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Colossal Magnetoresistance of La-Ca-Mn-O Films

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Abstract. We have investigated the magnetoresistance and magnetization of the thin films of $\text{LaCa}_{0.25}\text{Mn}_{1.2}\text{O}_{3+\delta}$. The films were prepared by rf-sputtering at 650°C on single crystal $\text{LaAlO}_3(100)$, $\text{MgO}(100)$ and rough MgO surfaces, with a thickness of 480 nm, and they were thermally treated at 1050°C. The dependence of the magnetoresistance on the grown conditions such as substrate materials and the surface roughness of the substrate was examined. The significant magnetoresistance appeared at different temperatures when the film epitaxy changed.

1. Introduction

Calcium doped lanthanum manganite ($\text{La}_{1-x}\text{Ca}_x\text{MnO}_3$) shows a large magnetoresistance. This material is expected to be applied for various magnetic devices. The large magnetoresistance of the thin film occur near the temperature where as metal-semiconductor transition takes place. The transition temperature is strongly dependent on the deposition conditions of the film. We have investigated the influence of substrate conditions on the magnetic and electric properties of the films.

2. Experimental

La-Ca-Mn-O films ($a_0=3.85\text{\AA}$) were deposited by rf sputtering at 650°C on $\text{MgO}(100)$ ($a_0=4.20\text{\AA}$) single crystal substrates, and on MgO rough surface substrates which were ground with a diamond paste of #1200. The sputtering conditions are given in Table 1. The size of the films was $4\times 7\text{mm}$ and thickness was 480nm. The deposited films were thermally treated at 1050°C in air for 5h. The resistance of the films was measured by 2 point method with a direct current of about 100 μA and a magnetic field of 9kOe in the temperature range from 77K to room temperature. Magnetization was measured in a field of 0.5kOe or 8kOe with a high sensitivity VSM in the same temperature range. The MR ratio is defined as $\Delta R/R_H$ where $\Delta R=(R_H-R_0)$ and R_H is the resistance at an applied magnetic field of 9kOe, and R_0 is the resistance without magnetic field. The thickness of the films was measured using a surface step analyzer (DEKTAK³ST). The chemical composition of the films was determined by inductively coupled plasma spectroscopy. The surface of substrate was observed with a SEM. The films were examined by X-ray diffraction.

Table 1. Sputtering conditions.

Target	$\text{La}_{0.67}\text{Ca}_{0.33}\text{MnO}_3$
Sputter gas	Ar:O ₂ =3:2
Base pressure	$1.1\times 10^{-3}\text{Pa}$
Sputter pressure	8.0Pa
Substrate	$\text{LaAlO}_3(100)$ $\text{MgO}(100)$ MgO rough
Substrate temperature	650°C
Input power	$2.5\text{W}/\text{cm}^2$

Table 2. Preparation conditions of sample films

Sample No	Film composition	Substrate	Thermal treatment temperature	Film thickness
1	$\text{La}_{1.0}\text{Ca}_{0.25}\text{Mn}_{1.2}\text{O}_{3+\delta}$	$\text{LaAlO}_3(100)$	1050°C	480nm
2	$\text{La}_{1.0}\text{Ca}_{0.25}\text{Mn}_{1.2}\text{O}_{3+\delta}$	$\text{MgO}(100)$	1050°C	480nm
3	$\text{La}_{1.0}\text{Ca}_{0.25}\text{Mn}_{1.2}\text{O}_{3+\delta}$	$\text{MgO}(100)$ mat	1050°C	480nm

3. Results and Discussion

Table 2 shows the film compositions, substrates and temperatures of thermal treatment. The film compositions are normalized by lanthanum contents. Figures 2-4 show the MR ratio $\Delta R/R_H$ (%), magnetization M measured in a field of 0.5kOe and resistivity ρ of the films. The metal-semiconductor transition is observed in Samples 1 and 2, and substantial magnetoresistance appears in the metallic conduction region near the transition temperature. The MR ratio is about -20%. A larger MR ratio of -175% ($\rho_0 = 11.9 \Omega \text{ cm}$, $\rho_H = 32.7 \Omega \text{ cm}$) was observed at 9kOe at 108K with an LCMO film which was deposited on MgO(100) with the composition of $\text{La}_{1.0}\text{Ca}_{0.35}\text{Mn}_{1.1}\text{O}_{3.8}$. The magnetoresistance appeared only in the films which show the metal-semiconductor transition. Above the transition temperature, a linear relation was obtained between $\log \sigma$ and $1/T$, where σ is the conductivity of the films and T is temperature.

The magnetization reduces with temperature in all the samples. The temperature of the metal-semiconductor transition corresponds considerably to the temperature at which the magnetization disappears in Samples 1 and 2. The magnetization curve of Sample 1 have a shoulder at about 240K. In Sample 1 the ρ - T curve is sharp and the magnetization disappears at the transition temperature. Samples 1 and 2 are different in substrate material. There is a difference in lattice mismatch between film and substrate. The temperature range where the magnetoresistance appears is wider in Sample 2 than in Sample 1. It is expected that the larger lattice mismatch brings about the magnetoresistance in the wider temperature range.

Samples 2 and 3 are different in the roughness of the substrate surface. The roughness of the substrate of Sample 3, which was measured with a SEM, was about 100nm. Sample 3 shows neither metal-semiconductor transition nor magnetoresistance. The resistivity of Sample 3 at room temperature is 20 times as large as that of Sample 2. The resistivity of Sample 3 increases sharply below 150K. The temperature dependence of magnetization in Sample 3 does not differ from that in Sample 2.

In conclusion, we consider that the CMR of thin films strongly depends on the surface structure of the substrate.

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Fig.1. X-ray diffraction patterns of the LCMO films grown on different substrates.

Fig.3. $\Delta R/R_H$, ρ and M vs. temperature for $\text{La}_{1.0}\text{Ca}_{0.25}\text{Mn}_{1.15}\text{O}_{3.8}$ film deposited on $\text{MgO}(100)$, $H=9\text{kOe}$.

Fig.2. $\Delta R/R_H$, ρ and M vs. temperature for $\text{La}_{1.0}\text{Ca}_{0.25}\text{Mn}_{1.15}\text{O}_{3.8}$ film deposited on $\text{LaAlO}_3(100)$, $H=9\text{kOe}$.

Fig.4. $\Delta R/R_H$, ρ and M vs. temperature for $\text{La}_{1.0}\text{Ca}_{0.25}\text{Mn}_{1.15}\text{O}_{3.8}$ film deposited on MgO rough, $H=9\text{kOe}$.

Reference

- 1) S. Jin, T. H. Tiefel, M. McCormack, R. A. Fastnacht, R. Ramesh, L. H. Chen, Science 264, 413-415 (1994)
- 2) M. Kitagawa and Y. Yamazaki, J. Magn. Soc. Jpn., in press