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Correlation of thickness and magnetization in LCMO film*

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Abstract. High quality thin films of $La_{0.67}Ca_{0.33}MnO_3$ (LCMO) of different thickness were grown on LAO substrates by pulsed laser deposition (KrF, $\lambda = 278$ nm). The AFM images suggest a two-dimensional step-growth. DC magnetization measurements of the films in a field of 500 Oe show that the magnetic ordering temperature is the same for all the films in both FC and ZFC conditions and is the same as that for the bulk. However, a difference is seen between the FC and ZFC magnetization of the films. There seems to be a systematic in this difference with respect to the thickness of the film, with the difference decreasing with thickness. We suggest that the difference in the magnetization under FC and ZFC conditions may be due to strain-induced anisotropy arising from the lattice mismatch between the substrate and the film or due to the shape anisotropy due to epitaxial growth.

Keywords. Colossal magnetoresistance; manganite; thin film; $La_{0.67}Mn_{0.33}MnO_3$.

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1. Introduction

It is well known that colossal magnetoresistance (CMR) in manganites is of importance in material research. Among the manganites, $La_{1-x}Ca_xMnO_3$ (LCMO) system is widely studied because of its large magnetoresistance (MR) at near room temperature, making it an excellent candidate for practical applications like bolometry. The metal-to-insulator transition (M–I) and the ferromagnetic-to-paramagnetic (FM–PM) transition at high temperatures in these substances are attributed to double exchange (DE) interaction and Jahn–Teller (J–T) distortion of the charge orbitals [1–3]. In this study, we focus on the magnetic properties of thin films of LCMO with $x = 0.33$ for different thickness.

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2. Experimental

LCMO thin films were grown epitaxially on (00l) LAO (lanthanum aluminate) substrates by pulsed laser deposition from a stoichiometric target. The KrF excimer laser that was used had 248 nm wavelength, 5 Hz pulse rate and ∼05 J/cm^2 fluence on the target. Three films of different thicknesses (∼2000, ∼4000, ∼6000 Å) were grown at optimum growth conditions with the substrate temperature at 800°C.

3. Results and discussions

3.1 *AFM results*

Microstructure pictures of the films of LCMO were taken by atomic force microscope (AFM) in a range of 500 nm (figure 1). The AFM images show a terrace growth and mean roughness 1–2 nm. With increasing film thickness, the individual, small grains on the film topology gradually change to 'islands' suggesting several grains coalesce, albeit the terrace-layering still continues.

3.2 *Magnetization results*

Magnetic measurements on the LCMO thin films were done with a commercial SQUID magnetometer in a field of 500 Oe in the temperature range 5–300 K (figure 2). All the films show clear magnetic ordering $(T_{\rm C})$ at ∼260 K, which is the same as that shown by bulk LCMO. The magnetization under field-cooled (FC) condition is nearly the same for all the three samples. However, there is significant difference in the magnetization under zero-field-cooled (ZFC) condition. Below $T_{\rm C}$, while the FC magnetization is virtually constant with respect to temperature, the ZFC magnetization decreases with decreasing temperature. A noteworthy feature of our results is that the difference in the magnetization measured under FC and ZFC conditions appears to be systematically dependent on the thickness, being largest for the thinnest film and smallest for the thickest film.

4. Discussions

Generally, the CMR mechanism has been understood in the light of double exchange (DE) interaction in the system having a transition from an insulating, anti-ferromagnetic (I-AF) phase to a ferromagnetic, metallic (F-M) phase; corresponding to hole deficient and hole rich regimes, respectively. Any lattice distortion influences spin structure, thereby altering the micromagnetic behaviour [4–7]. Our magnetization results are consistent with this correlation. The epitaxial growth process always brings in a lattice mismatch between the film and the substrate. This results in a lattice strain in the film [6,7]. Further, in the epitaxial growth, the substrate being a single crystal, the grains are crystallographically oriented. The strain would induce an anisotropy and the orientation from the epitaxial growth enables this anisotropy to reflect in the properties. But the effect of lattice mismatch would

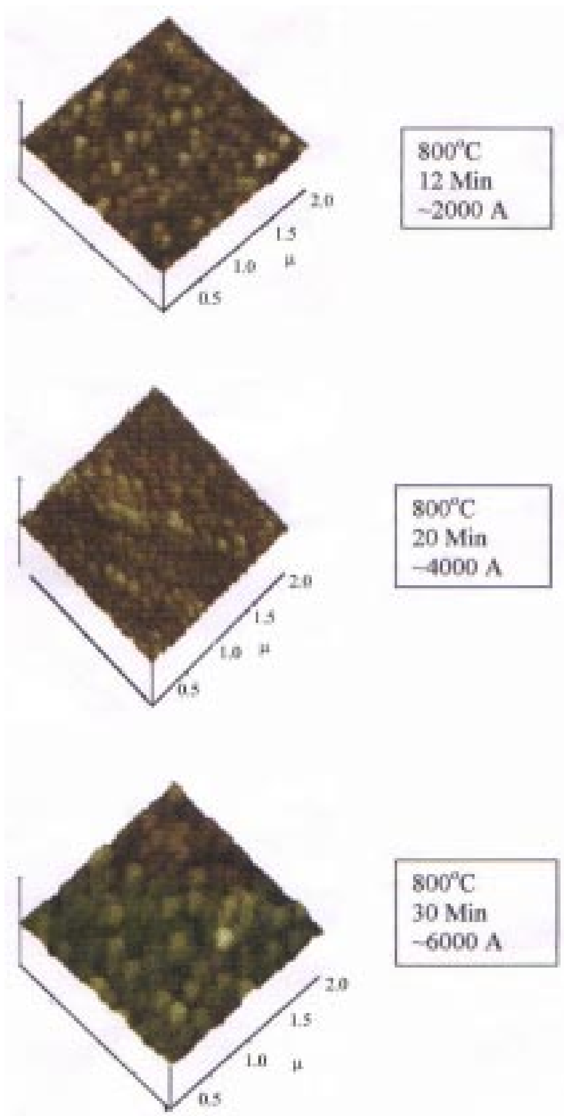

Figure 1. AFM images of LCMO films of different thickness for a scan area of 2 μm $\times$ 2 μm. The numbers in the box indicate the substrate temperature, duration of film deposition and the thickness of the grown film.

reduce as the thickness is increased, thereby reducing the strain-induced anisotropy in thicker films. It is known that the presence of anisotropy results in thermomagnetic irreversibility as seen in our results. Thus we observe a larger irreversibility in the thinner film compared to a thicker film. It is also possible that there could be some shape anisotropy effect. With increasing thickness, the shape anisotropy could also change. Further work is in progress to investigate these films in detail.

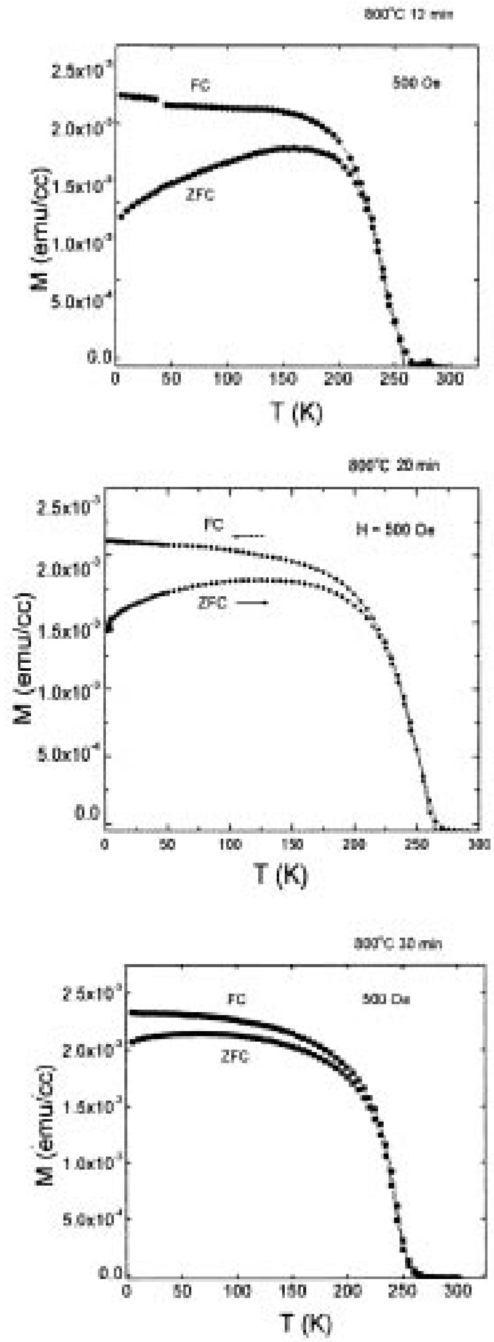

Figure 2. Magnetization (M) vs. temperature (T) plots of LCMO films of different thicknesses as indicated in figure 1, in an applied field of 500 Oe and under zero-field-cooled (ZFC) and field-cooled (FC) conditions.

5. Conclusions

We have prepared epitaxial thin films (2000–6000 Å thickness) of $La_{0.67}Ca_{0.33}MnO_3$. Our results show that below T_C, the magnetization measured under zero-field-cooled and field-cooled conditions are significantly different. The difference seems to systematically reduce with increasing thickness. We suggest that the observed effect is either due to a strain anisotropy arising from the mismatch of the lattices of the substrate and the film or due to shape anisotropy.

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