Ferromagnetism in $LaCoO_3$ Epitaxial Thin Films

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Abstract Body: Although $LaCoO_3$ (LCO) has been studied in its bulk form over the past 50 years, its magnetic ground state is still under debate. While bulk LCO exhibits a combination of diamagnetic and paramagnetic behavior, early studies of epitaxial thin films of LCO surprisingly show ferromagnetism [1, 2]. Epitaxial thin films provide model systems in which epitaxial strain and non-equilibrium deposition processes enable us to probe the role of cation valence, cation distribution and lattice strain on the magnetism and transport behavior. In this work, we have observed ferromagnetism in epitaxial LCO thin film samples on (La, Sr)(Al, Ta)O_3, $SrTiO_3$, and $LaAlO_3$ substrates. Through the variation of oxygen deposition pressures (10 mTorr to 320 mTorr of O2) and epitaxial lattice mismatch with the substrate, we have correlated structure, stoichiometry and magnetism in these films. Standard $2\theta - \theta$ and rocking curve X-ray diffraction shows epitaxial growth and excellent crystalline quality, for films grown under all oxygen pressures and all substrates. The films' c/a ratio changes as a function of the oxygen deposition pressure, indicating a change in nominal oxygen stoichiometry. Careful magnetic characterization of LCO films using SQUID magnetometry reveals long range magnetic order at temperatures below 75K for the high oxygen pressure depositions and non-ferromagnetic behavior for films grown at lower oxygen pressures. The high oxygen deposition pressure films have a magnetization of 80 - 160 emu/cm^3 at 5T, which is equivalent to 0.6 – 1.2 μ_B per formula unit and comparable to other LCO thin films [1]. All films show insulating behavior. X-ray magnetic circular dichroism spectra show that the magnetism originates from Co^{3+} in an octahedral symmetry. The results suggest that the ferromagnetism originates from a modification of the superexchange mechanism among Co^{3+} with possible accompanying orbital ordering.

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