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Thickness dependence of the x-ray magnetic circular dichroism of $La_{0.6}Sr_{0.4}MnO_3$ thin films

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Introduction

Perovskite manganese oxides show various phase transitions such as metal-to-insulator transition (MIT) and ferromagnetic-to-antiferromagnetic transition as functions of temperature, magnetic field, hole concentration and strain etc. Among them, $La_{1-x}Sr_xMnO_3$ shows large magnetoresistance and half metallicity, and has been widely investigated because of its potential application to spintronics devices. Recently, Yoshimatsu *et al*. [1] have found that, in an $SrTiO_3$ (STO)/ $La_{0.6}Sr_{0.4}MnO_3$ (LSMO)/STO heterostructure, when the LSMO layer thickness is reduced, an MIT and the disappearance of the ferromagnetism occur. They ascribed these thickness-dependent transitions to the formation of 'dead layers' between STO and LSMO. However, this hypothesis has not been verified directly.

In this study, we have performed x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) measurements of the STO/LSMO/STO heterostructures. We discuss the origin of the thickness-dependent phase transition of the LSMO thin films.

Experimental condition

STO/LSMO/STO heterostructure samples were grown by the molecular beam epitaxy method. The thickness of the LSMO layer was varied from 2 monolayer (ML) to 50 ML. The STO substrate was doped with Nb to prevent charging effect. Between the LSMO layer of n ML thickness and the top STO layer (2 ML), a layer of $La_{0.6}Sr_{0.4}TiO_3$ was inserted to avoid excess hole doping [1]. After deposition, the samples were annealed in an O_2 atmosphere of 1 atm for 45 minutes to remove oxygen deficiencies. The XAS and XMCD spectra were taken at BL-16A2, using the surface-sensitive total electron (TEY) yield mode. The magnitude of the magnetic field was varied from 0.1 T to 3 T, and the field was applied perpendicular to the sample surface. The sample temperature is set at 20 K.

Results and discussion

Figures 1(a) and 1(b) show the Mn 2*p*-3*d* XAS and XMCD spectra of LSMO films of the various thicknesses, respectively. The XMCD intensity decreases with decreasing film thickness, consistent with the previous

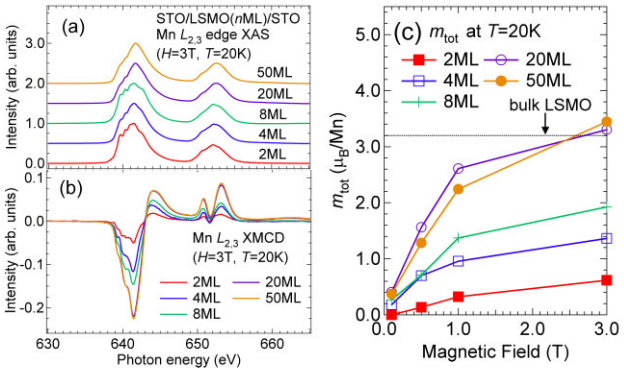

Fig. 1. Mn 2*p*-3*d* (a) XAS and (b) XMCD spectra of the STO/LSMO/STO heterostructures for various LSMO thicknesses. (c) Magnetization curves estimated using the XMCD sum rules.

SQUID measurements [1]. On the other hand, the XAS spectra in Fig. 1(a) show no clear thickness dependences. This indicates that the valence state of the manganese ions did not change when the LSMO film thickness is reduced, and that the reduced magnetization is not due to charge transfer.

Fig. 1(c) shows the magnetic-field dependence of the magnetic moment of Mn ions estimated using the XMCD sum rules [2]. The value for bulk LSMO [3] is also shown. As the film thickness decreases, the magnetic state changes from ferromagnetic to paramagnetic. The important point is that the magnetic moment of the 50ML sample is almost the same as that of the bulk. Considering that the TEY mode is surface sensitive, this indicates that there is no magnetically dead layer at the top STO/LSMO interface. From these observations, it turns out that the decrease of magnetization is due to the ferromagnetic-to-paramagnetic phase transition of entire the sample.

References

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