BL-2A/2016G096

Resonance photoemission spectroscopy study of SmO thin films

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1 Introduction

Rare-earth materials show intriguing physical phenomena such as valence fluctuation, Kondo insulating state, and heavy-fermion behavior. Samarium compounds with mixed valence are attracting renewed interest because some of them are proposed to have topologically non-trivial band structures [1,2]. Recently, SmO thin films have been synthesized and reported to have the mixed valence of 2.9+ [3], although Sm chalcogenides such as SmS and SmSe show the integer valence of 2+ at ambient pressure. This mixed-valence state of SmO consisting of $4f^6$ (Sm^{2+}) and $4f^5 5d^1$ (Sm^{3+}) configurations appears because the small lattice constant of SmO compared to the Sm chalcogenides makes the bottom of the 5*d* conduction bands lie below the 4*f* levels.

In the present study, we have performed resonance photoemission spectroscopy measurements of SmO thin film at the Sm M_5 absorption edge to reveal the valence band structure.

2 Experiment and Calculation

A 20-nm-thick SmO (001) epitaxial thin film was grown on $YAlO_3$ (110) substrates by pulsed laser deposition. The sample was capped with a 2-nm-thick AlO_x layer to protect the sample from oxidation. The photoemission experiment was performed at the beamline BL-2A of Photon Factory. The measurements were done at the temperature of 11 K with the photon energies of 1-1.3 keV, which cover the Sm $M_{4,5}$ absorption edge.

3 Results and Discussion

Figure 1(a) shows valence-band photoemission spectra of the SmO thin film taken with the photon energies of 1070 eV (off resonance) and 1079 eV (on resonance). These photon energies correspond to the energies below and at the Sm M_5 absorption edge as indicated by bars on the x-ray absorption spectrum shown in Fig. 1(c). The photoemission spectra are normalized to their maxima.

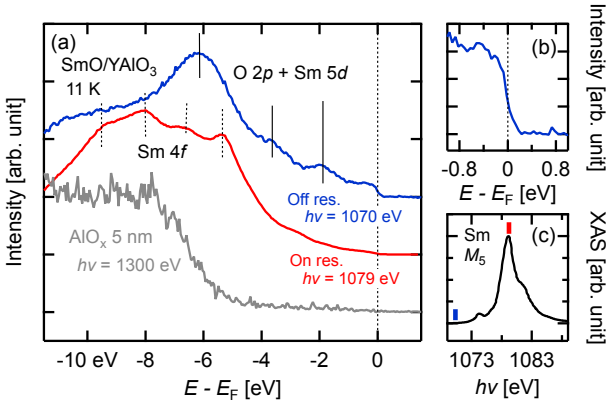

Fig. 1 (a) Resonance valence-band photoemission spectra of the SmO thin film. (b) Magnified plot around the Fermi level. (c) Sm M_5-edge absorption spectrum.

The signals from the capping AlO_x layer were separately measured using the sample with a thick (5 nm) capping layer as shown at the bottom of Fig.1(a). The featureless spectrum of AlO_x guarantees that the valence-band photoemission spectra reflect the electronic structure of SmO.

The on-resonance spectrum, in which the Sm 4*f* contribution is enhanced, looks significantly different from the off-resonance spectrum. This indicates that the off-resonance spectrum predominantly consists of O 2*p* bands strongly hybridized with Sm 5*d* orbitals. The off-resonance spectrum shows a clear Fermi edge as shown in Fig. 1(b). This Fermi edge most likely originates from the Sm 5*d* bands, indicating that Sm has a mixed valence with finite $4f^5 5d^1$ (Sm^{3+}) contribution.

References

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