Materials Science

7A/2007G685

XPS study of epitaxial $EuTiO_3$ 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 magnetooptical properties. Among them, $EuTiO_3$ (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 appling 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 appling 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 $EuTiO_3$ thin films on $SrTiO_3$ substrates, which have no lattice mismatch with ETO, and observed AFM-FM transition [3]. However, the saturated magnetization is evaluated to be $5.9\mu_B$/Eu, which is slightly smaller than the expected value ($7\mu_B$/Eu) from ground state of divalent Eu ($^8S_{7/2}$). 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

$EuTiO_3$ (100) thin films were grown on $SrTiO_3$ (100) substrates by pulsed laser deposition. Typical film thickness was 90nm. The crystalinity 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 $EuTiO_3$ film was confirmed to be perovskite structure without any impurity phase by XRD. Figure 1 shows the Eu 4*d* core level photoemission spectra of the $EuTiO_3$ thin film taken at $h\nu$ = 800 eV. Compared with the previous reports on Eu 4*d* spectra of europium compounds [4,5], the peaks at a binding energy around 125 eV can be assigned as Eu^{2+}. In addition to Eu^{2+}, Eu^{3+} 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 $^7F_0$ with small magnetic moment derived from Van Vleck paramagnetism.

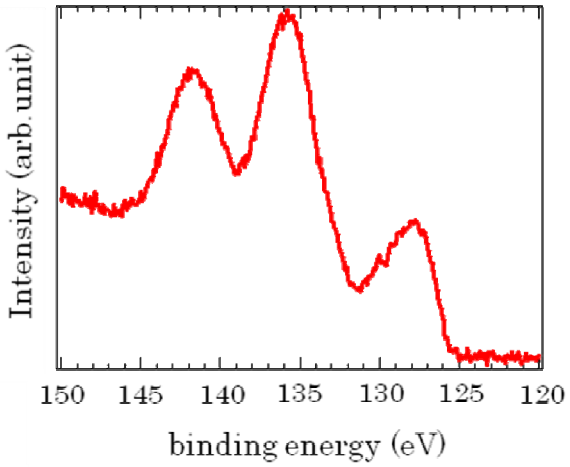

Fig. 1 Eu 4*d* core level photoemission spectrum of the $EuTiO_3$ thin film

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