Transport and Magnetic properties of the micro-fabricated perovskite-type manganese oxides

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Abstract

We studied the resistivity under pulsed high electric field for thin films and micro-meter sized wires of perovskite-type manganese oxide, $Pr_{0.65}Ca_{0.35}MnO_3$ (PCMO). The thin films were prepared by the pulsed laser deposition (PLD) method. Wires of the oxides were fabricated by the electron-beam lithography and Ar-ion etching methods. By applying a pulsed electric field upto 5×10^5 V/cm with a duration of 10ms, the resistivity of the wire with the size of 10 μm $\times$ 10 μm reduced by 60 % at 150K.

Key words: perovskite ; manganese oxides ; electric field ; insulator-to-metal transition

1. Introduction

Perovskite-type manganese oxides, $R_{1-x}A_xMnO_3$ (R and A being trivalent rare-earth and divalent alkaline-earth ions, respectively) have attracted much attention because of several fascinating properties due to the interplay among the charge, spin and orbital degrees of freedom. It was reported that the electric field induced a switching of resistive state of $Pr_{0.7}Ca_{0.3}MnO_3$ from the charge-ordered (CO) insulator to ferromagnetic metal [1-4]. The electric-field switching phenomena of the manganates might be used as micro-electronics devices. For the practical applications small applying voltage is required to switch the electronic state. In order to reduce the applying voltage and apply an effectively high electric field we prepared samples in the form of narrow wire and made electrodes with a short distance. In this paper, we report the change of the resistance of a micro-meter sized wire of the manganese oxide by applying pulsed electric field.

2. Experiment

The PCMO thin films were prepared on $LaAlO_3$ (100) substrate by a pulsed laser deposition (PLD) method with a KrF excimer laser (λ = 248 nm) operating at 1 Hz and 1 J/cm^2. Polycrystalline $Pr_{0.65}Ca_{0.35}MnO_3$ (PCMO) target was prepared by the conventional solid-state reaction method. A mixture of Pr_6O_{11}, $CaCO_3$, and Mn_3O_4 was sintered finally at 1528 K for 24 hours. The substrate temperature was 973 K and the oxygen pressure in the chamber was 0.1 Torr. After deposition, the film was cooled to room temperature at an oxygen pressure of 400 Torr. The thickness of the film was 100 nm. The XRD measurement confirmed that the thin films were epitaxially grown on the substrate.

The wire of PCMO was fabricated by a lithography process using electron-beam patterning and Ar ion beam etching. The contact Ag electrodes was made in a lift-off process using electron-beam lithography. Both of the length and width of the wire were 10 μm. The measurement of current-voltage characteristics was carried out by two probe method because the contact resistance between the wire and electrode was negligibly small as compared with the resistance

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of the wire. The pulsed current was applied by using Keithley constant current source unit.

3. Results and Discussion

Figure 1 shows the temperature dependence of the resistivity for the PCMO thin film. The behavior of the resistivity is comparable to that of $Pr_{0.7}Ca_{0.3}MnO_3$ single crystal, indicating that the film has the bulky quality.

Plotted in Fig. 2 are the pulsed electric field dependence of the resistance for the thin film and wire of PCMO. The measurement was done at 100K and 150 K for the film and wire, respectively. The applied pulse width was 10ms. The size of thin film was 1 mm wide and 4 mm long. As the limit of the voltage is 500 V for our system, maximum electric field is 5×10^3 V/cm for the thin film, while it reaches up to 5×10^5 V/cm for the wire. The decrease of the resistance at the maximum electric field is about 60 % for the wire.The observed decrease of resistance is considered to be due to the melting of pinned CO state by applying electric-field. To confirm depinning mechanism of CO state of PCMO wire measurement of the pulse form and the delay in pulse response is now in progress.

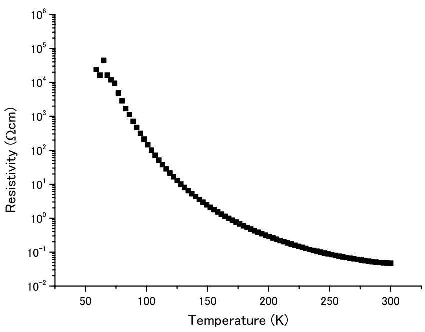

Fig. 1. Temperature dependence of resistivity of a $Pr_{0.65}Ca_{0.35}MnO_3$ thin film. The applied voltage is 1 V and pulse width is 10ms.

4. Conclusion

We have succeeded to apply a significantly high electric field to PCMO by using a sample in the form of narrow wire and observed a large reduction of the resistivity. Further reduction of the size of the wire is needed to investigate the resistive state at high electric field.

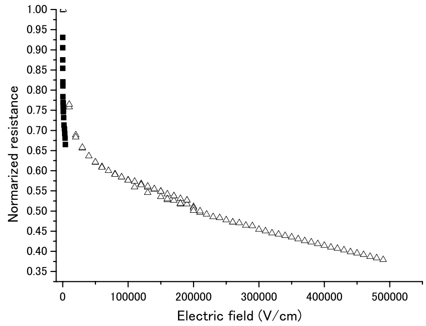

Fig. 2. Electric-field dependence of normalized resistance of a $Pr_{0.65}Ca_{0.35}MnO_3$ thin film (square dots) measured at 100 K and a wire (triangle dots) measured at 150 K. The applied electric pulse width is 10ms.

Acknowledgements

One of the authors Mr. A. Masuno would like to thank Dr. N. Ichikawa for his support.

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