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Journal of Magnetism and Magnetic Materials 297 (2006) 88–92
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Effects of annealing procedures on the structural and magnetic properties of epitaxial $La_{0.7}Sr_{0.3}MnO_3$ films

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Received 15 December 2004; received in revised form 28 January 2005
Available online 17 March 2005

Abstract

The effects of annealing procedures on the structural and magnetic properties of the LSMO films epitaxially grown on (1 0 0) $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) substrates have been studied. A gradual lattice contraction is observed with the increase of annealing temperatures. This can be explained as the increase in Mn^{4+}/Mn^{3+} ratio before it reached the ideal one value (3:7). Annealing procedures at the higher temperatures can enhance the ferromagnetic order and Curie temperature (T_c) and dramatically reduce the coercivity values due to the increase in the oxygen content. On the other hand, a larger surface roughness caused by the lattice mismatch between the films and the substrates is presumably responsible for a higher coercivity.

PACS: 68.55.Ac; 61.50. –f

Keywords: $La_{0.7}Sr_{0.3}MnO_3$ films; Annealing procedures; Oxygen; The coercivity

1. Introduction

Due to the very large magnetoresistance exhibited by perovskite manganites, they have attracted a great deal of interest for potential applications [1–3]. As an example of the CMR materials, $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) possesses the highest value of Curie temperature (>370 K), which makes these materials very promising in room-temperature applications [4].

It is believed that the double exchange interaction between pairs of Mn^{3+} and Mn^{4+} ions is responsible for the ferromagnetic and metallic properties in these manganese oxides. Pairs of Mn^{3+} and Mn^{4+} can be controlled by oxygen stoichiometry. Therefore, it seems that oxygen content will be important for the magnetic and electronic properties in these materials [5]. However, there is no quantitative relation between the

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0304-8853/$ - see front matter
doi:10.1016/j.jmmm.2005.02.062

oxygen content and the magnetic and transport properties in films because of the difficulty in the determination and control of oxygen content. It was found that preparation conditions such as substrate temperature, oxygen partial pressure, and deposition rate could affect the oxygen content in the resulting film severely [6,7]. Especially in the magnetron sputtering method, the as-grown LSMO films feature a reduction of oxygen content, because of the low oxygen partial pressure during deposition [8]. Some previous studies on the effects of annealing have been primarily focused on the role of oxygen content since oxygen-annealing on the perovskite manganite can lead to an increase of T_c and saturation magnetization value.

In this article, we have studied the effect of annealing procedures on the structural and magnetic properties of epitaxial LSMO films grown on LAO and STO substrates by the RF magnetron sputtering technique. The main advantage of the magnetron sputtering method is its superiority in large-area deposition techniques compatible with microelectronics applications. Furthermore, we can obtain films with smoother surfaces using low-energy plasma during deposition in comparison to films prepared by, for example, the PLD method.

2. Experiment

LSMO films of about 100 nm were deposited on (1 0 0) $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) substrates by using a RF magnetron sputtering. The process was carried out in a gas mixture of argon with 20 vol% of oxygen and a total pressure of 1 Pa. The substrate temperature was kept at 800 °C. In order to improve the oxygen content, the samples were annealed ex situ at different temperatures in flowing oxygen at atmospheric pressure for 0.5 h. The heating and the cooling were done at 3 °C/min.

The thickness of the LSMO films was measured with a Seimitzu Surfcom 480A profiler. The XRD diffraction curves of films were measured by a Bruker diffractometer (AXS D8 ADVANCE) with the Cu K_α radiation. All the crystallographic planes and directions of LSMO films used in this work are indexed according to cubic notation. The surface morphology of the films was observed by a Digital Nanoscope III atomic force microscopy (AFM). An MPMS-5 superconducting quantum interference device (SQUID) magnetometer was used to study the magnetic properties.

3. Results and discussion

The roughness of as-grown LSMO films deposited on (1 0 0) LAO and STO substrate, respectively, determined from AFM measurements in a 500×500 nm scan area (as shown in Fig. 1), are about 0.66 and 0.52 nm. The results indicate that the LSMO film deposited on (1 0 0) STO substrate

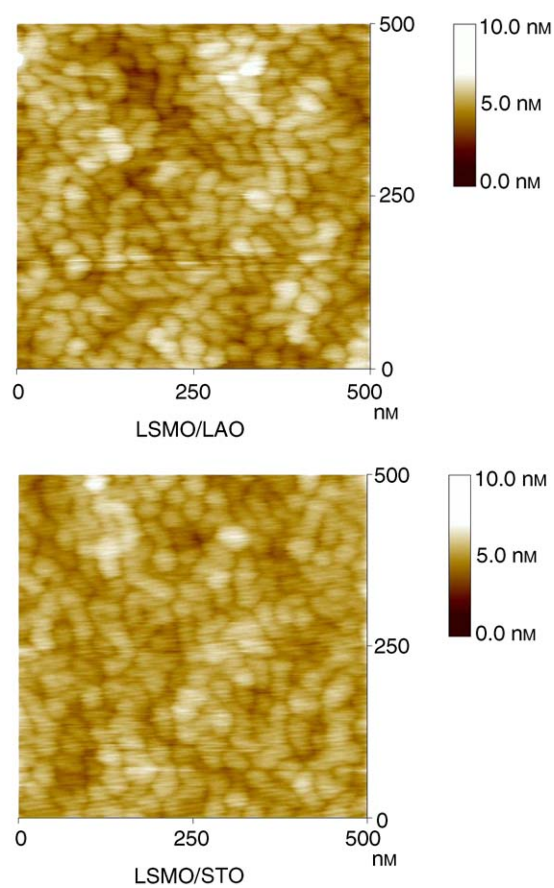

Fig. 1. The surface morphology of as-grown LSMO epitaxial films deposited on (1 0 0) LAO and STO substrates by AFM.