Interfacial Magnetism in Nickelate-Titanate Superlattices and MCD RIXS in the topological ferromagnetic metal Fe_3Sn_2

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In this lecture, I will give an overview about two topical studies employing Resonant Inelastic X-ray scattering on quantum materials: 1) Emergence of Interfacial Magnetism in Strongly-Correlated Nickelate-Titanate Superlattices & 2) Spin waves and orbital contribution to ferromagnetism in the topological metal Fe_3Sn_2.

1) Strongly-correlated transition-metal oxides are widely known for their various exotic phenomena. This is exemplified by rare-earth nickelates such as $LaNiO_3$, which possess intimate interconnections between their electronic, spin, and lattice degrees of freedom. Their properties can be further enhanced by pairing them in hybrid heterostructures, which can lead to hidden phases and emergent phenomena. An important example is the $LaNiO_3/LaTiO_3$ superlattice, where an interlayer electron transfer has been observed from $LaTiO_3$ into $LaNiO_3$ and is predicted to result in a high-spin state. However, macroscopic emergence of magnetic order has so far not been observed. Here, by using muon spin rotation, x-ray absorption, and resonant inelastic x-ray scattering, we present direct evidence of an emergent antiferromagnetic order with high magnon energy and exchange interactions at the $LaNiO_3/LaTiO_3$ interface [1]. As the magnetism is purely interfacial, a single $LaNiO_3/LaTiO_3$ interface can essentially behave as an atomically thin quasi-two-dimensional antiferromagnet, potentially allowing its technological utilization in advanced spintronic devices. Furthermore, its strong quasi-two-dimensional magnetic correlations and orbitally-polarized planar ligand holes make its electronic and magnetic configurations resemble the precursor states of superconducting cuprates and nickelates, but with an $S\rightarrow 1$ spin state instead.

2) Magnetic metals with kagome structure can host various topologically non-trivial spin or electronic states, providing an extraordinary platform for studying the fundamental physics of quantum materials. The metallic ferromagnet Fe_3Sn_2, built from compact AB-stacked kagome bilayers, shows a topologically non-trivial electronic band structure controllable by modest external magnetic fields and hosts anomalous bulk properties, including a first-order spin reorientation transition, a large anomalous Hall effect, and skyrmionic bubbles. Meanwhile the underlying physics is still under debate and requires spectroscopic understanding especially concerning the magnetic degrees of freedom. Using magnetic circular dichroism (MCD) in X-ray absorption and resonant inelastic X-ray scattering (RIXS) for the unambiguous isolation of magnetic signals, we report a nearly flat spin wave band and large (compared to elemental iron) orbital moment for Fe_3Sn_2 [6]. As a function of out-of-plane momentum, the flat optical mode and the global rotation symmetry-restoring acoustic mode are out of phase, consistent with a bilayer exchange coupling that is larger than the already large in-plane couplings. Our results suggest the defining units of this very popular topological metal are therefore a triangular lattice of octahedral iron clusters rather than weakly coupled kagome planes. The spin waves are strongly damped when compared to elemental iron, opening the topic of topological interactions of topological bosons (spin waves) and fermions (electrons).

References

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2. W. Zhang, T. Schmitt et al., Nature Communications **15**, 8905 (2024).