PS-12-9

Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp324-325

Synthesis And Characterization of Electron Doped $La_{0.85}Te_{0.15}MnO_3$ Thin Film Grown on $LaAlO_3$ Substrate By Pulsed Laser Deposition Technique.

Irshad Bhat[1,*], Shahid Husain[1] and S. I. Patil[2]
Irshad Bhat[1] and Shahid Husain[1]
[1]Department of Physics, Aligarh Muslim University, Aliagrh-202002, India
Email: bhat.amu85@gmail.com; s.husain@lycos.com
S. I. Patil[2]
[2] Department of Physics, University of Pune, Ganeshkhind- 411007, Pune, India
Email; patil@physics.unipune.ac.in

Abstract

We report the structural, morphological and magneto-transport properties of pervoskite oxide $La_{0.85}Te_{0.15}MnO_3$ (LTMO) thin film grown on (001) $LaAlO_3$ single crystal substrate by pulsed laser deposition. X-ray diffraction (XRD) results confirm that the film has good crystalline quality, single phase, and *c*-axis orientation. The atomic force microscopy (AFM) results show that the film consists of grains with average size in the range of 20–30 nm and root-mean square (rms) roughness of 0.07nm. The resistivity measurements show an insulator to metal transition (MIT). We have noticed a huge value of magnetoresistance (~93%) close to MIT in presence of 8T field. X-ray photoemission spectroscopy confirms the electron doping and suggests that Te ions could be in the Te^{4+} state, while the Mn ions stay in the Mn^{2+} and Mn^{3+} valence state.

1. Introduction

The discovery of colossal magnetoresistance (CMR) [1], in doped manganite thin films have attracted a great deal of attention as these materials are able to vary their resistivity by orders of magnitude due to the application of magnetic or electric fields. This property has made them promising candidate for magnetic field sensors, magnetic random access memories, infrared detectors and spintronic devices [2, 3].The properties, like magnetoresistance (MR), metal-insulator transition (MIT) and the Curie temperature (T_c) of such materials are known to be very sensitive to the nature of the substrate, and the strain that are imposed by the lattice mismatch between the film and the substrate [4,5].

In the present work we have successfully grown the thin film of $La_{0.85}Te_{0.15}MnO_3$ and investigated the structure, morphology and the magneto-transport properties of this film.

2. Experimental

The PLD (Lamda physic, Germany model complex, 201, λ=248nm) of the $La_{0.85}Te_{0.15}MnO_3$ (LTMO) film (thickness ~40nm) was carried out using an excimer laser charged with KrF (wavelength of 248 nm and repetition rate of 10 Hz). The substrate temperature was kept at ~750 °C at 350 mTorr oxygen (O_2) pressure. The structure of the film was characterized using high resolution X-ray Bruker-D8 discovery diffractometer. The thickness of the film is measured with the help of an XP1 telystep profilometer. Surface growth has been studied by AFM, using contact mode Nanoscope E-digital (NSE) Instrument. The resistivity of the film is measured using standard four-probe method. The core level x-ray photoemission spectra were recorded using VSW make spectrometer (Al-K-alfa radiation) with a resolution of 0.9eV and energy 1486.6eV

3. Results and Discussion

3.1. Crystal Structure and Morphology

Fig.1 shows the normal high resolution XRD pattern in the 2θ range of 20° –60° for LTMO film grown on the $LaAlO_3$ (001) substrate. Peaks corresponding to only the (001) (with respect to the pseudocubic unit cell) family of planes of LTMO film are seen at the left of the substrate peaks, confirming that the film has good crystalline quality, single phase, and *c*-axis orientation. The thickness of the film measured with the help of XP1 telystep profilometer is 40nm. Further, the epitaxial nature of the films are confirmed by taking a ϕ -scan measurement along the (110) plane of LTMO. The epitaxial growth process always brings in a lattice mismatch between the film and the substrate that result in a lattice strain in the film [6]. The lattice mismatch of about -4.23% has been found, and hence indicates the compressive in-plane strain. The surface morphology of the LTMO thin film was examined by atomic force microscopy (AFM) for an area of 5 mm^2 as shown in Fig.2. As can be seen from the ($1x1\mu m^2$) size, the $La_{0.85}Te_{0.15}MnO_3$ film appears to consist of grains with a diameter in the range of 20–30nm**.**

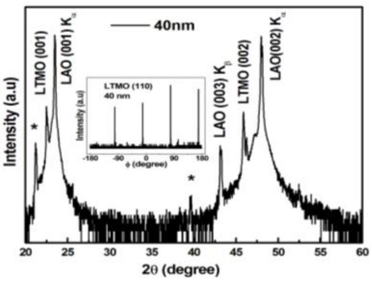

Fig.1 2θ X-ray diffraction pattern of $La_{0.85}Te_{0.15}MnO_3$ thin film across the LAO substrate. The symbol '*' denotes reflections from the substrate. Inset shows the ϕ scan.

The root-mean square roughness (R_{rms}) of the film is 0.07 nm, revealing a smooth surface.

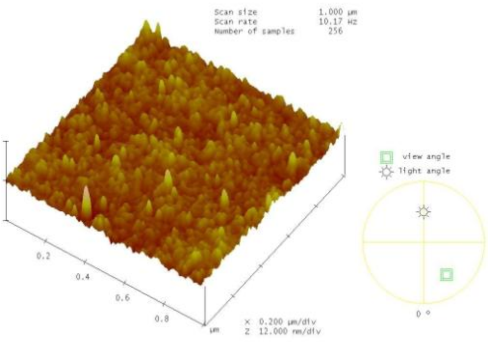

Fig.2 AFM image of LTMO thin film deposited on LAO (100) substrate at 750 °C with a repeat rate of 10 Hz, The scan area for the images is $(1 \times 1)\mu m^2$

3.2. Transport Properties

Fig.3 shows the temperature dependent resistivity for LTMO film. The film exhibits metal to insulator transition with transition temperature of 182K at 0T, which correlates well with the magnetization results reported elsewhere. We have noticed an unusual behaviour in resistivity versus temperature plot, an occurrence of resistivity up-turn (minima) at lower temperatures. The film starts to behave like an insulator at low temperature and the resistivity keep on increasing upto the lowest temperature measured. The presence of insulating phase suggests the presence of simultaneous interaction such as anti-ferromagnetic order, in the system which causes localization of charge carriers [7]. Moreover, when the external magnetic field of 5T and 8T is applied, the resistivity is hugely suppressed and the temperature of resistivity peak shifts significantly to higher values.

The inset in Fig. 3 shows the magnetoresistance (MR %) versus temperature plots at magnetic fields of 5 and 8T respectively. It is evident that a huge value of MR (of the order of ~93% near to the MIT is observed in presence of 8T field.

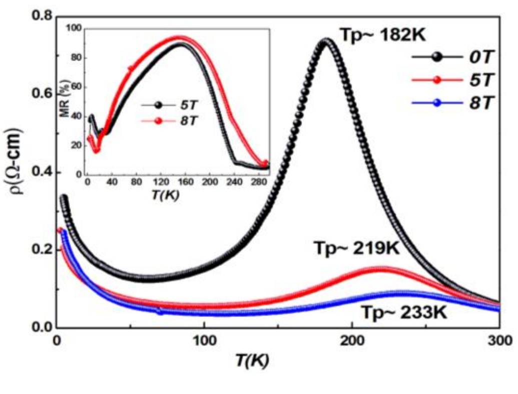

Fig.3 Temperature dependence of resistivity of $La_{0.85}Te_{0.15}MnO_3$ thin film across the LAO substrate in 0, 5 and 8T fields. Inset shows the temperature dependence of magnetoresistance.

3.3. X-ray Photoelectron Spectroscopy

In order to explore the Mn valence, the Mn core level signals should naturally provide the most relevant information. Fig.4 shows the Mn-2p core-level XPS spectrum of the LTMO thin film. The Mn-2p core-level spectrum of the LTMO display $2p_{3/2}$ and $2p_{1/2}$ spin–orbit coupling doublet peaks located at 642.13 eV and 653.7 eV respectively. The spin orbit splitting of the Mn-2p lines is 11.57 eV, which is very close to that observed in MnO_2 (11.7 eV). That confirms the existence of Mn^{2+}.

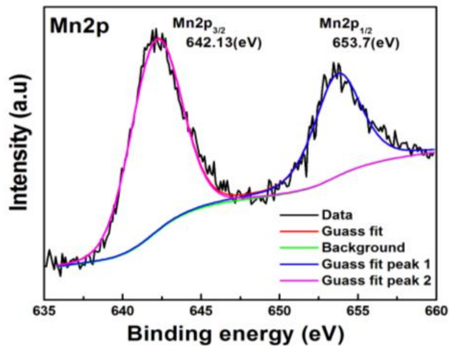

Fig.4 The XPS core level signals of (Mn-2p for $La_{0.85}Te_{0.15}MnO_3$ thin film on LAO (100) substrate.

3.4. Conclusions

In summary highly crystalline electron-doped $La_{0.85}Te_{0.15}MnO_3$ film on LAO substrate is grown by PLD technique. XRD, ϕ-scan and AFM results reveal that the film is of good crystalline quality, single phase, *c*-axis orientation, highly epitaxial and has a smooth surface. The XPS results suggest that the thin film is electron-doped (*n*-type) CMR manganite and that the Mn is in a mixed state of Mn^{3+} and Mn^{2+}. A metal-insulator transition is observed, and a very high magneto-resistance of the order of 93% is observed near MIT in a field of 8T.

Acknowledgements

The authors are greatly thankful to the UGC-DAE Consortium for Scientific Research, Indore-India, for providing the PLD and other experimental facilities.

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