Fabrication and magneto-transport properties of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films

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Abstract

We have grown $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films by a pulsed laser deposition technique on MgO(100) substrates, which we expect a strain free growth, and measured the magneto-transport properties. The films were *a*-axis oriented according to the x-ray diffraction patterns. Magneto-transport properties of the films showed similar features with that of single crystals.

Key words: layered perovskite manganite; colossal magneto-resistance; thin films; tunneling magneto-resistance

Perovskite type manganites have renewed their interest since the discovery of a large magneto-resistance (MR) effect observed near the Curie temperature, so called colossal magneto-resistance (CMR) effect [1]. CMR effect brings out several orders of change in resistivity. However, for the realization of CMR effect, a tesla order of high magnetic field is necessary. At present, several approaches are being examined on how to achieve a low field CMR. One example is to use the tunneling magneto-resistance (TMR) effect observed in a layered perovskite $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) [2,3]. Another example is to use it in a form of thin films where spin dependent transport between grain boundaries gives rise to a low field MR at low temperature [4,5]. From these points, fabrication of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films could be one of the methods for achieving low field CMR. There have been some reports on fabrication of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ thin films on $SrTiO_3$ substrates in compositions of $x = 0.3$ [6] and 0.4 [6,7]. It is well known that physical properties of manganite thin films change dramatically due to the lattice mismatch with the substrates [8]. Therefore, substrate with little mismatch as $SrTiO_3$ or $LaAlO_3$ is usually used. In the recent report on the fabrication of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films on $SrTiO_3$ substrates by Philipp et al. [6], magneto-transport properties of the films showed considerably different features compared to the ones observed in single crystals [2], perhaps due to the substrate striction. In this study, we have grown $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films by a pulsed laser deposition technique on MgO(100) substrates, which we expect a *strain free growth*, and measured the magneto-transport properties.

$La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films were fabricated by a pulsed laser deposition technique on MgO(100) substrates. Substrate temperatures and oxygen pressures (P_{O_2}) were changed 800–1140°C and 2–100 Pa, respectively. After the deposition, x-ray diffraction (XRD) patterns and magneto-transport properties of the films were measured. All samples showed (h00) peaks in XRD patterns. The lattice constant of the films fabricated below 900°C were estimated to be 3.9–3.97 Å. The lattice constant of the films fabricated above 900°C were estimated to be 3.85–3.89 Å, which is nearly consistent with the *a*-axis value of the single crystal (3.86 Å) [2].Temperature dependence of resistance R ($R - T$) was measured by a conventional four-probe method. Measurements of magnetization M as a function of temperature ($M - T$) and magnetic field H ($M - H$) were performed by a

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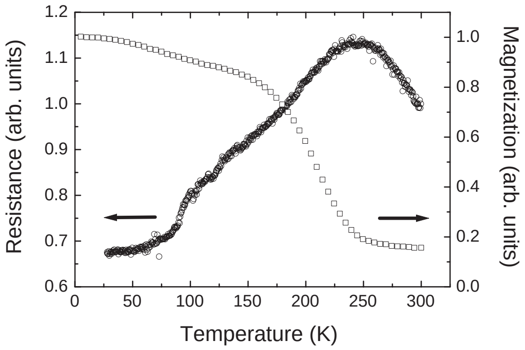

Fig. 1. Temperature dependence of resistance (open circles) and magnetization (open squares) of the film fabricated under $T = 900°$C, $P_{O_2} = 30$ Pa. The respective data was normalized by the value at room temperature for resistance, and at 5 K for magnetization.

SQUID magnetometor with H parallel to the film.

Figure 1 shows the R–T and the M–T curves of a sample deposited at 900°C under $P_{O_2} = 30$ Pa condition. The M–T curve is taken from a field cooling run under 50 Oe. The R–T curve showed insulator–metal (I–M) transition near 250 K. When the temperature was further decreased, a steep drop in resistance was seen near 100 K. As in the case of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) thin films fabricated on $SrTiO_3$ substrates by Philipp et al., no metallic behavior appeared in the R–T curve. As compared to the results by Philipp et al., our reault on a MgO substrate fairly agrees to the temperature dependence of resistivity of the ab plane in single crystals reported by Kimura et al. [2]. As clearly seen in the M–T curve of Fig. 1, magnetization rise was seen near 250 K corresponding with I–M transition. Hysteresis was observed below I–M transition temperature (T_C) in the M–H measurements. These results suggest paramagnetic insulator to ferromagnetic metal transition is taking place near 250 K. Temperature dependence of coercive force was measured by taking M–H curves at variable temperatures. Coercive force was definable in the vicinity of T_C and it increased as the temperature decreased. Coercive force was estimated to be near 250 Oe at 30 K. The coercivity measurement indicates the formation of small grains and the existance of a low field MR. Actually, several percent of MR was observed around T_C under H of 100 Oe which was induced parallel and perpendicular to the film, respsctively.

Films fabricated below 900°C showed insulating behavior in R–T curve and I–M transition did not occur in all temperature region. In these samples, no magnetization was observed even under H of 1 T. On the other hand, films deposited in 900–1040°C conditions showed I–M transition near 230–270 K (see, Fig. 1). These samples showed significant magnetization even under H of 5 Oe. Therefore, the latter temperature conditions are indispensable for obtaining the films which have similar magneto-transport properties with that of single crystals.

We have fabricated a-axis oriented thin films of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.3$) on MgO(100) substrates under suitable growth conditions of 900–1100°C for substrate temperatures, and 2.5–60 Pa for oxygen pressures. Pulsed laser deposition apparatus was used for the fabrication. Magneto-transport properties and the lattice constant estimated from the XRD patterns were fairly consistent with the ones reported on single crystals. The results suggest that the films fabricated under suitable conditions have grown strain free on MgO substrates. Several percent of low field (100 Oe) MR was also observed in the film. Measurements of further detailed charactristics such as low-energy charge dynamics are now in progress.

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