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Conductance and conduction noise of polycrystalline $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ films on different substrates

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Abstract

$La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ (LCBMO) films were prepared by ultrasonically assisted spray pyrolysis deposition on $LaAlO_3$ and Al_2O_3 single crystal substrates. Conductance–voltage (G–V) characteristics and conduction noise of the two films were found to be different. G–V characteristics of LCBMO film on $LaAlO_3$ were linear indicating the spin dependent scattering across the grain boundaries whereas for the film on Al_2O_3, G–V characteristics at low temperature ($T < 210$ K) were nonlinear indicating dominant transport mechanism as spin polarized tunnelling. Normalized conduction noise of LCBMO film on $LaAlO_3$ was one order lower to that of film on Al_2O_3. These differences in conductance–voltage and conduction noise characteristics of the two films are attributed to the presence of more disordered grain boundaries in LCBMO film on Al_2O_3 as compared to the films on $LaAlO_3$ substrate.

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1. Introduction

The doped rare earth manganite materials $R_{1-x}A_xMnO_3$ (R = La, Pr, Nd etc. and A = Ca, Ba, Sr etc.) have received a great deal of interest because of colossal magnetoresistance (CMR) [1,2]. The fundamental mechanism of CMR effect and its potential for device applications have been addressed in a number of studies [3–5]. The effect of grain boundaries in doped rare earth manganites has been studied intensively [6–8], since the presence of grain boundaries in the polycrystalline samples are attributed to large low field magnetoresistance over a wide temperature range much below the ferromagnetic transition temperature [9–12]. The behaviour of grain boundaries in manganites has been addressed in several studies [6–8,13–18] and several models to explain the transport behaviour have been proposed [7, 8,19,20]. The transport and magnetoresistance properties of doped rare earth manganites are understood in the framework of double exchange model [3] with polaronic effect due to strong electron–phonon coupling and Jahn–Teller distortion [4]. In polycrystalline films, transport across the grain boundaries is proposed due to spin polarized tunnelling between ferromagnetic grains [7] or due to spin dependent scattering of polarized electrons at grain boundaries [8]. For tunnelling to be a dominant conduction mechanism across grain boundaries, one would expect strongly non-ohmic I–V characteristics; whereas for non-tunnelling mechanism such as spin dependent scattering one would expect ohmic I–V characteristics. Li et al. [8] reported the observation of ohmic I–V characteristics in $La_{0.67}Sr_{0.33}MnO_3$ polycrystalline films whereas study on the artificial grain boundaries in CMR films shows non-linear I–V characteristics [14,21–23]. The effect of strain due to substrate-lattice mismatch on transport properties of epitaxial films of doped rare earth manganites has also been investigated recently [24–28], where it has been

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envisaged that strain leads to a complex interaction between defect and transport properties of manganite films. It has been suggested that transport phenomena and mechanism dealing it exceedingly affected by grain boundary misorientation angle, nature of surfaces and interfaces. To get more insight into the effect of substrate on transport properties of polycrystalline films, we have studied the conductance and conduction noise of polycrystalline $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ films deposited on two different substrates $LaAlO_3$ and Al_2O_3. It is found that conductance and conduction noise behavior of the two films are very different and the dominant transport mechanism in one case is spin dependent scattering whereas in the other case it is spin polarized tunnelling.

2. Experimental details

Polycrystalline films of $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ (LCBMO) were prepared on $LaAlO_3$ (cubic, 100, $a = 3.821$ Å) and Al_2O_3 (hexagonal, $10\bar{1}0$, $a = 4.758$ Å) single crystal substrates by spray pyrolysis technique. The spray solution was prepared by dissolving 3N pure nitrates of La, Ca, Ba and Mn in double distilled water in the cationic ratio La/Ca/Ba/Mn = 0.7/0.2/0.1/1. The solution was sprayed on the substrates, which was maintained at 300 °C. These as deposited films were post annealed in air at 900 °C for 30 min. X-Ray diffraction (XRD) studies revealed that the films are single phase and polycrystalline in nature. The lattice parameter for the $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ film on $LaAlO_3$ substrate were $a =$ 5.479 Å, $b = 5.47$ Å, $c = 7.804$ Å, whereas for the film on Al_2O_3 substrate $a = 5.48$ Å, $b = 5.433$ Å, $c = 7.786$ Å. AC susceptibility of the films were measured using a lock in amplifier at 415 Hz. Temperature dependence of resistance and I–V characteristics of the films were measured using standard four-probe technique. A 200 μm wide microbridge was patterned on the film for the I–V characteristics and conduction noise studies. Dynamic conductance vs bias voltage (G–V) curves of the films were obtained numerically from the I–V data. Conduction noise of the films was also measured using four-probe technique. A 5 μA current was passed through the film using a battery operated low noise current source. The voltage signal was dc filtered and amplified by a low noise amplifier and measured by a dynamic signal analyzer for observing the frequency spectrum.

3. Results and discussion

Fig. 1(a) and (b) shows scanning electron micrograph (SEM) of the $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ film on $LaAlO_3$ and Al_2O_3 substrates respectively. The grain sizes of the film on two substrates were found to be different. The grain size for the film on $LaAlO_3$ and Al_2O_3 substrates are ∼150 nm and ∼100 nm respectively. The relatively smaller grain size in the $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ film on Al_2O_3 substrate shows that it has high density of grain boundary as compared to similar film on $LaAlO_3$ substrate. Fig. 2 shows the temperature dependence of ac susceptibility (χ') of the films on $LaAlO_3$ and Al_2O_3 substrates. The ferromagnetic transition temperatures of

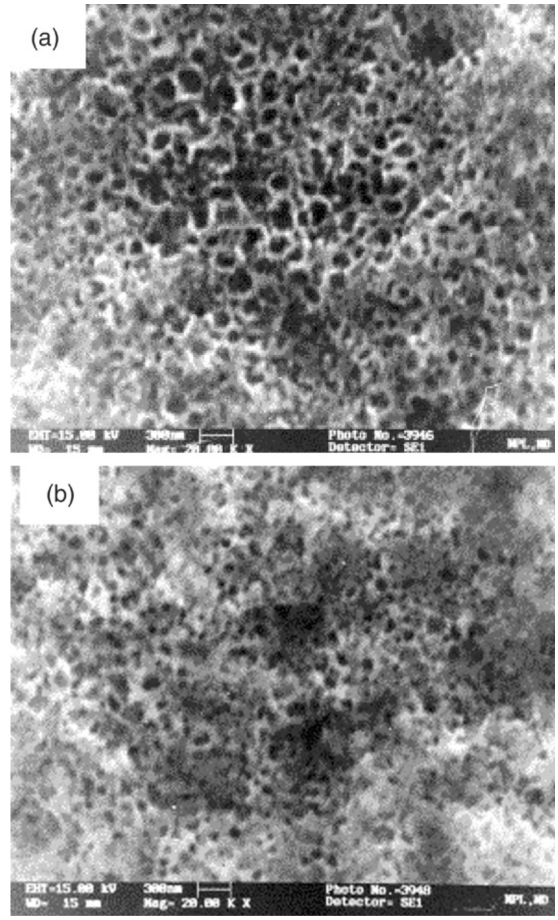

Fig. 1. SEM micrograph of polycrystalline $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ film on (a) $LaAlO_3$ and (b) Al_2O_3 substrates.

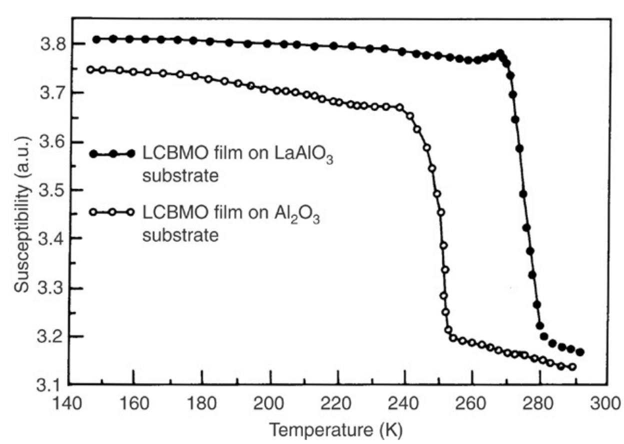

Fig. 2. Temperature dependent susceptibility for $La_{0.7}Ca_{0.2}Ba_{0.1}MnO_3$ films deposited on $LaAlO_3$ and Al_2O_3 substrates.

∼283 K and ∼253 K was obtained for the films on $LaAlO_3$ and Al_2O_3 substrates respectively. Temperature dependent resistance measurements showed that the film on Al_2O_3 was more resistive (one order higher) as compared to the film on $LaAlO_3$. The insulator to metal transition temperature were found to be 253 K and 160 K for the film on $LaAlO_3$ and Al_2O_3 substrate respectively. The observed difference in resistivity