitted THz radiation, opening new opportunities for functional THz emitters based on correlated oxide materials.

This research was sponsored by NSF DMR-2316664, NSF through the University of Delaware Materials Research Science and Engineering Center (MRSEC), and King Abdullah University of Science and Technology (KAUST), ORFS-2022-CRG11-5031.2.

11:30am **MI-MoM-7 Cobalt Doping on Topological Superconductor $FeTe_{0.55}Se_{0.45}$***, **John Drain**[1],* University of Wyoming*; Mykola Telychko,* Oak Ridge National Laboratory*; Zheng Gai,* Oak Ridge Natinal Laboratory*; TeYu Chien,* University of Wyoming

$FeSe_xTe_{1-x}$ (FTS) is an iron-based superconductor that has been shown to have non-trivial topology with the correct relative Te/Se content ($FeTe_{0.55}Se_{0.45}$) and relatively high superconducting transition temperature,

[1] **Falicov Student Award Finalist**

$T_C$, of 14.5 K. Majorana zero modes (MZM), a quasiparticle needed for the development of topological quantum computing, have also been observed in magnetic vortices as well as at Fe adatom sites in FTS. Thus, the introduction of new magnetic elements to FTS is of particular interest, due to their potential to influence the formation of MZM and local topology. In this study, the effects of depositing magnetic Co atoms on the FTS surface are explored using scanning tunneling microscopy. We observe an apparent surface reconstruction after cobalt deposition with Co adatoms on top of the surface as well as defects from evident Co absorption. Areas with high concentration of Co defects show suppressed superconductivity. When superconductivity is preserved, in-gap bound states are observed at Co defect sites at either finite energy or zero energy. Furthermore, the energy of these finite energy states shifts to zero as the tunnel-barrier conductance of the STM tip is increased during spectroscopy measurements. The origins of these features as MZM, Yu-Shiba-Rusinov bound states, or Kondo effect will be discussed. These results present a potential prospect for a way to influence FTS properties locally through the introduction of Co to produce conditions ideal for Majorana zero mode and their braiding.

This work was funded by the NSF through Award #: DMR-2228841

11:45am **MI-MoM-8 Magnetic and Magnetostrictive Properties of Multilayer $Fe_{50}Co_{50}$ – Ag with Varied Ag Thickness**, ***Thomas Mion,*** US Naval Research Laboratory*; Margo Staruch,* US naval Research Laboratory*; Zoey Warecki,* us naval Research Laboratory*; Konrad Bussmann, Peter Finkel,* US Naval Research Laboratory

Temperature stable high magnetostrictive materials are required for microelectromechanical systems (MEMS) devices that seek to function reliably at high temperatures. Due to the immiscibility of Ag with Fe and Co, multilayers of $Fe_{50}Co_{50}$ – Ag will not alloy up to at least 700 C allowing for a stable high magnetostrictive material for MEMS platforms. $Fe_{50}Co_{50}$ is known to be moderately magnetostrictive and with a curie temperature ~1,000 C and a high saturation magnetization. Previous studies have shown with ~10nm $Fe_{50}Co_{50}$ and ~3nm Ag layers the multilayer system remains up to 400 C where higher temperatures cause breakdown of the Ag interlayer. This investigation seeks to improve the thermal stability of the FeCo-Ag multilayer system through varied Ag thickness and understand the mechanism of the nonmagnetic layer breakdown. Transmission Electron Microscopy investigations reveal the Ag layer is coherent up to 77 multilayers (~930 nm) even with increased roughness as the thickness increases resulting in the restricted in-plane magnetization and subsequent lower coercive field.

# Author Index

## Bold page numbers indicate presenter