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

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Interfacial Magnetic Phenomena in Transition-Metal Oxide Heterostructures

Recent advances in thin film growth technology to create transition-metal oxide (TMO) heterostructures with atomic-level precision have enabled the discovery of a wide range of novel physical phenomena at engineered interfaces. These phenomena arise from the complex interactions between the lattice, charge, spin, and orbital degrees of freedom that are highly sensitive to external stimuli such as strain, chemical doping, and electric and magnetic fields. Among these TMO systems, heterostructures consisting of layers with competing magnetic characteristics have attracted great attention from a fundamental perspective as well as for their potential applications in magnetic sensors, magnetic random access memory, and future spintronics devices. One of the fundamental building blocks of such devices is the exchange-bias (EB) effect which is typically associated with interfacial exchange interactions between a ferromagnetic (FM) and an antiferromagnetic (AFM) material. A similar effect has also been observed at interfaces between hard and soft FM layers, where the hard (soft) layer possesses high (low) coercivity and low (high) saturation magnetization. In analogy to AFM/FM interfaces, the biasing effect at FM/FM interfaces originates from the magnetic unidirectional anisotropy induced by the exchange interactions between the hard and soft FM layers.

In this work, the exchange interactions in TMO heterostructures consisting of $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and $La_{0.7}Sr_{0.3}CoO_3$ (LSCO) layers were systematically studied. LSMO is a soft FM metal that shows a FM to paramagnetic (PM) and metal to insulator transitions at ~ 360 K in its bulk form. LSCO is a hard FM material and is known to show magneto-electronic phase separation (MEPS), where FM/metallic clusters are embedded in a non-magnetic/insulating matrix. Synchrotron radiation based resonant x-ray reflectivity, soft x-ray magnetic spectroscopy, and bulk magnetometry were used to investigate the magnetic and electronic structure of the LSCO/LSMO heterostructures. It was found that a 6 nm LSCO/ 6 nm LSMO heterostructure displayed unconventional magnetic switching behavior, which deviated from conventional metallic FM/FM systems in that reversible switching occurred not only within the soft LSMO layer but was also accompanied by the switching of a thin interfacial LSCO layer. This unique magnetic switching behavior was strongly dependent on the thickness of the LSCO layer. Soft x-ray magnetic spectroscopy allowed us to develop a physical picture where a form of MEPS occurred vertically through the LSCO film thickness and was driven by the competition between two different interfacial effects at the LSCO/LSMO and the LSCO/substrate interfaces. These findings provide further evidence of the high tunability of magnetic properties in TMO heterostructures through interface engineering.