HETEROEPITAXY OF $La_{0.7}Ca_{0.3}MnO_3$ ON MgO-BUFFERED R-Al_2O_3 SUBSTRATES

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Abstract. *Precisely (100)-oriented $La_{0.67}Ca_{0.33}MnO_3$ films have been grown by aerosol assisted metal-organic chemical vapor deposition technique on a sapphire (R-plane) substrate covered by a MgO(100) buffer layer. The film structure was characterized by techniques of x-ray diffraction and small-angle x-ray scattering. The temperature dependence of the electrical resistivity of the $La_{0.67}Ca_{0.33}MnO_3$ films was shifted toward lower temperatures by ~10 K in comparing with a typical single crystalline films grown on MgO(100) substrates.*

Index Terms: manganite, MgO, sapphire, epitaxy, orientation, resistivity.

I. Introduction

Mixed-valence manganites $La_{1-x}M_xMnO_3$ (M = Ca, Sr, Ba) with structure of perovskite have been extensively investigated in the last time due to their attractive properties, such as colossal magnetoresistance and half-metallicity[1], which make them very promising for applications in spintronics, especially as sources of highly spin-polarized electrons for spin injection devices[2]. Apart from the use in spintronics, manganites display electrically controlled memory effects for resistive random-access memory (RRAM)[3].

Manganites have been successfully grown on various oxide substrates such as $SrTiO_3$, $LaAlO_3$, $NdGaO_3$ and MgO. But, to make manganites attractive for practical use, they should be grown on substrates of the materials employed in microelectronics. Because of a chemical incompatibility, it is still difficult to grow high quality epitaxial manganite films directly on silicon substrates, even using appropriate buffer layers. It is well known the R-cut Al_2O_3 substrate can be explored by the Si-on-insulator technique, which makes it possible to realize the integration of oxide thin films and Si. R-plane sapphire is a good candidate for the growth of (001)-oriented cubic oxides, such as MgO(100)[4]. In turn MgO(100) is widely used for high quality growth of manganite thin films.

In this work, we have studied the structure and electrical properties of thin $La_{0.67}Ca_{0.33}MnO_3$ (LCMO) films grown by laser ablation on a sapphire substrate coated by a MgO buffer layer.

II. Experiments

The growth was carried out using a custom designed aerosol assisted metal-organic chemical vapor deposition system equipped by pneumatic nozzles and peristaltic pumps for the feeding of precursor solution. Commercial R-Al_2O_3 substrates were used. Before growth the substrates were annealed in oxygen atmosphere at 1100°C for 10 min to produce an oxygen terminated Al_2O_3 surface with a monoatomic height terraces and the root-mean-square roughness equal to 0.15 nm. The MgO films were deposited at a substrate temperature700ºC, whereas for LCMO growth the substrate temperature was increased up to 950°C. The precursors, β-diketonates of Mg^{2+}, La^{3+}, Ca^{2+} and Mn^{2+}, have been dissolved in dimethylformamide to obtain a solution with the molar concentration of 0.02M.

The film thickness was determined by a small-angle x-ray scattering (SAXS) and X-ray diffraction (XRD) were performed in a Siemens D5000 diffractometer. Four-probe resistance measurements by using silver paste contacts were performed in a He cryostat.

III. Results and discussion

The film thickness of each sample was calculated from the interference fringes in the respective SAXS curve, using the relation $t = \lambda/(2\Delta\omega)$, where λ is the CuK$_\alpha$ x-ray wavelength and $\Delta\omega$ is the oscillation angular period. In Fig. 1 we present the SAXS pattern of a MgO buffer as well as the pattern obtained after deposition of $La_{0.7}Ca_{0.3}MnO_3$ film on the buffer. Formation of the small-period oscillations (Kiessig fringes) due to the total film thickness are confirming both the smoothness of the film surface and substrate/film interface.

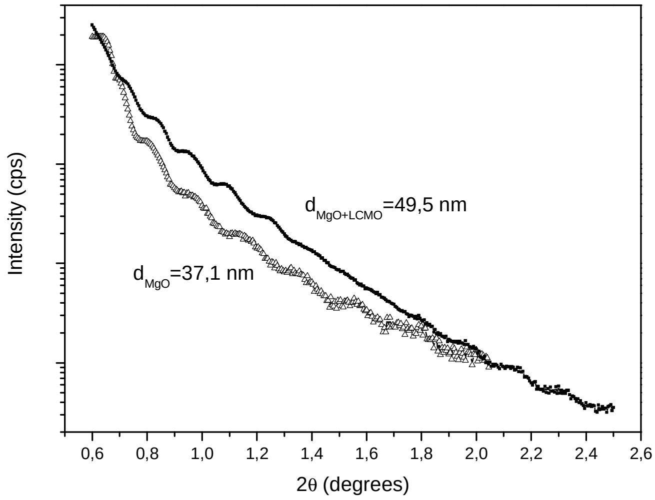

Fig. 1. X-ray reflectivity curves of MgO film and $La_{0.7}Ca_{0.3}MnO_3$/MgO heterostructure grown on R-Al_2O_3 substrate.

The XRD analysis indicates growth of single oriented MgO(100) and $La_{0.7}Ca_{0.3}MnO_3$(100) films, as shown on Fig. 2. (θ-2θ) diffraction patterns contain only the peaks of substrate (012), (024) and (036) as well as those from the MgO and LCMO films, belonging to the {*00l*} system of crystallographic planes with ***l=1,2,3,4***. Thus, manganite films are "cube-on-cube" epitaxially grown on MgO(100) buffer on R-plane sapphire substrates.

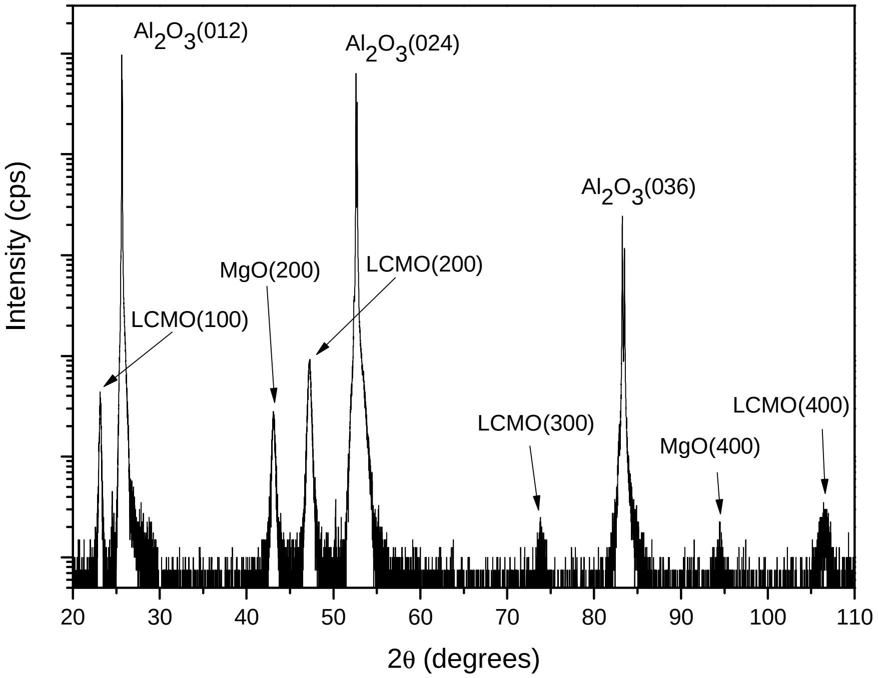

Fig. 2. X-ray diffraction scan of $La_{0.7}Ca_{0.3}MnO_3$ film grown on MgO(100) buffered R-plane sapphire substrate.

The temperature-dependent resistivity, shown in Fig. 3, reveals metallic behavior starting from T=258 K. The value of the metal-insulator transition temperature is shifted toward lower temperature by ~10K in comparison with the best LCMO films grown on MgO(100) single crystal substrates. The maximum value of the temperature coefficient of the resistance, TCR=(dR/dT)/R, is equal to 7% at T=319K.

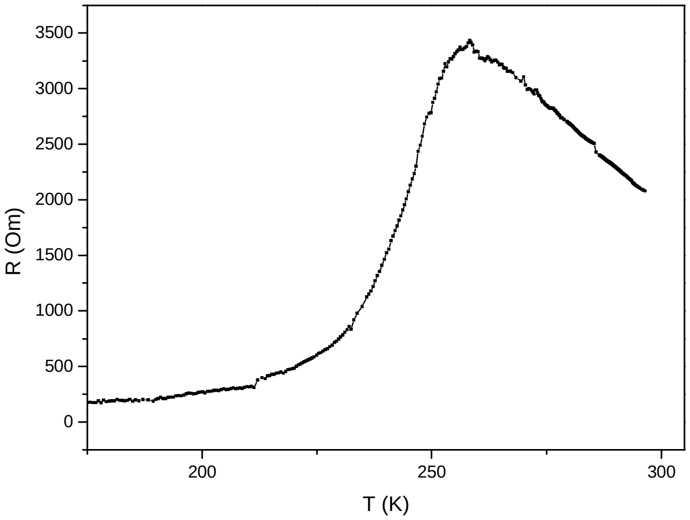

Fig. 3. Temperature-dependent resistivity of $La_{0.7}Ca_{0.3}MnO_3$ film grown on MgO buffered R-plane sapphire substrate.

IV. Conclusion

In summary, we investigated structural and electrical properties of $La_{0.7}Ca_{0.3}MnO_3$ film grown on MgO buffered R-plane sapphire substrate by aerosol assisted metal-organic chemical vapor deposition technique. Formation of single oriented (100) manganite film on (100)MgO buffer was confirmed by X-ray diffraction. Lowering of the metal-insulator transition temperature by ~10K hints on an incomplete stress relaxation due to a small film thickness in the heteroepitaxial system that includes materials with different crystal symmetries and lattice parameters.

V. References

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