XPS study of epitaxial EuTiO₃ thin films grown by pulsed laser deposition

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Introduction

Divalent europium compounds such as EuX (X=O,S,Se,Te) have been extensively studied due to their interesting magnetic, transport, and magneto-optical properties. Among them, EuTiO₃ (ETO) is a quite unique divalent europium compound because its magnetic properties strongly coupled with dielectric properties. ETO has G-type antiferromagnetic (AFM) structure at Neel temperature of 5.5K, below which dielectric constant drops [1]. By applying magnetic field, antiferromagnetic state to ferromagnetic (FM) state transition takes place and the dielectric constant increases simultaneously [1]. Recent first principle calculation predicted that this magnetodielectric coupling is enhanced divergently by applying biaxial strain, which also favorable for ferroelectric ordering [2]. This suggests that ETO is a promising candidate for multiferroic materials. In epitaxial films, such strains can be introduced by use of lattice mismatch between the film and the substrate.

As the first step toward realizing ETO-base multiferroics, we have fabricated antiferromagnetic EuTiO₃ thin films on SrTiO₃ substrates, which have no lattice mismatch with ETO, and observed AFM-FM transition [3]. However, the saturated magnetization is evaluated to be 5.9μB/Eu, which is slightly smaller than the expected value (7μB/Eu) from ground state of divalent Eu (⁵⁷F₀). In this study, we have performed X-ray photoemission spectroscopy (XPS), and determined valence state of Eu in order to clarify this suppression of magnetic moments.

Experiments

EuTiO₃ (100) thin films were grown on SrTiO₃ (100) substrates by pulsed laser deposition. Typical film thickness was 90nm. The crystallinity and surface morphology of the films were characterized by X-ray diffraction (XRD), in-situ reflection high-energy electron diffraction, and atomic force microscopy. Their magnetic properties were measured using SQUID susceptometer. XPS were measured at the Photon factory BL-7A of KEK.

Results and discussion

The EuTiO₃ film was confirmed to be perovskite structure without any impurity phase by XRD. Figure 1 shows the Eu 4d core level photoemission spectra of the EuTiO₃ thin film taken at hν = 800 eV. Compared with the previous reports on Eu 4d spectra of europium compounds [4,5], the peaks at a binding energy around 125 eV can be assigned as Eu²⁺. In addition to Eu²⁺, Eu³⁺ peaks were observed at a binding energy around 135 eV and 140 eV. These results suggest that the suppression of the saturated magnetic moments in our samples is attributable to the existence of trivalent Eu, which ground state is ⁷F₀ with small magnetic moment derived from Van Vleck paramagnetism.

References

[3] K. Hatabayashi et al., submitted

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