Magnetic Interfaces and Nanostructures
Room Ballroom A - Session MI-ThP
Magnetic Interfaces and Nanostructures Poster Session

MI-ThP-1 Wilson Loop as a Tool to Investigate Chirality-Induced Spin Selectivity: Role of Vibrations and Multiple Channels*, **Leonardo Celada**, D. K. Andrea Phan Huu, Alessandro Chiesa, Paolo Santini, Luca Griguolo, Stefano Carretta,* Università degli studi di Parma, Italy

Chirality-induced spin selectivity (CISS) has been observed in a wide range of chiral molecular systems, yet the minimal microscopic ingredients required for spin polarization remain debated [1]. Here we introduce the Wilson loop as a general theoretical criterion to identify when spin polarization can emerge in model Hamiltonians relevant to CISS.

Using open tight-binding models with spin-orbit coupling, we show that the Wilson loop provides a gauge-invariant characterization of spin-dependent interference and recovers the known absence of CISS in single-channel purely electronic models, where a local spin gauge transformation removes all spin dependence. By contrast, non-trivial Wilson loops arise in systems with multiple transport channels, providing a direct symmetry-based criterion for finite spin polarization, consistent with previous theoretical studies of CISS mechanisms [2].

We then extend this framework to electron-vibration models and show that vibronic pathways can generate non-trivial Wilson loops even in nominally single-channel systems. In particular, Peierls-type coupling creates spin-dependent interference in vibronic space and enables CISS, whereas Holstein coupling preserves a trivial Wilson loop and cannot induce spin polarization. This establishes a distinction between vibrational mechanisms proposed in the literature [3].

Beyond reproducing known results, the Wilson-loop formulation provides a unifying path-based picture connecting gauge structure, interference, and spin selectivity across electronic and vibronic mechanisms. The framework can be generalized to arbitrary molecular architectures and offers a tool to identify necessary conditions for CISS in transport and electron-transfer settings, including systems where spin selectivity has recently been observed experimentally [4].

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References

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MI-ThP-2 Experimental Insights into Spin-Driven Correlated Phase Transitions in CrN*, **Khan Alam**,* Department Of Physics, Kfupm, Saudi Arabia*; Arthur Smith,* Department of Physics

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Abstract

Chromium nitride (CrN) is an important transition metal nitride that serves as a model system for studying correlated structural, electronic, and magnetic phase transitions. The coupling among these transitions makes CrN a compelling example of a correlated material in which magnetic spin ordering plays a central role in driving the observed transformations. Upon cooling, CrN undergoes a first-order transition involving antiferromagnetic spin ordering, along with structural and electronic transitions. These structural, electronic, and magnetic transitions are not independent but strongly intertwined, offering insight into the mechanisms of magnetostructural coupling in correlated electron systems.

Our experimental investigations of these coupled transitions in CrN include neutron diffraction, reflection high-energy electron diffraction, variable-temperature x-ray diffraction, electronic transport measurements, and scanning tunneling microscopy, we probe the evolution of structural symmetry, magnetic spin order, and electronic states across the transition. The results elucidate how spin ordering triggers and stabilizes the structural and electronic phase transitions, highlighting the cooperative nature of these coupled phenomena. These findings not only deepen our understanding of CrN but also shed light on the broader class of correlated transition metal nitrides that exhibit intertwined spin-lattice-charge interactions.

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MI-ThP-3 Utilizing MOKE Magnetometry to Observe Properties of Magnetic Thin Films*, **Ivan Gray**, Seth Woodwyk, Femi Akinrinola, Raj Bhandari, Jeremy Fanelli, Mikel Holcomb,* West Virginia University

In the study of thin film materials, magnetometry can be a powerful tool for understanding the magnetic properties and interactions of materials, though most widely available magnetometers are designed for bulk materials, so surface level probing at a focused point can be difficult. The magneto-optical Kerr effect (MOKE), however, offers a surface-sensitive alternative to bulk magnetometry techniques. MOKE is a magneto-optic phenomenon that results from interactions between light and the magnetization of a material. A magnetized material will experience differing refractive indices for left and right-circularly polarized light due to the off-diagonal tensorial elements of the dielectric constant of the material. As light reflects from this material, the two circularly polarized components are reflected with varying amplitudes and phase shifts, resulting in a changed polarization state of the reflected light. This is described by both the Kerr rotation, the angle in which the original polarization is rotated, and the Kerr ellipticity, describing the resulting elliptical polarization. Changes in these properties can be observed over a range of applied fields, showing the magnetic hysteresis of the material, noted as Kerr magnetometry. We are using this method to explore the mechanisms behind spontaneous magnetization reversal (SMR) in single layer thin films of $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) grown on $SrTiO_3$ (STO). SMR is more commonly seen in multilayer systems, while it has only been reported in a few single layer systems. In SMR, competing magnetic interactions under a cooling or applied field can result in the net magnetization reversing direction relative to the field. In particular, LSMO exhibits SMR both at low applied magnetic fields and near room temperature, allowing for potential real-world applications. Understanding how the mechanisms driving SMR in LSMO work will inform the design of future devices that exploit SMR under practical operating conditions.

MI-ThP-4 Early-Stage Experimental Training in Magnetism: A Hands-On Freshman Research Course as a Gateway to Advanced Magnetic Materials*, **Mikel Holcomb**,* West Virginia University*; Femi Akinrinola,* West Virginia University, USA*; Robbyn Trappen, Seth Woodwyk, Ivan Gray, Tap Raj Bhandari, Jeremy Fanelli, Dorian Davis, Nethmi Kankanamge, John Stewart,* West Virginia University

The development of advanced magnetic materials and low-dimensional magnetic systems relies critically on a skilled experimental workforce capable of integrating measurement and data interpretation at early stages of training. I describe a hands-on freshman-level research course designed to introduce students to experimental magnetism through direct engagement with measurement techniques and a variety of magnetic systems. In this course, students perform studies on magnetic materials, with an emphasis on data acquisition and physical interpretation. Projects are structured to connect fundamental concepts—such as magnetic anisotropy, hysteresis and types of magnetism—to experimental observables, providing an entry point into phenomena central to modern magnetism research. Students develop experimental intuition through open-ended investigations that reflect the uncertainty and exploratory nature of contemporary research, with each project structured as a potentially extensible research direction. I will discuss course design, representative experiments, and evidence for improved student readiness for research in physics and materials science. This model suggests a pathway for broadening participation and accelerating training in areas aligned with emerging challenges in magnetic interfaces and nanostructures. This work is supported by NSF DUE 2417349.

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