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The properties of $La_{0.7}Sr_{0.3}MnO_3$ films prepared by dc magnetron sputtering using nanosized powder compacted target: Effect of substrate temperature

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ABSTRACT

$La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films have been deposited on Si(1 0 0) substrates at different substrate temperatures in a mixed argon and oxygen atmosphere by dc sputtering using LSMO targets prepared from nanosized powder. The influence of the deposition temperature on the structural, magnetic and transport properties of LSMO films were studied. The results show that in our experimental conditions, the LSMO thin films deposited at 650 °C have the best crystalline quality. Magnetic and magnetotransport studies show the highest Curie temperature (T_c) of 300 K and metal insulator transition temperature (T_{MI}) of 250 K at room temperature.

1. Introduction

$La_{0.7}Sr_{0.3}MnO_3$ (LSMO) is a well-known colossal magnetoresistance (CMR) material with perovskite structure and has attracted a great research interest [1–6] both on fundamental and practical aspects. The CMR makes these materials good candidates for magnetic random access memory, read–head applications [7–9] and infrared detectors [10]. Many techniques including pulsed laser deposition [11], rf or dc sputtering [12,13], MOCVD [14], or spray pyrolysis have been employed to prepare LSMO thin films. Among these methods the sputtering process is the most promising method for depositing LSMO thin films because of its low cost, heat cycling and ability to grow films at low temperature with good properties. In addition sputtering of LSMO has a relatively high deposition rate and hence is well suited to industrial-scale large area deposition [15]. However, the characteristics of LSMO films are generally affected by the preparation conditions such as the deposition methods, working pressure, substrate temperature and the type of substrates [16]. Usually, the films either grown at relatively high substrate temperature above 750 °C, or, the as-deposited films annealed under ambient oxygen at high temperature (850 °C) for a prolonged period (10 h) show good properties [10]. The reduction of processing temperature of these materials is still a challenge to make them fully compatible with the technology of integrated circuits on silicon. In this study, LSMO films were deposited by dc magnetron sputtering from a LSMO sintered target prepared from nanosized powder compacted target [17] in a mixed argon and oxygen atmosphere. The influence of substrate temperature on the properties of LSMO film was studied.

2. Experimental

A sintered oxide disk of LSMO was prepared from nanosized synthesized powder for the deposition of films on a Si(1 0 0) substrate by dc sputtering. Before each deposition, a base pressure of less 2.1×10^{-4} Pa was established using a turbomolecular pump. The substrate was ultrasonically cleaned in acetone, rinsed in deionized water and subsequently dried in flowing nitrogen. The films were grown in a mixed atmosphere of 70% argon and 30%

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oxygen at different substrate temperatures. After deposition samples were cooled down to room temperature. The diffraction patterns of the films were recorded using a Philips PW 1917 X-ray powder diffractometer using Cu Kα radiation. Magnetoresistance and electrical properties of the LSMO films were measured by four-point probe technique. The probe current was parallel to the longitudinal direction of sample and the magnetic field was parallel to the current direction. The magnetization was measured by a vibrating sample magnetometer (VSM) in the range 100–300 K.

3. Results and discussion

Fig. 1 displays the typical X-ray diffraction patterns achieved for the LSMO films on a Si(1 0 0) substrate at different substrate temperatures. The thickness of all the films is same and is about 100 nm. The XRD patterns are corrected for Si substrate. Only peaks related to the film are presented without Si substrate peaks. The features of XRD do not change substantially for films deposited at the substrate temperatures (T_s) of 700 and 750 °C. More numbers of XRD peaks are evolved with the increase of substrate temperature. The intensity of the diffraction peak for the film decreases when T_s falls below 650 °C, indicating that the film is difficult to crystallize at low substrate temperature. At a substrate temperature of 650 °C, only the (1 0 4) diffraction line of the perovskite phase is present. The film is single phase without any impurity peak. The single phase deposited LSMO film on Si has not been reported so far. This indicates that highly preferred orientation films can be deposited at this substrate temperature. The FWHM of the LSMO (1 0 4) peaks as a function of growth temperature is plotted in Fig. 2, showing that the smallest line width correspond to the sample grown at the temperature of 650 °C, providing additional evidence that the best crystallinity occurs at 650 °C, corresponding to the optimum growth temperature.

The temperature-dependent resistance of as-grown films at different substrate temperatures is shown in Fig. 3. The films show a systematic increase in metal insulator transition temperature (T_{MI}) from 600 to 700 °C and then a decrease of T_{MI} at 750 °C substrate temperature. There is also a large variation in the resistance at different substrate temperature. So in order to represent it in one figure, resistance of the film at different temperature is normalized with room temperature and presented in Fig. 3. The magnitude of the high resistance could be related to

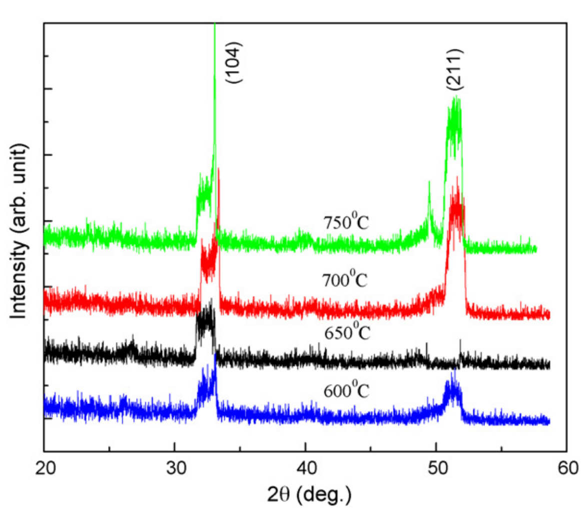

Fig. 1. XRD pattern of LSMO film deposited at different substrate temperatures.

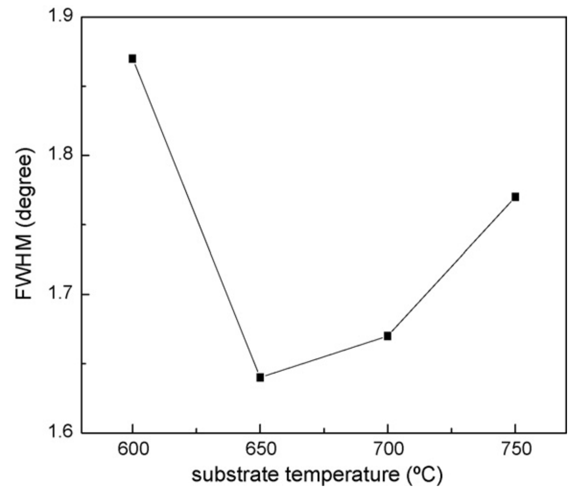

Fig. 2. Full-width at half maximum (FWHM) of XRD (1 0 4) peaks at various substrate temperatures.

phase separation and/or the presence of a number of grain boundaries. It is seen that film shows at least two resistivity peaks on the *R*–*T* curve except for the sample prepared at 650 °C substrate temperature. Film prepared at 650 °C substrate temperature indicated T_{MI} of 250 K. The formation of the resistivity peak at lower temperature may be a special property of the magnetic granular perovskite. It has never been seen in granular transition metals or other granular ferromagnets below T_c [18–20]. Since the peak appears at a temperature well below T_c, it is difficult to explain by the theory of the metal insulator like transition as used for crystals. The spin dependent interfacial tunneling and the intrinsic transport mechanisms simultaneously exist in these samples and the contribution of interface gradually reduces as grain growth increases. The peak at lower temperature shrinks

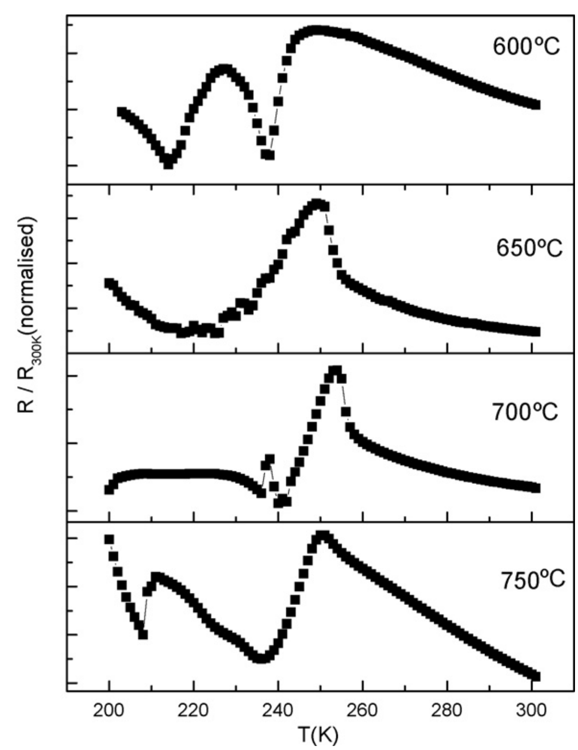

Fig. 3. Temperature dependent resistance of LSMO film at different substrate temperatures.