Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Magnetism and Magnetic Materials 272–276 (2004) 1171–1173
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Oxygen and disorder effect in the magnetic properties of manganite films

M. Sirena[a,*], N. Haberkorn[a,b], M. Granada[a], L.B. Steren[a], J. Guimpel[a]

[a] *Centro Atómico Bariloche and Instituto Balseiro, Comisión Nacional de Energía Atómica and Universidad Nacional de Cuyo, Centro Atomico bariloche k. 9.5, 8400-San Carlos de Bariloche, Río Negro, Argentina*
[b] *Universidad del Sur, Bahia Blanca, Argentina*

Abstract

We have made a systematic study of the magnetic properties of low doped manganite films submitted to different oxygenation treatments. We have found that oxygenation dynamics depends critically of the strain field in the sample. The T_C and the Mr increase as the oxygen content is increased. A decrease of the coercive field of the LSMO-STO films was observed, indicating that annealing treatments increase the oxygen content reducing oxygen vacancies.

PACS: 75–60; 75–70i

Keywords: Manganite fims; Oxigenation; Magnetic properties

Half-metallic manganite films are excellent candidates for technological applications such as magnetic reading devices, tunnel junctions for MRAM, etc. Manganites also present a high degree of correlation between the transport, magnetic and structural properties that is the origin of many exciting phenomena. All these have renewed the interest in these compounds in the last years. Different authors have reported that changing the oxygen content (x_{ox}) in manganite films and bulk compounds modifies the transport and magnetic properties of the samples [1–3]. Post-deposition annealing treatments, at different oxygen pressures and/or annealing times, usually varies x_{ox} in films [4–6]. Although, a recent study performed on $(La_{1-x}Nd_x)_{0.7}Sr_{0.3}MnO_3$ thin films report only a weak dependence of the transport properties of the samples with the oxygen pressure during samples deposition.

$La_{0.96}Sr_{0.04}MnO_3$ (LSMO) films of 120 nm nominal thicknesses were grown by DC-magnetron sputtering. The films were grown in a mixed atmosphere of O_2 (7.7E-3 mTorr) and Ar (7.7E-2 mTorr) at a substrate temperature $T_s = 760^\circ C$ In order to study the oxygenation process in manganite films, we have annealed LSMO thin films at different oxygen pressures and annealing times. We have also studied the effect of substrate induced strains in the oxygen dynamics by studying films grown over (1 0 0) MgO–MGO and (1 0 0) $SrTiO_3$STO single-crystalline substrates. Magnetization measurements were performed in a commercial SQUID magnetometer.

The samples are strongly textured in the direction perpendicular to samples surface and no evidence of grain boundaries was observed through AFM or SEM. The remanent magnetization of the LSMO films, grown on (a) STO and (b) MGO at different annealing times, as a function of temperature is shown in Fig. 1. Similar results were obtained for the films annealed at different oxygen pressure. It is interesting to note that although the bulk compound is canted antiferromagnetic [7], all the measured films were found to be ferromagnetic. Similar results were found in previous works [8]. Moreover, the increasing of x_{ox} in films increases the Curie temperature (T_C) and the remanent magnetization (Mr(50 K)). Films grown on STO are much more sensitive to post-deposition annealing than LSMO-MGO

*Corresponding author.
E-mail address: sirenam@ib.cnea.gov.ar (M. Sirena).

0304-8853/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2003.12.027

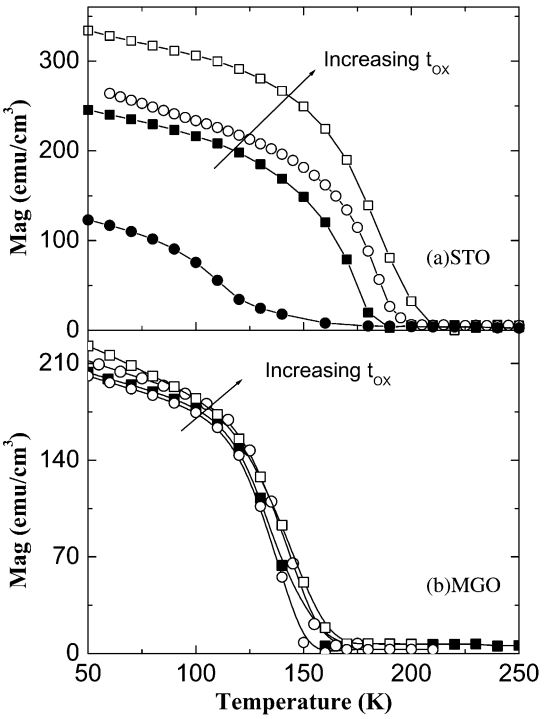

Fig. 1. Temperature dependence of the remanent magnetization for annealed $La_{0.96}Sr_{0.04}MnO_3$ thin films at T_A: 600°C, P_{OX}: 100 Torr., grown over (a) STO and (b) MGO, for different annealing times (t_{OX}: (●) 0, (■) 5, (○) 30 and (□) 60 min).

ones, as observed in Fig. 1. The oxygen dynamics and therefore the influence of post-deposition annealing in these two systems are clearly different. The lattice mismatch between substrate and manganite is larger for LSMO-MGO (~9%) than for LSMO-STO (~1%) leading to different films growths [9]. Strains are more important in LSMO-STO films than in LSMO-MGO, where the relaxation of the large mismatch occurs by structural defects like dislocations or point defects. These results suggest that strained samples, i.e., LSMO-STO, present a faster oxygenation dynamics.

To obtain more information about the oxygen dynamic in these systems we have analyzed the effect of x_{ox} on the coercive field of the samples. Since the increase of x_{ox} has a larger effect in the magnetic properties of the LSMO-STO films than in the LSMO-MGO ones, we have tested its influence in the first series of films. Magnetization loops for different annealing treatments, performed at 35 K, are show in Fig. 2. It is clearly seen that as x_{ox} is increased, the coercive field of the samples is drastically reduced. Point defects, like oxygen vacancies, act as centers of domain wall pinning. The decrease of the coercive filed is related to the decrease of point defects and structural disorder. In both, the strong to the weak pinning regime, the density of these defects determinate the characteristic and

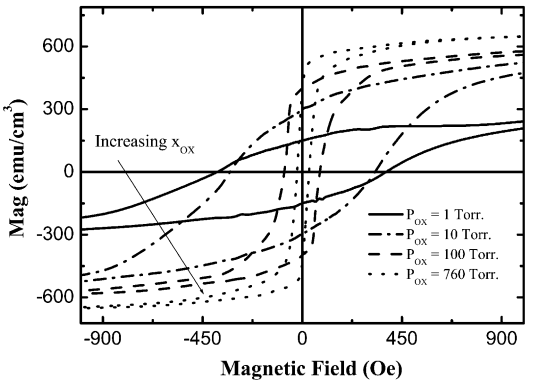

Fig. 2. Magnetization loops at $T = 35$ K for annealed $La_{0.96}Sr_{0.04}MnO_3$ thin films grown over STO.

magnitude of the coercive field [10]. Two important conclusions can be obtained from these results. First, x_{ox} is increased in these manganite films filling oxygen vacancies rather than increasing the cation vacancies (which would increase point defects and disorder). Second, the hole concentration of the fully oxygenated films is given by the Sr concentration, indicating that the films are in the low doped concentration regime, far from the ferromagnetic-metallic zone of the phase diagram ($0.2 \leqslant x \leqslant 0.5$).

In conclusion, we have made a systematic study of the magnetic properties of low doped manganite films for different oxygenation treatments. We have found that oxygenation dynamics depends critically of the strain field in the sample. The T_C and the Mr increases as x_{ox} is increased. A decrease of the coercive field with the oxygen content, of the LSMO-STO films was observed, indicating that annealing treatments increase x_{ox} by reducing oxygen vacancies.

This work was partially supported by ANPCYT (PICT 3-6340), Fundación Antorchas. L.B.S. and J.G. are members of CONICET Argentina, M.S. and N.H. acknowledge fellowships from CONICET and ANPCYT respectively.

References

[1] V.G. Prokhorov, G.G. Kaminsky, V.A. Komashko, Y.P. Lee, J.S. Park, H.C. Ri, Appl. Phys. Lett. 80 (2002) 2707.
[2] W. Zhang, W. Boyd, M. Elliot, W. Herrenden-Harkerand, Appl. Phys. Lett. 69 (1996) 3929.
[3] J.-M. Liu, C.K. Ong, Appl. Phys. Lett. 73 (1998) 1047.
[4] M. Rajeswari, R. Shreekala, A. Goyal, S.E. Lofland, S.M. Bhagat, K. Ghosh, T. Boettcher, Appl. Phys. Lett. 73 (1998) 2672.
[5] X.D. Zhu, W. Si, X.X. Xi, Q. Li, Q.D. Jiang, M.G. Medici, Appl. Phys. Lett 74 (1999) 3530.

[6] A. Goyal, M. Rajeswari, R. Shreekala, S.E. Lofland, S.M. Bhagat, T. Boettcher, C. Kwon, R. Ramesh, T. Venkatesan, Appl. Phys. Lett. 71 (1997) 2535.
[7] A. Urushibara, Y. Moritomo, T. Arima, A. Asamitsu, G. Kido, Y. Tokura, Phys. Rev. B. 51 (1995) 14103.
[8] X.J. Chen, S. Soltan, H. Zhang, H.-U Habermeier, Phys. Rev. B. 65 (2002) 174402.
[9] J. Guimpel, M. Sirena, L.B. Steren, Thin Solid Films 373 (2000) 102.
[10] P. Gaunt, J. Appl. Phys. 59 (1986) 4129.