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X-ray Magnetic Circular Dichroism of $SrRuO_3$(xML)/Nb:SrTiO3 Thin Films

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1 Introduction

Ferromagnetic metal $SrRuO_3$ (SRO) is a promising material for oxide electronic devices in terms of chemical stabilization and perovskite-type crystal structure. It is commonly known that electronic and magnetic properties of epitaxial gown thin films are sensitive to thickness, which show larger resistivity compared with bulk state by making film thickness thinner. This phenomenon is considered that interface between substrate and film and/or structural defect influence with state of films.

In these days, Toyota et al. reported conductance and X-ray photoemission result of epitaxial grown SRO on Nb dopped $SrTiO_3$ (Nb:$SrTiO_3$), saying that 4-5ML thickness SRO films shows transition from insulator to metal with increasing film thickness [1]. While, Mahadevan et al. reported density functional theory's (with generalized gradient approximation) calculation result, saying that 8ML thickness SRO shows transition from antiferromagnetic insulator to ferromagnetic metal with increasing thickness [2]. Xia et al. explained the inconsistency of transition thickness according to an antiferromagnetic layer between SRO and Nb:$SrTiO_3$ (an antiferromagnetic surface and a ferromagnetic bulk (AFMS-FMB)) suggested with Magneto-optical Kerr effect measurement[3]. With there works, it was found that SRO thin films shows antiferromagnetic insulator under 4ML, AFMS-FMB metal state upper 4ML and metal-insulator transition occur together with ferromagnetic-antiferromagnetic transition.

However, transition of magnetic state cause by the antiferromagnetic layer (variation of hybridization between ruthenium and oxygen) has never been measured directly yet. The goal of this study is directly measure the magnetic transition of SRO thin films with the antiferromagnetic layer by X-ray Magnetic Circular Dichroism (XMCD) and comparison magnetic structure with electronic one.

2 Experiment

SRO thin film ware fabricated epitaxially on TiO_2-terminated Nb:$SrTiO_3$ substrate by laser Molecular Beam Epitaxy (MBE) method. The thickness of thin films (xML = 4,2ML) examined by Reflection High Energy Electron Diffraction (RHEED) oscillation. Crystallographic properties examination by Atomic Force Microscope shows a step-and-terrace structure and well-ordered surface. Total electron yield XMCD spectra taken at 20.0K under vertically applied 0.1-8.0T external magnetic field with thin film surface. XMCD measurement performed on BL16A at PF and on BL23SU at SPring-8.

3 Results and Discussion

We have measured behaviour of magnetization with changing the thickness of SRO on Nb:$SrTiO_3$. In 4ML case, it shows Ru 3p 1/2 XMCD peak. On the other hands, 2ML thickness SRO doesn't (Fig. 1 (left)). By plotting XMCD ratio for each magnetic field, 2ML won't react with any external magnetic field even 8.0T, on the other hands 4ML shows ferromagnetic behaviour. In critical thickness 4ML case, ferromagnetic and antiferromagnetic states coexist. The coexistence is consistent with the results from first principle calculation.

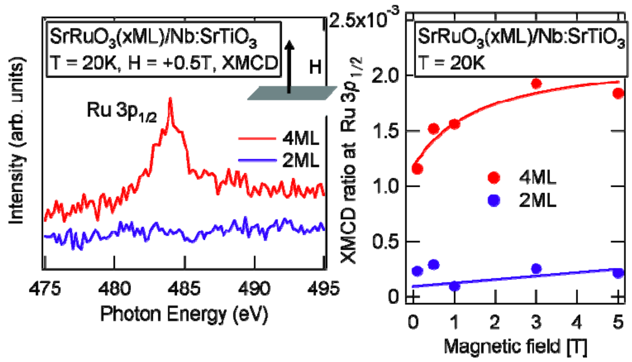

Figure 1: (left) variety of Ru 3p 1/2 XMCD spectra with 2 and 4 ML thickness SRO. (right) XMCD ratio as a function of magnetic field.

References

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