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Epitaxial-strain effect on charge and orbital order in $Pr_{0.5}Ca_{0.5}MnO_3$ films

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Introduction

Half-doped perovskite manganites showing colossal magnetoresistance (CMR) have been extensively studied as a candidate of resistance switching nonvolatile memories. The gigantic responses to various kinds of stimuli, such as magnetic field, electric field, x-ray, light and pressure were observed in CMR manganites [1]. The plausible origin of the CMR effect is that the external stimuli melt the insulating charge and orbital order (CO-OO), and as a result, the metalic state emerges. In this report, we demonstrate another method of phase control, which is the growth orientation dependence of the CO-OO state in the epitaxial film.

Experimental results and Analysis

The target material is a typical CMR manganite $Pr_{0.5}Ca_{0.5}MnO_3$. $Pr_{0.5}Ca_{0.5}MnO_3$ films on [011]- and [001]-oriented substrate (denoted as (011)-film and (001)-film, respectively) were grown by PLD method. The total thickness of the films is about 40 nm. The x-ray diffraction experiments were performed on four-circle diffractometers installed at the beamline 3A and 4C. The energy of incident x-ray was tuned near 9.5 keV. In Figs. 1 (a) and (b), the schematic views on the relation between the film with pusedo-cubic symmetry and the LSAT substrate are shown. The stripe-type CO-OO is realized on these films. The blue lobes and red circles indicate the shematic e_g-orbital in Mn^{3+} and Mn^{4+} ion, respectively. In (001)-film, both of the *a*- and *b*-lattice constants are locked to those of substrate. In contrast, *a*-lattice constant and [01-1] axis are locked in the (011)-film, while *b*, *c*, and the angle between them have some freedom.

Figs. 1 (c) and (d) show the temperature dependences of resistivity in (011)- and (001)-film, respectively. The (011)-film shows a clear anomaly in zero field, similarly to the bulk behavior. In contrast, the (001)-film does not show the anomaly. Furthermore, the response to the magnetic field is quite different. The (011)-film show the CMR effect at 14 Tesla, although little change is observed in (001)-film. The origin of the difference of resistivity data is clarified from x-ray diffraction experiment. The superlattice (1/4 7/4 2) reflection was observed in both films, which indicate the emergence of the CO-OO, as shown in Figs. 1 (e) and (f). The superlattice reflection in (011)-film begins to grow at 220 K in accord with the anomaly in resistivity. In contrast, the intensity of the superlattice reflection in (001)-film subsists at higher temperature than that of (011)-film and bulk sample, and finally disappears near room temperature. This difference can be also shown in the temperature dependence of lattice constants in Figs. 1 (g) and (h). In the (011)-film, the nature of elongated *b*- and shortened *c*-lattice constant is similar to the bulk behavior, in contrast to no anomaly and reduced *c*-lattice constant in (001)-film. In this manner, the growth orientation highly affects the CO-OO state. Detailed information is reported in ref. [2].

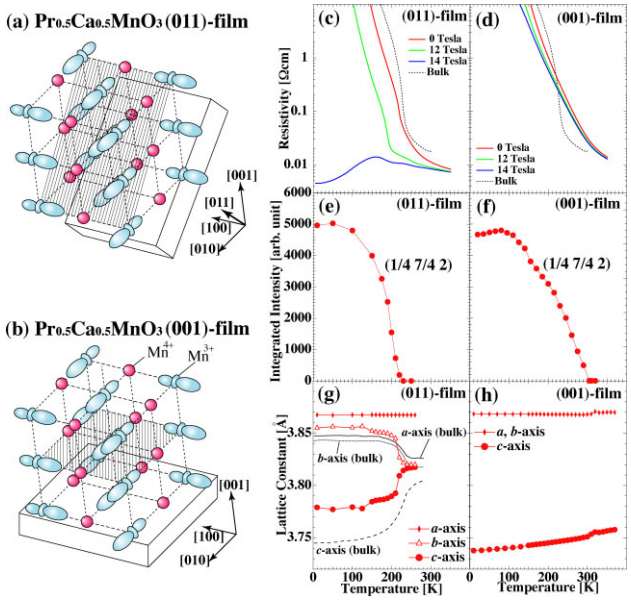

Fig. 1: Schematic views of PCMO film and LSAT substrate in (a) (011)- and (b) (001)-film, respectively. (c,d) The resistivity data of both films. (e,f) The (1/4 7/4 2) reflection due to the CO-OO. (g,h) The temperature dependences of lattice constant.

References

[1] Y. Tokura, Rep. Prog. Phys. **69**, 797 (2006).
[2] D. Okuyama et al., Appl. Phys. Lett. **95**, 152502 (2009).

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