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# Tricks of Strain and Treats of Emergent Phases: Unraveling Altermagnetism and Polar Metallic States in Epitaxial $RuO_2$ Films

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$RuO_2$, 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 [1-3]. 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:**

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