University of California, Davis
Department of Chemical Engineering
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PhD EXIT SEMINAR

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Growth and Characterization of Magnetic Perovskite and Perovskite-related Phases

Perovskite oxides *ABO_3*, where *A* is usually an alkaline-earth or rare-earth cation and *B* a transition metal element, have received a great deal of interest because of their wide range of functional properties such as ferroelectricity, superconductivity, and ferromagnetism, with a unique sensitivity to external stimuli including chemical doping, lattice strain, and electrical and magnetic fields. This sensitivity makes perovskite oxides highly tunable materials, and further investigation into their fundamental physical properties are critical for future device development. Unlike metallic systems that have been studied for decades for a variety of applications such as hard disk drives and logic/memory devices, thin films of perovskite oxides are a relatively new field and they show much more diverse functional properties compared to their metal counterparts, creating novel pathways for designing specific device applications. The work in this dissertation was focused on extending our current knowledge on the magnetic perovskite oxides, and further exploring the ability to precisely tune and control their functional properties.

Resonant x-ray reflectivity, soft x-ray photoemission electron microscopy (X-PEEM), and magnetometry measurements were employed to study the physical properties of perovskite oxide $Nd_{0.5}Sr_{0.5}MnO_3$ (NSMO) thin films grown on (110)-oriented $SrTiO_3$ substrates, where it displays coupled magnetic and electronic transitions from paramagnetic/insulator to ferromagnetic (FM)/metal and then to antiferromagnetic (AFM)/charge-ordered insulator with decreasing temperature, due to the anisotropic strain state induced by the underlying substrate. The FM and AFM properties of the NSMO film were probed as a function of temperature using soft x-ray magnetic spectroscopy, and the coexistence of lateral FM and AFM domains was demonstrated using X-PEEM, showing both vertical and lateral magnetic phase separation in the film. These characterization techniques demonstrate the multiple magnetic and electronic phase transitions in the NSMO films, and thus the possibility and diversity of functional properties to be applied in next generation devices.

Ion migration-induced modification of physical properties is another emerging research direction in the search for tunable materials that can revolutionize the growing field of neuromorphic computing. Among the candidate materials, perovskite oxides including cobaltites ($La_{0.7}Sr_{0.3}CoO_3$, LSCO and $LaCoO_3$, LCO) and ferrites ($La_{0.7}Sr_{0.3}FeO_3$, LSFO) are ideal candidates due to their high oxygen vacancy conductivity, relatively low oxygen vacancy formation energy, and strong coupling of the magnetic and electronic properties to the oxygen stoichiometry. The evolution of the physical properties of LSCO, LCO and LSFO thin films upon exposure to highly reducing environments was studied in this dissertation. In the cobaltite systems, the rarely-reported crystalline Ruddlesden-Popper (RP) phase was observed, which involved the loss of both oxygen anions and cobalt cations upon annealing, where the cobalt is found as isolated Co ions or Co nanoparticles. First principles calculations confirm that the concurrent loss of oxygen and cobalt ions is thermodynamically possible. In the ferrite system, however, the films remained in the oxygen-deficient perovskite phase even when annealed at the most reducing conditions explored in this dissertation. The strong correlation of the magnetic and electronic properties to the crystal structure highlights the potential of utilizing ion migration as a basis for emerging applications such as neuromorphic computing.