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In situ synchrotron-radiation photoemission spectroscopic study of strain-controlled $La_{0.6}Sr_{0.4}MnO_3$ thin films

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Introduction

Hole-doped perovskite manganese oxides $La_{1-x}Sr_xMnO_3$ (LSMO) have attracted much attention because of their interesting magnetic and electronic properties such as colossal magnetoresistance, half-metallicity, and metal-insulator transition. The extensive studies have demonstrated that the physical properties of these manganese oxides can be controlled by epitaxial strain.[1] However, little is known on the effects of epitaxial strain on the electronic structure of these films. In this study, we report *in situ* photoemission (PES) study of LSMO (x = 0.4) thin films deposited on $LaAlO_3$ (LAO) with lattice mismatch of – 2 %, $(LaAlO_3)_{0.3}$-$(SrAl_{0.5}Ta_{0.5}O_3)_{0.7}$ (LSAT) with that of ± 0 %, and $SrTiO_3$ (STO) with that of + 1 % substrates to investigate the changes in the electronic structure of LSMO thin films.

Experimental

The strain-controlled LSMO (x = 0.4) has been epitaxially grown on LAO, LSAT, and STO substrates in a laser MBE chamber connected to a synchrotron radiation PES system at BL2C of the Photon Factory.[2] The film thickness was estimated to be 40 nm by monitoring the intensity of the specular spot in reflection high-energy electron diffraction (RHEED) patterns. The coherent growth of these films was confirmed by the four-circle X-ray diffraction measurements. The PES spectra were taken *in situ* with a total energy resolution of 150 meV in the photon energy range of 600-700 eV.

Results and Discussion

Figure 1 shows the valence band photoemission spectra of LSMO thin films under different epitaxial strain from different substrates, where LSMO/STO and LSMO/LSAT are ferromagnetic metal, while LSMO/LAO is antiferromagnetic insulator. The valence band spectra consist of four main structures labelled as A, B, C, and D. From the band structure calculation[3], the two prominent structures A and B are assigned to O 2p states, while a shoulder structure C and a broad hump structure D closest to the Fermi level (E_F) are assigned to Mn 3d t_{2g} and e_g states, respectively. At the first glance, the overall valence band structure does not seem to change with epitaxial strain. However, closer look reveals that the peak position of the e_g state shifts to the higher binding energy side by 100 meV from LSMO/LSAT (strain free) to LSMO/LAO (compressive strain). The shift of e_g state is more clearly seen in the expansion near E_F (inset). The energy shift of e_g state in LSMO/LAO is explained by the energy splitting of degenerated e_g state to $d(x^2\text{-}y^2)$ and $d(3z^2\text{-}r^2)$ states due to the Jahn-Teller distortion induced by the compressive epitaxial strain.[3] The results suggest that the resultant formation of energy gap at E_F is responsible for the strain-induced metal-insulator transition in the strain-controlled LSMO.

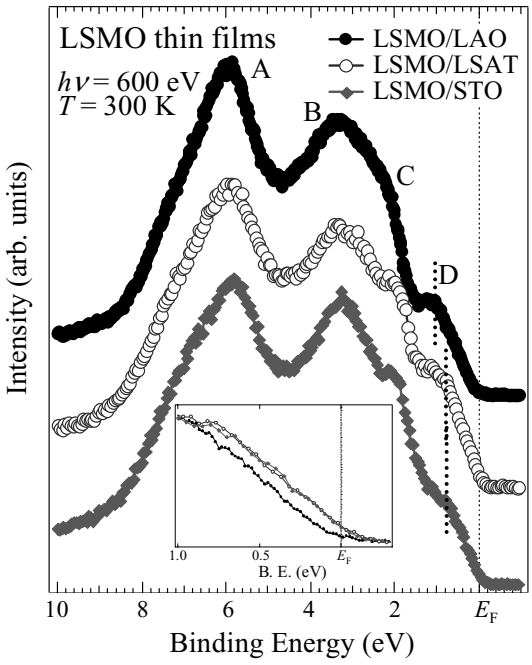

Fig. 1: The valence band spectra of LSMO thin films on various substrates. Inset shows the spectra near E_F.

References

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