Stress and magnetism in LaCoO$_3$ films

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Cobaltates exhibit a wide variety of exciting electronic properties resulting from strong electron correlations; these include superconductivity, giant magnetoresistance, metal-insulator transition, and strong thermoelectric effects. This makes them an excellent platform to study correlated electron physics, as well as being useful for various applications in electronics and sensors. In the ground state in the bulk, the prototypical complex cobalt oxide LaCoO$_3$ is in a spin-compensated low-spin state ($t_{2g}^6$), which results in the ground state being nonmagnetic. In a recent experiment, Fuchs et al. (Phys. Rev. B 75, 144402 (2007)) have demonstrated that a ferromagnetic ground state could be stabilized by epitaxial tensile strain resulting in a Curie temperature ($T_C$) of $\sim 90$ K when LaCoO$_3$ (LCO) is grown on SrTiO$_3$ (STO) using pulsed laser deposition. In this talk I will discuss our recent successful attempt to integrate a LCO/STO heterostructure with Si (001) using molecular beam epitaxy. We have grown strained, epitaxial LaCoO$_3$ on (100)-oriented silicon using a single crystal STO buffer (Appl.Phys. Lett. 98, 053104 (2011)). SQUID magnetization measurements confirm that the ground state of the strained LaCoO$_3$ is ferromagnetic with a $T_C$ of 85 K. Our first-principles calculations of strained LaCoO$_3$ using the LSDA+$U$ method show that beyond biaxial tensile strain of 2.5% local magnetic moments, originating from the high spin state of Co$^{3+}$, emerge in a low spin Co$^{3+}$ matrix. Ferromagnetism found in tensile-strained LaCoO$_3$ is tightly coupled to the material’s orbital and structural response to applied strain. Theoretical calculations show how LaCoO$_3$ accommodates tensile strain via spin state disproportionation, resulting in an unusual sublattice structure.

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