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X-ray Magnetic Circular Dichroism Study of $SrRuO_3$ Thin Films Grown on $SrTiO_3$(001) Substrates

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1 Introduction

Ferromagnetic metal $SrRuO_3$ (SRO) is a promising material for oxide electronic devices because of its chemical stability and perovskite-type crystal structure. It is commonly known that the electronic and magnetic properties of epitaxially gown thin films are sensitive to the film thickness. In particular, resistivity generally increases with decreasing film thickness.

Recently, Toyota *et al.* [1] reported transport and photoemission studies of SRO thin films epitaxially grown on Nb-doped $SrTiO_3$ (Nb:$SrTiO_3$) substrates, and indicated that below 4-5 ML thickness, the SRO films show a transition from a metal to an insulator. Mahadevan *et al.* [2] reported a density functional theory calculation that SRO film shows a transition from a ferromagnetic metal to an antiferromagnetic insulator below the thickness of 4 ML. Xia *et al.* [3] performed a magneto-optical Kerr effect measurement of SRO thin films and observed a transition from a ferromagnet to non-ferromagnet below 4 ML.

2 Experiment

SRO thin films were fabricated on TiO_2-terminated Nb:$SrTiO_3$ substrates by the laser molecular beam epitaxy (MBE) method. The thickness of thin films were 2, 3, 4, 5, and 50 ML as determined by reflection high energy electron diffraction (RHEED) oscillation. Crystallographic properties examination by atomic force microscopy showed a step-and-terrace structure and well-ordered surfaces. According to photoemission measurements, the sample shows a metal-insulator transition between 3 and 4 ML. XMCD spectra were taken in the total electron yield mode at 20.0 K under magnetic fileds of 0.1-8.0 T applied perpendicular to the film surface. XMCD measurements were performed at BL16A of PF and at BL23SU of SPring-8.

3 Results and Discussion

The magnetic-field dependence of the orbital magnetic moment m_{orb} and the spin magnetic moment m_{spin} obtained using the orbital and spin sum rules are shown in Fig. 1. The figure shows that a ferromagnetic behavior is observed in samples with thicknesses larger than 4 ML and that non-magnetic behavior is observed in samples with the thickness less than 3 ML. Comparing the m_{orb}/m_{spin} values of the ferromagnetic 4 ML and 50 ML films with that of ferromagnetic bulk crystals [4], the value of m_{orb}/m_{spin} is larger in films than in the bulk. This fact would arises from the epitaxial strain from the Nb:$SrTiO_3$ substrates and the finite spin-orbit interaction of the Ru 4*d* electrons as in the case of Ru-doped $La_{1/6}Sr_{0.4}MnO_3$ thin films grown on $SrTiO_3$ substrates [5]. The SRO films fabricated on Nb:$SrTiO_3$ feel an in-plane (ab-plane) compressive strain from the substrate Nb:$SrTiO_3$, and the strain splits the degenerate t_{2g} levels.

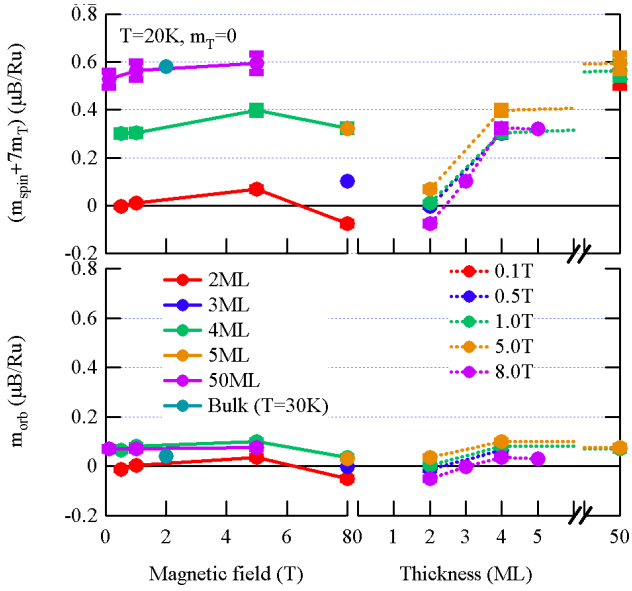

Fig. 1: Thickness and magnetic-field dependences of the spin magnetic moment (m_{spin}) and the orbital magnetic moment (m_{orb}), of $SrRuO_3$/Nb:$SrTiO_3$. The electron occupation number n_{4d} is assumed to be 4.

References

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