Structural and electronic phase transition in a metal-insulator manganite superlattice

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Phase competition between the ferromagnetic-metallic (FM-M) state and the charge/orbital ordered insulating (COO-I) state is an essential ingredient of the colossal magnetoresistance in perovskite manganites. Recently it was found that these two contrastive phases can be reproduced even in the thin-film form by using (011) surface of perovskite substrates [1][2]. This finding opened up the thin-film-specific new approaches to the control of the phase competition, such as the anisotropic stress imposed by the epitaxial strain [3][4], combinatorial method [5] and artificial superstructures [6]. Here we demonstrated that the superstructures composed of nanoscale FM-M and COO-I layers can be a novel host of the phase competing state[6].

A superlattice composed of 5 layer $La_{0.5}Sr_{0.5}MnO_3$ (FM-M) and 5 layer $Pr_{0.5}Ca_{0.5}MnO_3$ (COO-I) was grown on LSAT(011) substrate. The superlattice first became FM-M at 240 K and succesively turned into the COO-I state at 180 K with a large thermal hysteresis, supporting the senario of phase coexistence and their competition in the superlattice. We further confirmed the existence of both COO-I and FM-M phases by synchrotron X-ray diffraction and infra-red (IR) optical conductivity. The synchrotron X-ray diffraction clarified the 4-fold periodicity associated with the charge/orbital ordering, while the IR optical conductivity showed a gap-less feature even in the insulating ground state. These results indicate that the two phases are coexisting in the superlattice and the phase domain boundaries are locating near the chemical composition boundaries.

Magnetic-field dependence of the resistivity and magnetization after field cooling shows a relaxor-like behavior. This indicates that the phase domain boundaries are stable at low temperatures and their positions are tunable by a magnetic field.

[1] M. Nakamura *et al.*, Appl. Phys. Lett. **86**, 182504 (2005).
[2] Y. Ogimoto *et al.*, Phys. Rev. B **71**, 060403(R) (2005).
[3] D. Okuyama *et al.*, Appl. Phys. Lett., **95**, 152502 (2009) .
[4] K. Lai and M. N. *et al*., Science **329**, 190 (2010).
[5] J. S. Lee *et al*. Phys. Rev. B **82**, 052406 (2010).
[6] M. Nakamura *et al*., Adv. Mater. **22**, 500 (2010).

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