Conductance of perovskite oxide thin films and interfaces

Mubeen Dildar, I.

Author: Mubeen Dildar, Ishrat
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Summary

This thesis deals with the properties of doped perovskite manganites in the form of thin films, and with interfaces between insulating perovskites. In perovskite manganites, the correlations among the manganese d-electrons lead to the occurrence of two coupled transitions when going from high temperatures to low temperatures, an Insulator-to-Metal and a Paramagnetic-to-Ferromagnetic transition. Various questions still surround this phenomenon, in particular in films which are thin enough so that strain induced by the substrates becomes a parameter also. The basics of the physics is formed by doping an insulating so-called Mott insulator (in this case $LaMnO_3$) so that the material becomes metallic, at least at low temperatures. Doping means replacing the trivalent La, and we have used two different divalent doping ions, Sr and Ca, to study the magnetotransport properties of the prototype manganites $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and $La_{0.7}Ca_{0.3}MnO_3$ (LCMO). These compositions are chosen such that they give the highest magnetic/metal-insulator transition temperature for these materials and a wide ferromagnetic-metal regime in the phase diagram.

The first question we investigate has to do with the strong reduction of the metal-insulator (MI) transition temperature when the films are strained. In particular, we investigate whether there is an influence of a change in carrier density due to strain. This is done by growing LSMO and LCMO by the so-called sputtering technique, discussed in **chapter 3**, on substrates with different lattice parameters, and measuring the Hall effect. The results, presented in **chapter 4**, show that there is no difference in carrier density for strained and unstrained films, and that the lowering of the transition temperature is purely the effect of a smaller hopping probability or bandwidth of the Mn *d* electrons. The data also shows, however, that the carrier density averaged over the film thickness decreases when the films become very thin. This we ascribe to the effects of the interface, and of magnetically dead layers which form close to the interface, in which charge discontinuities prob-

ably play a role. The anomalous Hall effect indicates that the different scattering mechanism are participating in thin/strain and thick/relaxed films.

Another issue, addressed in **chapter 5**, is the behavior of such films when structured into bridges of sub-micron dimensions. For LCMO, it was found before that in the narrow temperature range of the MI transition the resistance becomes current-dependent, or, in other words, that the current(I) - voltage(V) characteristics become non-linear. Here, we investigate a similar manganite, but now Sr-doped instead of Ca-doped. The results are quite different. Down to bridges with a width of 1 μm, the IV characteristics are perfectly linear, showing that the Sr-doped material is less sensitive to strain and disorder. For bridges of 300 nm width this changes, IV-characteristics now do become non-linear, but not specifically in the transition. This effect can be ascribed to a slight oxygen deficiency which is occurring in the bridges, possibly due to structuring.

We then turn the attention to a different issue in **chapter 6**, namely the conductance of the interface between two band insulators $LaAlO_3$ (Lanthanum aluminate) and $SrTiO_3$ (Strontium titanate). This is a much debated phenomenon, which was extensively studied on interfaces grown by pulsed laser deposition (PLD) in a background of low oxygen pressure. Using the sputtering technique, this pressure has to be much higher in order to grow good films and interfaces, and to our surprise we find the interfaces to be perfectly insulating. Apparently, the charge transfer mechanism (often called electronic reconstruction) which is supposed to play a role in generating the conducting interface, can be made non-operative when enough oxygen is available. A detailed study of the properties of the sputtered $LaAlO_3/SrTiO_3$ films and interfaces indicates that the La to Al ratio in the film is not stoichiometric, but that the films are rather $La_{1.1}Al_{0.9}O_3$, presumably because the high pressure leads to enhanced scattering of the light Aluminum atoms. This ratio higher than 1 makes it difficult to vary the amount of oxygen at the interface during or after the growth, which then leads to its insulating character. For the conducting interfaces fabricated by the PLD technique, the La/Al ratio is found to be less than 0.9, showing that deposition pressure, La/Al ratio and conductivity are strongly related, and that both the La/Al stoichiometry of the $LaAlO_3$ film, and the oxygen stoichiometry at the interface play a vital role in defining the conductance of the interface. Magnetic measurements were also performed on the sputter-grown and non-conducting interfaces, and they were found to be non-magnetic, again in contrast to what is found on PLD-grown conducting interfaces. Since the magnetism is thought to derive from defects in the oxygen octahedra surrounding the Ti atoms at the interface, this once more emphasizes the importance of the interface oxygen stoichiometry in the mechanisms for conductance and magnetism.