Role of Strain in the Transport Properties of Manganites

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The colossal magnetoresistance (CMR) observed in hole-doped manganites has resulted in sustained interest in these materials. The CMR and other novel properties of these materials like 100% spin polarization at low temperatures and charge ordering hold out promise for device fabrication. For such applications high quality thin films of manganites are essential. However, the same properties which make the manganites interesting also result in extreme sensitivity to the physical form of the sample. In the case of thin films this translates to a strong dependence of the transport and magnetic properties of the film on the growth conditions which has till now restricted the device engineering of these materials.

We have shown that substrate induced strain in manganite thin films has drastic effects on their transport properties and magnetism (Figure 1). Thin films of $La_{0.67}Ca_{0.33}MnO_3$ (LCMO) (150 Å thick) were grown on LAO and the lattice matched substrate NGO.

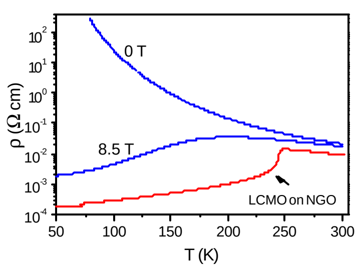

Figure 1. *Strain drives the LCMO film on LAO to the insulating state.*

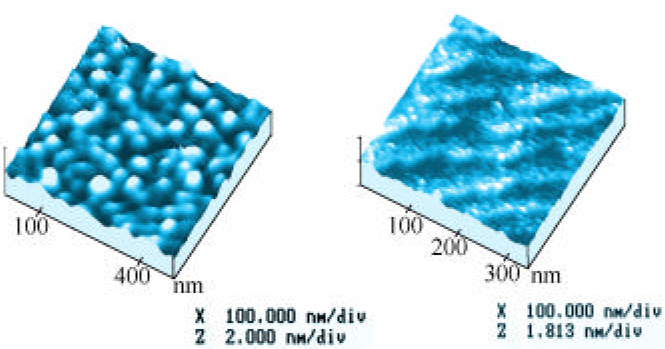

Figure 2. ***AFM images of LCMO films on (a) LAO and (b) NGO***

Compressive strain leads to an island growth mode (figure 2) and hence a non-uniform distribution of strain. The top of the islands are relatively strain free while the edges of the islands are regions of very high strain (higher than just due to the lattice mismatch strain) (Figure 3). This leads to a two-phase behavior in

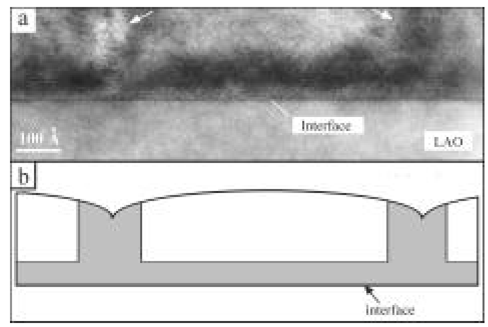

Figure 3.(a) A cross sectional TEM image showing the variation in strain. (b) A schematic representation of the strain variation over the film.

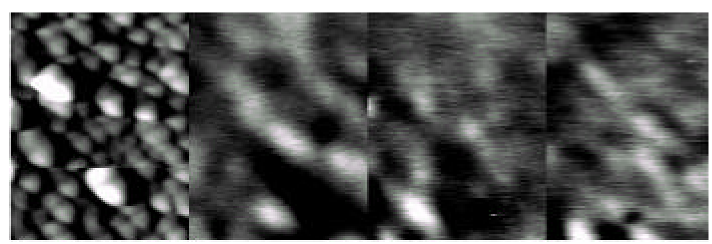

Figure 4. MFM images of the film of LCMO on LAO at 80 K. The first image is a 1.4 × 1.4 μm topographic image showing the island growth mode. The other three are magnetic images at the same scale showing the magnetic domains. *MFM images courtesy Q. Lu and A. L. de Lozanne, University of Texas, Austin*

the strained thin films with the top of the islands displaying properties similar to the bulk compound and the edges of the islands are insulating. This behavior is clearly seen from the magnetic force microscopy (MFM) images of the film on LAO (figure 4). The magnetic domain sizes are similar to the island sizes. Strain free films of LCMO grown on NGO show a terrace growth mode (figure 2) and magnetic domains about 10 times larger. On further study, the insulating state shows clear evidence of being in the charge ordered state as seen from the H-T phase diagram in figure 5.

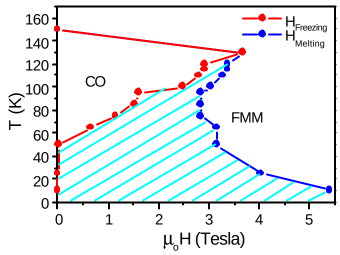

Figure 5. T-H phase diagram of the LCMO film on LAO

From these observations we conclude that the sensitivity of manganites to structural perturbations leads to strong strain dependence of the properties of thin films of these materials. From this study the energetics of the transitions, between the ferromagnetic metallic and antiferromagnetic charge ordered states, can be estimated. It also provides some of the reasons why device fabrication using manganites has been such a challenge.

References

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