Magneto-transport in LaTi 1 x Mn x O 3 / SrTiO 3 oxide heterostructures

Pramod Kumar, Anjana Dogra, and R. C. Budhani

Citation: AIP Conference Proceedings **1591**, 1367 (2014); doi: 10.1063/1.4872961
View online: http://dx.doi.org/10.1063/1.4872961
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1591?ver=pdfcov
Published by the AIP Publishing

Magneto-transport in $LaTi_{1-x}Mn_xO_3/SrTiO_3$ Oxide Heterostructures

Pramod Kumar*, Anjana Dogra and R.C. Budhani

Quantum Phenomena & Applications Division, National Physical Laboratory (CSIR), Dr. K.S. Krishnan Marg, New Delhi-110012, India
**Email: pramodnpl2011@gmail.com*

Abstract: We report the growth of ultrathin film of Mn doped $LaTiO_3$ on TiO_2 terminated $SrTiO_3$ (*001*) substrate by pulsed laser deposition (PLD) and their electrical transport characteristics including magnetoresistance (MR). Though the replacement of Mn in $LaTiO_3$ at the Ti site in dilute limit does not affect the metallic behaviour of films but variation in resistance is observed. Normalised resistance behaviour is explained on the basis of variation in charge carriers and increased interaction between Mn atoms in the system under investigation.

Keywords: q-2DEG, Resistance, Magnetoresistance
PACS: 73.43.Qt-73.50.-h

INTRODUCTION

Artificially tailored oxide films on the (*001*) oriented $SrTiO_3$ single crystal substrate show novel opto-electronic properties at the interface due to the formation of a quasi two dimensional electron gas[1,2] (*q-2DEG)* having electron concentration of $\approx 10^{13}$ cm^{-2} and mobility of the order $\approx 10^4$ cm^2/Vs. Proposed mechanisms for formation of (*q-2DEG*) are electronic reconstruction (polar catastrophe)[1,3] atomic reconstruction[4], inter-site mixing of elements[4] and oxygen vacancy during growth[5]. This (*q-2DEG*) also shows various anomalous properties like coexistence of ferromagnetism and superconductivity[6] and photoconductivity[7]. In these systems, one of the extensively studied systems is $LaAlO_3$ [LAO] deposited on TiO_2 terminated $SrTiO_3$ [STO] (*001*). Another very interesting system is the interface of 3d transition metal oxide $LaTiO_3$ [LTO]/$SrTiO_3$ [STO] which also exhibits (*q-2DEG*) at the interface and goes to superconducting state at 260 mK[2,8]. So, both LTO and LAO films, which are prototype of Mott and band insulators respectively, show the characteristic property of electron confined conductivity at the interface, while other 3d transition metals like $LaMnO_3$ (LMO) and $LaCrO_3$ (LCO) do not. However, the interface of LMO/STO remains semiconducting, with Mn spins being ferromagnetically ordered[9]. Thus, Mn doping in LTO will be a good topic to understand such systems in detail. Here, our focus is to synthesize $La(Ti,Mn)O_3$ films on TiO_2 terminated $SrTiO_3$ substrate by pulsed laser deposition and thereafter investigate their transport properties. This paper describes some preliminary results of this study.

EXPERIMENTAL

Bulk PLD targets in chemical stoichiometric form of $LaTi_{1-x}Mn_xO_3$ (x = 0, 0.12) were prepared by solid state technique. Thin films with thickness ~ 4nm from each of the stoichiometric target were fabricated by PLD using KrF Excimer laser of wavelength 248 nm. The films were deposited on TiO_2 terminated STO at 800ºC with O_2 partial pressure of $1x10^{-4}$ mbar. In order to get the flat TiO_2 terminated surface on STO the substrates were etched with the buffered (NH_4F-HF)[10] solution for 30 seconds and then annealed at 800 ^{0}C for 1 hour in $7.4x10^{-2}$ mbar O_2 pressure. During deposition of films, the laser repetition rate was maintained at 2 Hz and laser energy density was $\approx$ 1 Jcm^{-2}. Samples were cooled down to room temperature in same O_2 pressure after completion of growth. With these optimised conditions and slow growth rate of 0.10 A^0/sec, 2D growth was realised in the deposited films. All the transport measurements were performed in standard four probe geometry by using

Solid State Physics
AIP Conf. Proc. 1591, 1367-1369 (2014); doi: 10.1063/1.4872961

Quantum design Physical Properties Measurements system (PPMS).

RESULTS AND DISCCUSION

Figure 1 shows the variation in normalized resistance as a function of temperature for pristine and 12% Mn doped films. For both the films normalized resistance decreases on lowering the temperature from 300K indicative of a metallic characteristic down to 2K. The observed metallic nature for all the samples can be explained on the basis of electronic reconstruction i.e. polar catastrophe[1,3,4] which give rise to two dimensional conductivity at the interface and formation of (*q-2DEG)*. Thus, the observed metallicity in these films can be correlated to the (*q-2DEG)* phenomena. Moreover, the possibility of intermixing at

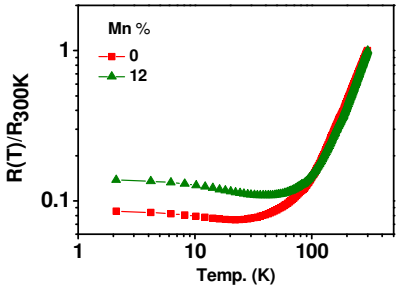

FIGURE 1. Variation of the normalized resistance as a function of temperature.

interfaces cannot be ruled out in such material that can also lead to the metallic nature of grown films.

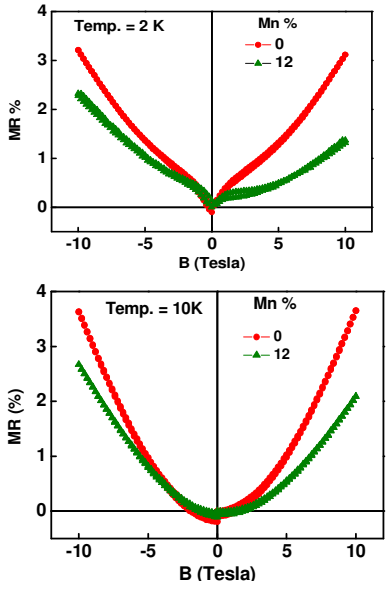

FIGURE 2. Change in the magnetoresistance with applied magnetic at 2K and 10K.

In LTO, formal valance state of Ti is +3 having $3d^1$ electron in outer most shell. With the Mn doping in LTO, there is increase in the correlation between Mn atoms in the system compared to Ti atoms since Mn is having higher correlation factor due to a larger number of electrons in the 3d shell. Therefore, enhancement in the normalized resistance for Mn doped films can be corroborated to the increase in the number of scattering centers due to the increased interaction between the Mn atoms. For $LaTiO_3$ minima in the resistance were observed at 22K while for 12% Mn doped samples, minima was observed at 40K, which shows the temperature for minimum resistance also increased with the doping. This can be correlated to the increase in the correlation effect due to addition of Mn atoms. A detailed understanding of the minimum in resistance followed by ln T growth and then saturation at the lowest temperature are being understood in the framework of Kondo scattering and weak antilocalization. To ensure our explanation few more doped samples are under investigation.The MR characteristic as a function of applied field perpendicular to the film plane for all the samples at 2 and 10K are shown in Fig. 2. Change in the resistance is measured from -10 to 10 Tesla field. The observed change in MR is parabolic, which show the quadratic dependence on the applied magnetic field (MR is proportional to B^2). With Mn doping the MR percentage decreases which can again be explained on the basis of increased scattering centers with Mn doping.

We have successfully grown thin films of pure $LaTiO_3$ and 12% Mn doped $LaTiO_3$ on STO. Metallicity in the thin films was intact with Mn doping whereas change in the resistance is being reported. Studies on samples with various concentration of Mn doping in LTO is ongoing.

ACKNOWLEDGMENTS

We thank Dr. V.P.S. Awana for his help during the use of PPMS. Pramod Kumar acknowledges CSIR-SRF fellowship. Funding under IFCPAR is also acknowledged.

REFERENCES

1. A. Ohtomo, H.Y. Hwang, *Nature* **427**, 423 (2004).
2. A. Rastogi, A. K. Kushwah, T. Shiyani, A. Gangwar and R.C. Budhani, *Adv. Mater.* **22**, 4448-4451 (2010).
3. A. Ohtomo, H.Y. Hwang, *Nature* **441**, 120 (2006).
4. N. Nakagama, H. Y. Hwang and D. A. Muller, *Nature Materials*. **5**, 204 (2006).
5. Y. Chen, N. Pryds, J. E. Kleibeuker, G. Koster, J. Sun, E. Stamate, B. Shen, G. Rijnders and S. Linderoth, *Nano Letters* **11**, 3774 (2011).

6. L. Li, C. Richter, J. Manhart and R.C. Ashoori, *Nature Physics* **7,** 762 (2011).
7. A. Rastogi and R.C. Budhani, *Optics Letters* **37**, 317 (2012).
8. J.Biscars, N. Bergeal, A. Kushwaha, T. Wolf, A. Rastogi, R.C. Budhani and J. Lesueur, *Nature communications* **1**, 89 (2010).
9. H.S. Kim and H.M. Christen, *J. Phys : Condens. Matter* **22**, 146007 (2010).
10. G. Koster, B. L. Kropman, Guus J. H. M. Rijnders, D. H. A. Blank and H. Rogalla, *App. Phys. Lett.* **73**, 20 (1998).