Light Source Enabled Science
Room 319 - Session LS-MoM

Light Source Enabled ARPES

Moderators: Dr. Lucía Pérez Ramírez, CEA Saclay, **Dr. Nicholas Strange**, SLAC National Accelerator Laboratory

10:00am **LS-MoM-1 Depth-Resolved X-Ray Spectroscopy of Emergent Electronic and Magnetic States at Oxide Interfaces***, **Alexander Gray**,* Temple University **INVITED**

The emergence of novel electronic and magnetic states at correlated oxide interfaces is governed by a complex interplay of charge transfer, orbital reconstruction, and interfacial magnetism. In this talk, I will demonstrate how the combination of complementary synchrotron-based probes, including hard X-ray photoelectron spectroscopy (HAXPES), angle-resolved photoelectron spectroscopy (ARPES), polarization-dependent X-ray absorption spectroscopy (XAS), and resonant X-ray magnetic reflectivity, enables a comprehensive, depth-sensitive view of these phenomena in buried oxide heterostructures. Using $LaNiO_3/CaMnO_3$, $CaMnO_3/CaRuO_3$, $NdNiO_3/CaMnO_3$, and $VO_2/LaAlO_3/TiO_2$ interfaces as model systems, we reveal how interface engineering, defect chemistry, and interfacial charge transfer can stabilize emergent ferromagnetism and tune electronic phase transitions [1-3]. Looking forward, these synchrotron-enabled insights also establish a foundation for ultrafast studies at X-ray free-electron lasers (FEL), where intense IR or THz electric-field pulses can be used to manipulate interfacial electronic and magnetic states on their intrinsic timescales [4]. These studies highlight the unique power of combining multiple synchrotron techniques to disentangle coupled charge, spin, and orbital interactions at complex interfaces and provide pathways toward controllable oxide-based electronic and spintronic functionalities.

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[1] J. R. Paudel *et al.*, *Phys. Rev. B* **108**, 054441 (2023).
[3] D. Mondal *et al.*, *Nature Comm.* **14**, 6210 (2023).
[3] J. R. Paudel *et al.*, *Nano Letters***24**, 15195 (2024).
[4] A. M. Derrico *et al.*, *Adv. Mater.* **38**, e12328 (2026).

10:30am **LS-MoM-3 Layer-Specific Spin-Polarization in a Triple-Layer Ferromagnetic Oxide***, **Jonathan Denlinger**,* Lawrence Berkeley National Laboratory*; Prosper Ngabonziza,* Louisiana State University*; Alexei Fedorov,* Lawrence Berkeley National Laboratory*; Gang Cao,* University of Colorado Boulder*; James W. Allen,* University of Michigan, Ann Arbor*; G. Gebreyesus,* University of Ghana, Accra, Ghana*; Richard M. Martin,* Stanford University

The transport and magnetic properties of triple-layer oxides can be distinctly affected by the different structural environments of the outer versus central layers. Here we highlight the layer-specific *spin-polarized* electronic structure of the ferromagnetic triple-layer ruthenate $Sr_4Ru_3O_{10}$, using high resolution synchrotron angle- and spin-resolved photoemission spectroscopy (ARPES) [1]. Two separate narrow-band van Hove singularities (vHS) are found ∼30 meV below the Fermi-level at the zone center and at the zone-edge, which exhibit almost pure spin-polarization, but with opposite-sign. Comparison of the ARPES to spin-polarized DFT calculations quantifies the FM exchange splitting energy, and thus the predicted layer-specific spin polarization contributions to the magnetism, which is then indirectly evidenced by ARPES multi-zone matrix element intensities.

Furthermore, the vHS peaks exhibit dramatic Kondo-coherence-like temperature-dependence, that are the result of multi-orbital Hund metal physics. Fine T-dependent effects at various momenta, including oxygen-band spin-polarization and spin-dependent energy and momentum-shifts provide a more refined picture of the itinerant versus localized description of its magnetism. Finally, rotations of oxygen octahedra induce a zone-folded hybridization of opposite spin bands that break up the zone boundary vHS into smaller lower energy scale mini-vHSs that are relevant to the field-induced metamagnetism of the system.

[1] P. Ngabonziza et al. Phys. Rev. B **111**, 115146 (2025)

10:45am **LS-MoM-4 In-situ Strain Tuning of Electronic Order at a Light Source: Insights from μ-ARPES and μ-Diffraction***, **Yucheng Guo**,* Rice University*; Zhaoyu Liu,* Clemson University*; Na Hyun Jo,* University of Michigan, Ann Arbor*; Ji Seop Oh,* Sookmyung Women's University, Korea (Democratic People's Republic of)*; Yichen Zhang,* Rice University*; Aaron Bostwick, Chris Jozwiak, Nobumichi Tamura,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Makoto Hashimoto, Donghui Lu,* SLAC National Accelerator Laboratory*; Robert J. Birgeneau,* University of California, Berkeley*; Jiun-Haw Chu,* University of Washington*; Eli Rotenberg,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Ming Yi,* Rice University

In quantum materials, the manipulation of atomic spacing and electron-cloud overlap enables precise control of the many-body Hamiltonian, influencing the material's ground state, excitations, phases, and competing orders. To investigate how these effects are manifested in the electronic band structure, we integrated a piezo-driven stress cell compatible with μ-ARPES and Laue μ-diffraction beamlines at the Advanced Light Source.

Using this capability, we investigate an intriguing phenomenon reported by P. Malinowski *et al.* [1], who demonstrated that continuously applied uniaxial strain can strongly suppress the superconducting transition temperature, Tc, in an optimally doped iron-based superconductor, while the underlying microscopic mechanism remains elusive.

In this presentation, we discuss in-situ uniaxial strain tuning of electronic correlations in an orbital- and momentum-resolved manner, using decoupled strain channels in $BaFe_2(As_{0.7}P_{0.3})_2$. Our results are largely consistent with a nematic quantum critical point scenario.

[1] P. Malinowski *et al.*, *Nature Physics* **16**, 1189–1193 (2020).

11:00am **LS-MoM-5 Large Exciton Binding Energy in a Bulk Van Der Waals Magnet from Quasi-1D Electronic Localization***, **Shane Smolenski**, Ming Wen, Qiuyang Li, Eoghan Downey, Adam Alfrey,* University of Michigan, Ann Arbor*; Wenhao Liu, Aswin Kondusamy,* University of Texas at Dallas*; Aaron Bostwick, Chris Jozwiak, Eli Rotenberg,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Liuyan Zhao, Hui Deng,* University of Michigan, Ann Arbor*; Bing Lv,* University of Texas at Dallas*; Dominika Zgid, Emanuel Gull, Na Hyun Jo,* University of Michigan, Ann Arbor

Excitons, bound electron-hole pairs, influence the optical properties in strongly interacting solid-state systems and are typically most stable and pronounced in monolayer materials. Bulk systems with large exciton binding energies, on the other hand, are rare and the mechanisms driving their stability are still relatively unexplored. Here, we report an exceptionally large exciton binding energy in single crystals of the bulk van der Waals antiferromagnet CrSBr. Utilizing state-of-the-art synchrotron-based angle-resolved photoemission spectroscopy and self-consistent ab-initio *GW* calculations, we present direct spectroscopic evidence supporting electronic localization and weak dielectric screening as mechanisms contributing to the amplified exciton binding energy. Furthermore, we report that surface doping enables broad tunability of the band gap offering promise for engineering of the optical and electronic properties. Our results indicate that CrSBr is a promising material for the study of the role of anisotropy in strongly interacting bulk systems and for the development of exciton-based optoelectronics.

11:15am **LS-MoM-6 Probing Domain-Specific Charge Density Wave Dynamics and Strain Tunability in Bulk 1T-VTe2***, **Pratik Saud**,* Carnegie Mellon University, USA*; Sandy Adhitia Ekahana,* Carnegie Mellon University*; Aalok Tiwari,* Carnegie Mellon University, USA*; Mohan Bikram Neupane,* Purdue University, USA*; Sagnik Bajpeyi,* Carnegie Mellon University, USA*; Chris Jozwiak, Eli Rotenberg, Aaron Bostwick,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Arnab Banerjee,* Purdue University, USA*; Simranjeet Singh, Jyoti Katoch,* Carnegie Mellon University, USA

In transition metal dichalcogenides, the emergence of a charge density wave (CDW) is highly sensitive to the material's dimensionality. While bulk and multi-layer 1T-VTe_2 host a robust CDW state, this ordered phase is unexpectedly suppressed in the monolayer limit. This contrast indicates that out-of-plane interactions are fundamental to stabilizing the CDW. Consequently, a rigorous, momentum-resolved investigation of the 3D bulk crystal is a requisite precursor to engineering these states in ultra-thin devices. Here, we utilize advanced synchrotron light sources to systematically investigate the structural and electronic phase transitions of pristine bulk 1T-VTe_2. We employ Laue microdiffraction (beamline 12.3.2) at the Advanced Light Source (ALS) to map local crystallographic symmetries, alongside high-resolution Angle-Resolved Photoemission Spectroscopy with micron-sized spatial resolution (microARPES) at the MAESTRO 7.0.2

beamline to track electronic dispersion. A key objective of this work is to spatially correlate these independent datasets to decouple lattice distortions from the CDW gap formation.

Temperature-dependent ARPES measurements reveal a dramatic phase evolution. At 500 K, the material exhibits a highly symmetric hexagonal Brillouin zone. Cooling to cryogenic temperatures triggers a macroscopic symmetry breaking, forming three distinct structural domains rotated 120 degrees relative to one another. Probing these individual domains enables the observation of highly directional, quasi-one-dimensional electronic features emerging from the symmetric parent state. Furthermore, this multi-domain landscape provides an opportunity to search for localized electronic states residing at the boundaries between these energetically equivalent regions. Next, we will present our work beyond static observation, where we introduce in-operando mechanical strain during photoemission measurements, to actively manipulate domain populations and tune their corresponding electronic signatures. By comprehensively detailing domain formation, boundary phenomena, and strain-engineered responses in the bulk, this research establishes a predictive framework for dimensional crossover effects. Ultimately, these insights lay the critical groundwork for future efforts to isolate, manipulate, and control fragile correlated phases within mechanically exfoliated two-dimensional heterostructures.

11:30am **LS-MoM-7 Observing the Electronic Response of a Mott Insulator at a Current-Induced Insulator-to-Metal Transition Using Transport-ARPES**, ***Cissy Suen***, Max Planck Institute for Solid State Research, University of Britsh Columbia, Germany*; Igor Markovic, Marta Zonno, Niclas Heinsdorf, Sergey Zhdanovich,* University of British Columbia, Canada*; Na Hyun Jo,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Michael Schmid,* Max Planck Institute for Solid State Research, Germany*; Philipp Hansmann,* Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Germany*; Steef Smit, Christine Au-Yeung,* University of British Columbia, Canada*; Valentin Zimmermann,* Max Planck Institute for Solid State Research, Germany*; Berend Zwartsenberg,* University of British Columbia, Canada*; Maximilian Krauloher,* Max Planck Institute for Solid State Research, Germany*; Sergey Gorovikov,* Canadian Light Source, Inc., Canada*; Chris Jozwiak, Aaron Bostwick,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Marcel Franz,* University of British Columbia, Canada*; Eli Rotenberg,* Advanced Light Source, Lawrence Berkeley National Laboratory*; Bernhard Keimer,* Max Planck Insitute for Solid State Research, Germany*; Andrea Damascelli,* University of British Columbia, Canada

The quasi-two-dimensional Mott insulator Ca2RuO4 exhibits a convergence of spin-orbit coupling and electronic correlations that lead to exciting quantum phenomena [1], including a rare insulator-to-metal transition (IMT) induced by a DC current [2]. While structural changes have been tracked by neutron diffraction [3], Raman scattering [4], and x-ray diffraction [5], the associated electronic changes had not been observed. Here we report angle-resolved photoemission spectroscopy (ARPES) results under DC current, which show a substantial reduction of the Mott gap, along with a change in the Ru t2g band dispersion [6]. We have also captured the high temperature Fermi surface, whose spectral features are unique from the current-induced metallic Fermi surface. In conjunction with a free energy analysis, our results demonstrate that the current-induced phase, albeit thermodynamically equivalent, is electronically distinct from the high-temperature zero-current metallic phase.

Combining ARPES with transport, i.e. transport-ARPES, has been rare given the complexity of disassociating real field- or current-driven physics from the effect of stray electric and magnetic fields on the outgoing photoelectron trajectory. By taking advantage of the micron-sized beam spot at the MAESTRO beamline (7.0.2) at the Advanced Light Source and careful core level spectrum analysis, we show that transport-ARPES can be extended to the study of any ARPES-suitable material. I will include an overview on transport-ARPES, as well as a brief outlook on the exciting prospects of in operando spectroscopy.

[1] A. Jain et al., Nat. Phys. 13 (2017) 633-637

[2] R. Okazaki et al., J. Phys. Soc. Jpn 82 (2013) 103702

[3] J. Bertinshaw et al., Phys. Rev. Lett 123 (2019) 137204

[4] K. Fürsich et al., Phys. Rev. B 100 (2019) 081101

[5] K. Jenni et al., Phys. Rev. Mat 4 (2020) 085001

[6] C.T. Suen et al., Nat. Phys. 20 (2024) 1757–1763

11:45am **LS-MoM-8 Investigation of Momentum Resolved Electronic Structure of Cr1.17Te2**, ***Sagnik Bajpeyi***, Carnegie Mellon University, USA*; Sandy Adhitia Ekahana,* Carnegie Mellon University*; Aalok Tiwari,* Carnegie Mellon University, USA*; Mohan Bikram Neupane,* Purdue University, USA*; Pratik Singh Saud,* Carnegie Mellon University, USA*; Chris Jozwiak, Eli Rotenberg, Aaron Bostwick,* Lawrence Berkeley National Laboratory, US*; Arnab Banerjee,* Purdue University, USA*; Simranjeet Singh, Jyoti Katoch,* Carnegie Mellon University, USA

Chromium tellurides have attracted significant interest due to the strong interplay between electronic correlations and crystal structure. Among them, Cr1.17Te2 is a transition-metal chalcogenide that exhibits complex electronic behavior arising from non-stoichiometry and strong Cr–Te hybridization. Here, we investigate the electronic structure of Cr1.17Te2 using high-spatial-resolution angle-resolved photoemission spectroscopy (microARPES) performed at the MAESTRO Beamline of the Advanced Light Source.

We will present momentum-resolved band dispersion measurements acquired at 10 K using 84 eV photons with varying light polarizations, together with core-level spectroscopy of Cr and Te orbitals and out-of-plane kz dispersion measurements. Potassium surface dosing was further employed to tune the chemical potential and investigate the evolution of electronic states near the Fermi level. Our photon-energy-dependent measurements reveal a periodicity that deviates from expectations based on X-ray diffraction data, suggesting a more complex three-dimensional electronic structure than previously anticipated. These results motivate future soft X-ray ARPES measurements in the 300–700 eV range to further elucidate the intrinsic bulk electronic structure of Cr1.17Te2 and resolve the origin of this discrepancy.

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