University of California, Davis
Department of Materials Science and Engineering
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PhD EXIT SEMINAR

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Designing Magnetic Spin Textures in Complex Oxide Thin Films

Complex oxides, solid-state compounds comprised of oxygen and at least two metal cations, are an intriguing class of materials for implementation into future microelectronic devices. They possess a wide range of functional properties, such as magnetism, ferroelectricity, and superconductivity, that can all be readily modified by their sensitivity to lattice strain, electronic and magnetic fields, chemical doping, and other external stimuli. This sensitivity makes complex oxides highly capable materials, but also introduces many technical challenges. The work of this dissertation has focused on extending our current knowledge of the magnetic materials properties and interfacial effects present in epitaxial films into micro- and nanoscale features. Ferromagnetic (FM) spin textures are arrangements of magnetic moments within such patterned features. Their switching behaviors are essential components of current data storage applications, and complex oxides are ideal candidates for future designs. In any materials system, the deviation from bulk or thin film properties when scaling down to nanostructures can be difficult to predict due to either size induced effects or consequences of the fabrication process itself. Therefore, these magnetic films and multilayers must be studied in the modified state to understand the challenges and opportunities associated with designing practical structures.

Soft x-ray photoemission electron microscopy (X-PEEM) was used to observe and characterize the evolution of magnetic domain structure as a function of temperature in micromagnets patterned into epitaxial films of $La_{0.7}Sr_{0.3}MnO_3$ (LSMO). These images reveal the formation of novel spin textures that are a hybridization of well-described configurations, vortex and Landau, and emerge from the balance between fundamental materials parameters, micromagnet geometries, and epitaxial strain. Furthermore, slight perturbations to the lattice near the lithographically defined microstructure edges are shown to induce long range suppression of the magnetocrystalline anisotropy while other magnetic parameters, such as the saturation magnetization, remain unchanged. The results demonstrate how the magnetic domain state can be tailored through careful incorporation of these factors.

Additional complexity is added to the system by interfacing LSMO with antiferromagnetic (AFM) $LaFeO_3$ (LFO) or $La_{0.7}Sr_{0.3}FeO_3$ (LSFO). In unpatterned bilayers and superlattices, exchange coupling across the FM/AFM interface promotes a perpendicular alignment of the FM and AFM spin axes. Within patterned bilayers the alignment can be driven into a parallel configuration through changes in the micromagnet width, crystallographic orientation, and temperature. The importance of FM/AFM spin alignment is emphasized by magnetic reversal experiments of individual magnetic bits that demonstrate the coercivity can be adjusted over a wide range relative to LSMO single-layer micromagnets. In a superlattice of FM/AFM interfaces, the relative influence of the LSMO is reduced as the T_C drops from 360 K to 80 K due to the ultra-thin sublayer thickness. Like the initial study on LSMO, the magnetocrystalline anisotropy of the LSFO layer is fully suppressed near microstructure edges, and the AFM domain configuration is entirely dictated by a magnetostatic-type effect in that region. This behavior persists both above and below the T_C (with spin-flop coupling preserved) suggesting a new method to control AFM spin textures which are typically pinned to stochastic structural domains and defects and require large fields to manipulate.