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

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Synthesis and Characterization of Ferromagnetic/Antiferromagnetic Perovskite Oxide Superlattices

Perovskite oxides span a diverse range of functional properties such as ferromagnetism, superconductivity, and ferroelectricity, which makes them promising candidate materials for applications such as sensors, energy conversion and data storage devices. The structural compatibility of perovskite oxides allows them to be epitaxially grown in complex heterostructures such as superlattices with a large density of interfaces where the interplay between spin, charge, orbital, and lattice degrees of freedom gives rise to new behaviors. The ferromagnetic (FM)/antiferromagnetic (AF) interface is particularly interesting due to exchange coupling which is not only of interest for fundamental research but also is of great significance for industrial applications.

Epitaxial $La_{0.7}Sr_{0.3}MnO_3$ (LSMO)/$La_{0.7}Sr_{0.3}FeO_3$ (LSFO) superlattices serve as model systems to explore the magnetic structure and exchange coupling at perovskite oxide interfaces. Earlier work suggested that (001)-oriented LSMO/LSFO superlattices with compensated AF spins at the interface display spin-flop coupling characterized by perpendicular alignment between the AF spin axes and the FM moments at a sublayer thickness of 6 unit cells (u.c.). Changing the crystallographic orientation of the interface from (001) to (111) introduces changes to factors such as the charge density of each stacking layer, the magnetic structure of the AF layer at the interface, the symmetry of the lattice, and the orbital degeneracy. Therefore, different properties and exchange coupling mechanisms are expected.

(111)-oriented LSMO/LSFO superlattices with sublayer thicknesses ranging from 3 to 60 u.c. were synthesized and characterized. Detailed analysis of their structural, electronic, and magnetic properties were performed with the help of synchrotron radiation based resonant x-ray reflectivity, soft x-ray magnetic spectroscopy, and photoemission electron microscopy to explore the effect of sublayer thickness on the magnetic structure and exchange coupling at (111)-oriented perovskite oxide interfaces. Interfacial effects and ultrathin superlattice sublayers can stabilize orientations of the LSFO AF spin axis which differ from that of LSFO films and LSMO/LSFO bilayers. Exchange coupling in the form of spin-flop coupling exists only in superlattices which display both robust ferromagnetism and out-of-plane canting of the AF spin axis. The AF order in the spin-flop coupled superlattices was studied using angle-dependent x-ray magnetic linear dichroism. The AF order can be categorized into two types: the majority of the AF moments cant out-of-the-plane of the film along the $< 110 >$ or $< 100 >$ directions depending on the LSFO layer thickness, while the minority portion lies within the (111) plane in different AF domains. The energy difference between domains with their spin axes along the in-plane or out-of-plane directions is small, and the magnetic order of AF thin films is far more complex than in bulk LSFO. The complex AF structure in these (111)-oriented LSMO/LSFO superlattices illustrates that complex metal oxide heterostructures can serve as fertile ground for discovery of new magnetic phases, which may have the potential to be the basis of next generation information technology devices.