**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 metallic 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 pseudo-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 schematic $e_g$-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 state.

References

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