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Competing electronic orders in a composition-spread $(Pr_{0.6}Ca_{0.4})_{1-y}(La_{0.6}Sr_{0.4})_yMnO_3$ thin film

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Introduction

The state-of-the-art thin-film technology enables us to realize the composition dependent phase transition from insulator to metal. In the vicinity of the critical area between insulator and metal in a composition spread manganite film, we have found a new insulator state, which is not observed in the bulk materials.

Experimental results and Discussion

The composition-spread film of $(Pr_{0.6}Ca_{0.4})_{1-y}(La_{0.6}Sr_{0.4})_yMnO_3$ on $(LaAlO_3)_{0.3}(SrAl_{0.5}Ta_{0.5}O_3)_{0.7}$ (011) substrate. We can control the electronic state from insulator to metal by changing the y (content of $La_{0.6}Sr_{0.4}$) composition, as shown in Fig. 1 (a). The well-defined phase boundary between insulator and metal around y=0.14 was established by infrared spectroscopy. In the insulator region, a difference in the spectral weight of the infrared spectra between polarizations is clearly observed along [1 0 0] and [0 1 –1] in the pseudo-cubic setting. Especially, for $0.04 < y < 0.14$, the compound show strong optical anisotropy (See Fig. 1 (b)). To understand the insulating state and the origin of the optical anisotropy, we performed synchrotron x-ray diffraction experiment to investigate the structural properties.

Fig. 1 (c) shows the composition dependence of a superlattice reflection of (1/4 7/4 2) at 57 K, which has been observed for $Pr_{0.5}Ca_{0.5}MnO_3$ thin film and related to the stripe-type charge and orbital order as shown in Fig. 1 (e) [1]. The composition dependence of the lattice constant was also measured (Fig.1 (d)). In the vicinity of y=0, the lattice constants a, b, c satisfy the relation $a > b > c$. This is also consistent with that of $Pr_{0.5}Ca_{0.5}MnO_3$ thin film [1]. However, for $0.04 < y < 0.14$, the superlattice reflections (1/4 7/4 2) and other superlattice and forbidden reflection accompanied by the phase transition are not observed. Further, the difference between the lattice constant b and c becomes smaller. From these experimental results, we concluded that the orbital directional order as shown in Fig. 1 (f) maybe take place at low tempearture.

The experimental results of x-ray diffraction and infrared spectroscopy studies evidently indicated the presence of a hidden orbital ordered state between stripe-type charge and orbital ordering insulator and the metallic phases. Detailed information is found in ref. [2].

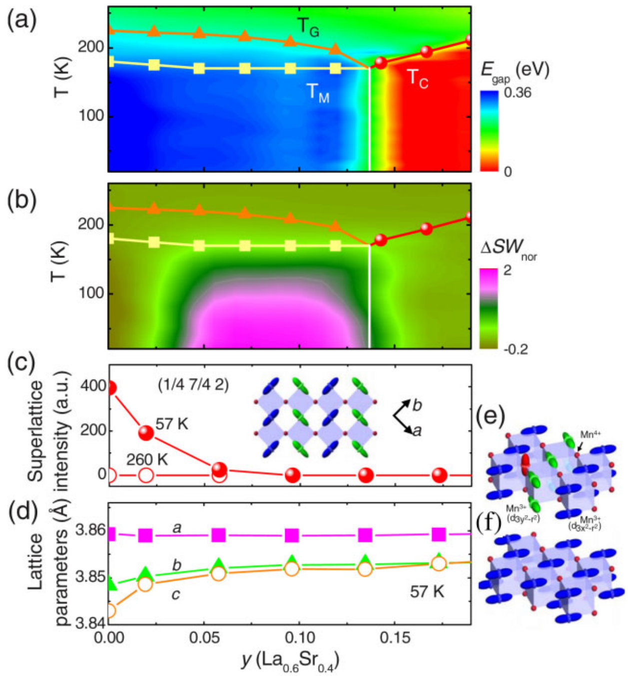

Fig. 1: (a) The phase diagram of $(Pr_{0.6}Ca_{0.4})_{1-y}(La_{0.6}Sr_{0.4})_yMnO_3$ determined by the charge gap from the infrared spectrum. Blue and red regions indicate the insulator and metallic phases, respectively. (b) The phase diagram of a difference in the spectral weight. (c, d) The composition dependences of the intensity of (1/4 7/4 2) superlattice reflection (c) and the lattice constants (d). (e, f) Schematic views of the charge and orbital states for $y < 0.04$ (e) and for $0.04 < y < 0.14$ (f).

References

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