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Oxygen pressure and thickness dependent strain effects in $La_{0.7}Sr_{0.3}MnO_3$ films

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I. Introduction

In recent years the doped perovskite manganites $La_{1-x}A_xMnO_3$ where A is a divalent alkaline-earth ion) have received much attention because of the colossal magnetoresistance (CMR) effect observed in the optimally doped sample (x ~ 0.3). Particularly, the epitaxial thin films possess their potential in technological applications such as magnetoresistive sensors and magnetic random access memory. For thin films, however, the strain effect that can be induced by lattice mismatch, film thickness, oxygen content, and so on is also crucial for determining the magnetic and transport properties even at the fixed doping level. It has been known that the strain of manganite films epitaxially grown on perovskite substrate is dependent on film thickness as well as lattice mismatch with the underlying substrate. Moreover, the strain effect is also influenced by growth conditions such as the oxygen background pressure and the substrate temperature.

II. Experimental method

Thin films of LSMO have been grown on (100)-$LaAlO_3$ (LAO), (110)-$NdGaO_3$ (NGO), and (100)-$SrTiO_3$ (STO) substrates at 750 ^{0}C by pulsed laser deposition. In order to fabricate the films under the same conditions, the three substrates were loaded side-by-side for simultaneous deposition. The oxygen background pressures used to grow were 250, 350, and 450 mTorr. After deposition, in-situ annealing was performed at 750 ^{0}C in an oxygen pressure of 500 mTorr for 30 min. (?????) The average thickness of the films, controlled by the deposition rate, is ranged from 11 to 110 nm (± 10 %). The films were characterized using x-ray diffraction (XRD). The XRD data indicate that all the films are single phase and (00*l*) oriented. Magnetization and resistivity measurements were performed using a superconducting quantum interference device (SQUID) magnetometer. The temperature dependent resistivity data were taken in zero and applied magnetic fields using a four probe technique.

III. Results and discussion

With increasing oxygen pressure, the LSMO (200) peak position of the film on LAO shifts to higher angle but the (200) and (220) reflections of STO and NGO, respectively, shift to lower angles. These changes indicate that lattice constants of the LSMO films gradually approach to that of the bulk LSMO material. Therefore, the lattice strain induced by the lattice mismatch is relaxed with increasing the oxygen partial pressure.

All the M(T) curves of the LSMO films clearly exhibit a PM to FM transition but their shapes and Curie temperatures (T_C) are dependent upon the oxygen partial pressure. The LSMO thin films grown on LAO and STO at 450 mTorr show their FM transitions near 350 K, which almost coincide with that of the bulk LSMO materials. With decreasing the oxygen pressure, however, the FM transition temperatures largely decrease and the M(T) curves display broad features. The differential magnetization dM/dT curves clearly reveal the broad transitions for the LSMO films grown at low oxygen pressure. These results suggest that the oxygen pressure influences on both T_C and sample homogeneity. Moreover, the increase of oxygen partial pressure may lead to reduce the inhomogeneous phases.

In order to understand the strain effect induced by the film thickness and compare with the oxygen pressure effect, we have studied on magnetic and transport properties of the LSMO films with various thicknesses where the films were grown on LAO in a fixed oxygen pressure (450 mTorr). The film thickness was estimated from deposition time normalized by calibration runs. From XRD data, we find the (200) peak is varied with the thickness. Namely, lattice constant tends to decrease with increasing thickness, indicating that the strain effect caused by lattice mismatch is relaxed with increasing thickness. For comparison, the XRD pattern of a LSMO film with 110 nm thickness grown at 250 mTorr is also included. The lattice constant calculated from this XRD data is similar to that of a 30 nm LSMO film grown at 450 mTorr.

We measured the temperature dependence of magnetization M(T) curves for the LSMO films with different thickness. As the film thickness decreases, the ferromagnetic transition temperature is slightly decreased from about 340 to 328 K. As the film thickness decreases, the local minimum position of dM(T)/dT shows a little change. In addition, the broadening of the dent in the dM(T)/dT curves is difficult to discern. This is in marked contrast to that found in the LSMO films grown in different oxygen pressure where T_C is drastically changed with the oxygen partial pressure.

IV. Conclusion

We have presented the studies on magnetic and transport properties of the LSMO films grown on various substrates under different conditions to examine the oxygen pressure and thickness dependent strain effects. We observe that those properties are more sensitive to oxygen pressure than film thickness. The strain effect induced by the oxygen pressure is accompanied by large changes in both T_C and T_{MI}. On the other hand, the strain effect produced by the film thickness does not significantly contribute to magnetic and transport properties of the LSMO film. These observations suggest that the oxygen partial pressure may be associated with the oxygen defect that leads to magnetic and structural in-homogeneity.

V. References

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