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Effect of substrate temperature on electrical and magnetic properties of epitaxial $La_{1-x}Pb_xMnO_3$ films

AJAY SINGH[1,*], D K ASWAL[1], SHASHWATI SEN[1], K SHAH[1], L C GUPTA[2], S K GUPTA[1] and V C SAHNI[1]

[1]Technical Physics and Prototype Engineering Division, Bhabha Atomic Research Center, Mumbai 400 085, India

[2]Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India

*Email: ajay_singh@rediffmail.com

Abstract. Epitaxial $La_{1-x}Pb_xMnO_3$ (LPMO) thin films, grown on (100) $SrTiO_3$ substrates by laser ablation technique at different temperatures between 600 and 850°C, have been characterized for electrical and magnetic properties. The temperature dependence of resistivity showed that the metal–insulator transition temperature (T_{MI}) decreases with increasing substrate temperature, which has been attributed to decrease in Pb content in the films. The $YBa_2Cu_3O_x/La_{1-x}Pb_xMnO_3$ heterostructures, exhibiting both superconductivity and ferromagnetism, have been fabricated.

Keywords. Colossal magnetoresistance; $La_{1-x}Pb_xMnO_3$; epitaxial films; heterostructures.

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1. Introduction

The discovery of colossal magnetoresistace in pervoskite manganite $La_{1-x}A_xMnO_3$ (A = alkaline earth metals, bivalent ion) has attracted extensive research not only for understanding the underlying physical mechanism but also for possible technological applications [1]. While a huge amount of work has been reported on alkaline earth metal doped manganite thin films [2], studies on other metal doping such as Pb, Sn have been very few. In this paper, we present thin film growth of $La_{1-x}Pb_xMnO_3$ (LPMO) and, fabrication of $YBa_2Cu_3O_{7-\delta}/La_{1-x}Pb_xMnO_3$ (YBCO/LPMO) heterostructures.

2. Experimental

The epitaxial $La_{1-x}Pb_xMnO_3$ thin films were grown on (100) $SrTiO_3$ single-crystal substrates by laser ablation technique. A target of nominal composition $La_{0.7}Pb_{0.4}MnO_3$ was synthesized by standard solid-state reaction method. The films were grown at different substrate temperatures between 600 and 850°C while keeping all other growth parameters at

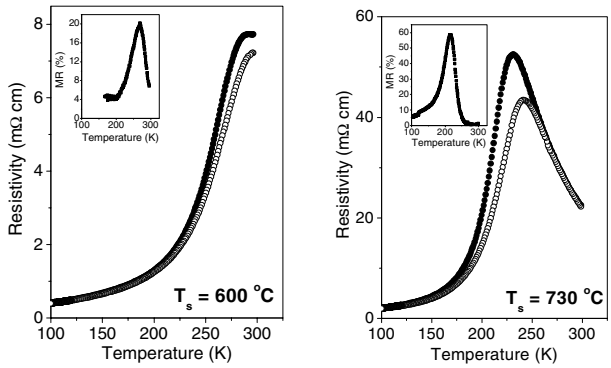

Figure 1. The temperature dependence of resistivity for LPMO films grown at different substrate temperatures (solid and open circles are the data in zero and 1 T magnetic field). The inset shows the variation of magnetoresistance with temperature.

fixed values, e.g., laser energy – 3.5 J/cm^2, target–substrate distance – 5 cm, oxygen partial pressure – 0.4 torr etc.YBCO/LPMO heterostructures were also fabricated at substrate temperature of 730°C and oxygen pressure of 0.2 torr. The thickness of YBCO and LPMO layers was 1000 Å and 500 Å, respectively.

3. Results and discussion

For all the films, X-ray diffraction (XRD) measurements showed the presence of only (00l) reflections, which indicated that grown films have high *c*-axis orientations. The atomic force microscopic images revealed well-aligned grains, and the grain size was found to increase with substrate temperature.

Typical plots of the temperature dependence of resistivity in zero field and in an applied magnetic field of 1 T for two LPMO films grown at 600°C and 730°C are shown in figure 1. All the films, grown at substrate temperatures < 800°C, exhibited a peak corresponding to a metal-to-insulator (MI) transition, similar to those shown in figure 1. The MI transition temperature (T_{MI}) was found to decrease monotonically with increasing substrate temperature. On application of magnetic field, the T_{MI} was observed to shift to higher temperatures, and exhibited a negative magnetoresistance (MR% $= [\{R(0) - R(H)\}/R(H)] \times 100$) as plotted in the inset of figure 1. The highest MR of $\sim 60\%$ was observed near T_{MI} for films prepared at 730°C. The temperature dependence of magnetization carried out under a magnetic field of 1 T (not shown here) revealed a paramagnetic-to-ferromagnetic transition at Curie temperature (T_{Curie}). Both the temperatures, namely, T_{MI} and T_{Curie}, were found to have nearly the same value, which suggests double exchange mechanism for the observed magnetoresistance. Films grown at temperatures > 800°C did not exhibit MI transition. The compositional analysis of the grown films carried out using energy dispersive X-ray (EDX) analysis revealed that the Pb content decreases with increasing substrate temperature, which explains the reduction in T_{MI} as substrate temperature is increased.

A typical plot of temperature dependence of resistance for grown YBCO/LPMO heterostructure is shown in figure 2a. It is seen that the heterostructure exhibits both supercon-

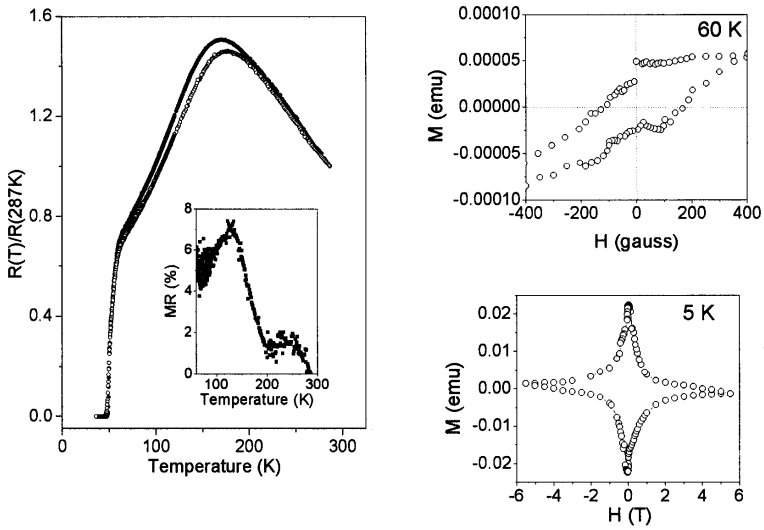

Figure 2. (**a**) The temperature dependence of resistivity for YBCO/LPMO heterostructure (solid and open circles are the data in zero and 1 T magnetic field). The inset shows the variation of magnetoresistance with temperature. (**b**) M–H hysteresis loops recorded at 60 K and 5 K.

ducting as well as magnetic properties. The T_{MI} is found to take place at $\sim$ 168 K and the superconductivity occurs at $\sim$ 50 K. The temperature dependence of magnetoresistance – shown in the inset – exhibits a highest MR value of $\sim$ 7% near T_{MI}. To confirm the existence of both ferromagnetism and superconductivity, M–H loops were recorded at 60 K and 5 K, and the results are shown in figure 2b. The M–H hysteresis at 60 K corresponds to ferromagnetic behavior, while that of 5 K suggests superconducting state with very high critical current density. Further characterization of these heterostructures is being carried out.

4. Conclusion

The metal-to-insulator transition temperature of epitaxial $La_{1-x}Pb_xMnO_3$ (LPMO) thin films is found to decrease monotonically with substrate temperature, which has been attributed to decrease in Pb content. The highest magnetoresistance of $\sim$ 60% at 1 T was found in the film grown at 730°C. The $YBa_2Cu_3O_{7-\delta}/La_{1-x}Pb_xMnO_3$ heterostructures, exhibiting both superconductivity and magnetism, have been fabricated and studied.

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