ELSEVIER

Journal of Magnetism and Magnetic Materials 226–230 (2001) 690–692

www.elsevier.com/locate/jmmm

Magnetoresistance of $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ film at room temperature

S.Y. Yang^{a,*}, W.L. Kuang^a, C.H. Ho^b, W.S. Tse^a, M.T. Lin^b,
S.F. Lee^a, Y. Liou^a, Y.D. Yao^a

^a*Institute of Physics, Academia Sinica, 128, Taipei 115, Taiwan*

^b*Department of Physics, National Taiwan University, Taipei 106, Taiwan*

Abstract

The $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ (LSMO) film is deposited successfully onto a MgO (001) substrate by using a magnetron DC sputtering system. The θ - 2θ X-ray diffraction pattern is detected to investigate the structure of the deposited LSMO film. According to the experimental temperature dependent magnetization result, the Curie temperature of the sample is 364.8 K. The magnetic hysteresis curve with a coercivity of 17 Oe was found for the LSMO film at 300 K, meanwhile, a significant magnetoresistance was observed. With these properties at room temperature, the LSMO-based devices might be very suitable for practical applications. © 2001 Published by Elsevier Science B.V.

Keywords: Thin films—ferromagnetic; Curie temperature; Magnetoresistance

1. Introduction

Due to the discovery of the colossal magnetoresistance (CMR) effect in epitaxial thin films of doped LaMnO_3 [1], there has been an increasing interest in these materials for device applications. The CMR effect is usually interpreted by using the double-exchange theory [2], which is based on the exchange of electrons between Mn^{3+} and Mn^{4+} ions. Most researches are focused on studying the CMR effect of $\text{La}_{1-x}\text{Ca}_x\text{MnO}_3$ (LCMO) [1,3]. Since the Curie temperature of LCMO is around 250 K, the CMR effect is to be observed at temperatures lower than 250 K. Thus, the aid of a cooling system is needed for the LCMO-based devices operating at room temperature. This is inconvenient for the practical applications. Fortunately, by replacing the doped rare-earth Ca with Sr, the Curie temperature becomes higher than room temperature [4]. This implies that the CMR effect can be achieved at room temperature for

$\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$. Hence, the $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ reveals a great potential in application. In this work, the deposition of the $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ (LSMO) film is developed. Furthermore, the properties of the LSMO film at room temperature are also investigated.

2. Experimental details

A magnetron DC sputtering system was used to deposit the $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ (LSMO) film onto a MgO (001) substrate from a stoichiometric target. The LSMO film was sputtered at around 750°C under a 300-mTorr mixed gas of Ar and O_2 . The thickness of the LSMO film used here is about 2000 Å. After deposition, the LSMO film was annealed at 700°C and under 660 mm Hg oxygen for 1 h, followed by lowering the temperature down to room temperature at the rate of 10°C/min. A θ - 2θ X-ray diffraction of the deposited LSMO film was used to determine its structural quality. In this experiment, the magnetization of the LSMO film was probed with a superconducting quantum interference device. A traditional four-point method was adopted to measure the resistance.

*Corresponding author. Fax: 886-2-2930-9439.

E-mail address: emesdolb@ms28.hinet.net (S.Y. Yang).

Fig. 1. θ - 2θ X-ray diffraction pattern of the LSMO film on a MgO (001) substrate.

Fig. 2. Magnetization of the LSMO film versus the temperature. The external magnetic field H is parallel to the plane of the film. The down-left inset shows the power law between M and $T_c - T$ at temperatures near T_c .

3. Results and discussion

To investigate the structure of the LSMO film onto a MgO substrate, a θ - 2θ X-ray diffraction pattern was detected and shown in Fig. 1. The wavelength λ of the X-ray is 1.54 Å. Since the lattice constant c of the MgO is 4.21 Å, the 2θ corresponding to (002) of MgO should be 42.9° via the relation $2\theta = 2 \sin^{-1}(\lambda/c)$. This peak can be observed obviously in Fig. 1. In addition, there are another two peaks attributed to the LSMO film at 22.8° and 46.7° in Fig. 1. According to the published report [5], the c -axis lattice constant of LSMO is around 3.88 Å. This implies that the 2θ for (001) and (002) of LSMO are 22.8° and 46.7° , respectively. This is consistent with the

Fig. 3. Magnetic hysteresis curve of the LSMO film at 300 K.

Fig. 4. Magnetic field dependent resistance (solid line) and the magnetoresistance (dashed line) of the LSMO film at 300 K. The external magnetic field H is parallel to the applied current I .

experimental result shown in Fig. 1. Hence, this X-ray diffraction pattern reveals that the c -axis of the deposited LSMO film is along that of the MgO (001) substrate.

In Fig. 2, the temperature dependence of the magnetization $M(T)$ of the LSMO film is shown. The applied magnetic field was 2.5 kOe and along the plane of the LSMO film. At lower temperatures, the LSMO exhibits the ferromagnetism. With the increase of the temperature, the magnetization of the LSMO is reduced monotonously and vanishes at 364.8 K. At temperature higher than 364.8 K, a paramagnetic property is found for the LSMO film. Thus, the Curie temperature T_c of the LSMO is 364.8 K. The inset of Fig. 2 gives the relationship between M and $(T_c - T)^\beta$ with β being 0.79 near T_c . The value of the β coincides with that predicted from the

numerical Monte Carlo simulations based on the semi-infinite Heisenberg model for the surface magnetization [6]. It is worthy to note that the LSMO shows a ferromagnetic behavior at room temperature. The hysteresis curve of the LSMO film at 300 K is shown in Fig. 3. This curve displays a hysteresis behavior with a low coercivity being 17 Oe. Besides, the magnetization of the LSMO film almost becomes saturated under 200 Oe.

The magnetic field dependent resistance of the LSMO film at 300 K is shown in Fig. 4. Here, the magnetic field is parallel to the applied current. Thus, the magnetoresistance due to the Lorentz force on the transporting charge carrier can be eliminated. It was found in Fig. 4 that the resistance of the LSMO film decreases rapidly with the increasing H under lower H 's. And then, the resistance decreases almost linearly when the H is raised up to 1 T. According to the experimental result, the magnetoresistance defined as $[R(H) - R(0)]/R(0)$ of the LSMO film at 300 K was found to be -3.81% under 1 T.

4. Conclusion

The $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ film was successfully sputtered onto a MgO (001) substrate. Some characterizations, such as the low coercivity and the colossal magnetoresistance, of the LSMO film at room temperature show that the LSMO is good for further development in practical applications.

References

- [1] S. Jin et al., *Science* 264 (1994) 414.
- [2] C. Zener, *Phys. Rev.* 82 (1951) 403.
- [3] R. Mahesh et al., *Appl. Phys. Lett.* 68 (1996) 2291.
- [4] J.H. Park et al., *Phys. Rev. Lett.* 81 (1998) 1953.
- [5] Z. Trajanovic et al., *Appl. Phys. Lett.* 69 (1996) 1005.
- [6] K. Binder, P.C. Hohenberg, *Phys. Rev. B* 9 (1974) 2194.