Structure, Magnetism, and Transport in $SrTiO_3(001)$ / $La_{1-x}Sr_xCoO_3$: Evidence for Interfacial Magnetic Phase Separation

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The remarkable functionality of perovskite oxides, when combined with the favorable matching of lattice, chemistry, and thermodynamics that is possible at their interfaces, provides many opportunities for new physics and applications. The doped perovskite cobaltites are a good example. From the basic science point of view they have proven to be excellent choices for the study of the ubiquitous magneto-electronic phase separation phenomenon. From the application point of view they are of interest as electrodes in ferroelectric memory and solid oxide fuel cells. Strong motivation exists for the study of these materials in films and heterostructures, the effect of dimensional confinement on the phase separation being a prime example. We have made a detailed investigation of the structure, magnetism, and magnetotransport, in epitaxial $La_{1-x}Sr_xCoO_3$ films on $SrTiO_3$ (001). Structure-property relationships, particularly with respect to strain state and oxygenation have been thoroughly investigated. Of particular interest, we have observed deterioration in ferromagnetism and conductivity in the thin film limit (e.g. < 8 nm at $x = 0.50$). Remarkably, we observe that the magnetotransport properties of *high doped* (e.g. $x = 0.5$) ultrathin films are strikingly similar to those of bulk materials at *low doping* (i.e. $x < 0.18$). The magnetoresistance in these low-doped bulk crystals is actually a simple and clear signature of magnetic phase separation, being due to an intercluster “GMR” effect. The obvious conclusion is that the deterioration in magnetism and conductivity at the interface with $SrTiO_3$ is due to interfacial phase separation, a phenomenon that also occurs in manganites, and is a serious issue for spintronic devices. Noise spectroscopy and multiterminal transport measurements provide a similar picture. The significance of these results is that we are provided with a simple means (magnetoresistance) to probe phase separation in the very thin film limit where some other techniques suffer from signal to noise issues. By measuring thickness dependences at multiple dopings we have been able to study the systematics, most importantly the remarkable effect of proximity to non-ferromagnetic phases. The results allow us to propose a simple model for the driving force for the interfacial phase separation.

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