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Soft x-ray angle resolved photoemission study on $SrRuO_3$ thin films

Kohei YOSHIMATSU[1], Hiroshi KUMIGASHIRA[1-3], Atsushi FUJIMORI[4], and Masaharu OSHIMA[1,3,5]
[1]Department of Applied Chemistry, The University of Tokyo, Tokyo 113-8656, Japan
[2]PRESTO, Japan Science and Technology Agency, Saitama 332-0012, Japan
[3]The Synchrotron Radiation Research Organization, The University of Tokyo, Tokyo 113-8656, Japan
[4]Department of Physics, The University of Tokyo, Tokyo 113-8656, Japan
[5]CREST, Japan Science and Technology Agency, Tokyo 113-8656, Japan

Introduction

Perovskite-type Ru oxides exhibit the unusual physical properties such as the superconductivity-metal-insulator transition in $Ca_{2-x}Sr_xRuO_4$ and the ferromagnetic-paramagnetic transition in $Ca_{1-x}Sr_xRuO_3$. In order to clarify the origin of these physical properties, it is essential to obtain the information on the band structures of these oxides.

Angle-resolved photoemission spectroscopy (ARPES) is one of the best experimental ways to determine the band structures. However, there are few ARPES studies on $Ca_{1-x}Sr_xRuO_3$ owing to the absence of any cleavage surfaces, which is in sharp contrast to the intensive ARPES studies on layered $Ca_{2-x}Sr_xRuO_4$ having cleavable planes.

In this study, we have performed *in-situ* soft x-ray ARPES studies on well-ordered surfaces of single-crystal $SrRuO_3$ (SRO) thin films grown by laser molecular beam epitaxy.

Experiment

SRO thin films were grown onto the Nb-doped $SrTiO_3$ (Nb-STO) substrates in a laser molecular-beam epitaxy chamber connected to a synchrotron radiation photoemission system at BL2C. SRO thin films were deposited at the substrate temperature of 700 ℃ under an oxygen partial pressure of 10^{-3} Torr. The crystal structures of the epitaxial SRO thin films were characterized by four-circle x-ray diffraction measurement. The in-plane lattice constant of SRO thin films matched perfectly with that of STO substrates. The atomically flat surfaces with step-and-terrace structures were observed in the atomic force microscopic image. The photoemission spectra were recorded at 20 K using an SES 2002 electron energy analyzer. The total energy and angular resolution were set at about 200 meV at the photon energy of 600 eV and 0.1°, respectively.

Results and Discussion

Figure 1 (a) shows the band structures of SRO thin films along the Γ-X direction obtained by the plotting the intensity of the second derivative ARPES spectra. The yellow parts correspond to the energy bands. The blue lines are the results of the band structure calculation based on the local spin density approximation (LSDA) [1].

In comparison of the experimental band structure and the calculated one, the energy bands from 3 eV to 9 eV and from the Fermi level (E_F) to 3 eV are of mainly O 2*p* and Ru 4*d* characters, respectively. The observed O 2*p* bands are in good agreement with the calculated ones. The Ru 4*d* bands are categorized into two general groups: one is the parabolic band centered at the Γ point with the bottom binding energy of 1.5 eV below E_F and the other is the almost dispersionless band near E_F. In contrast to the O 2p states, these Ru 4*d* states show significant discrepancies between the two, suggesting that the Ru 4*d* bands are renormalized owing to the strong electron-electron correlations.

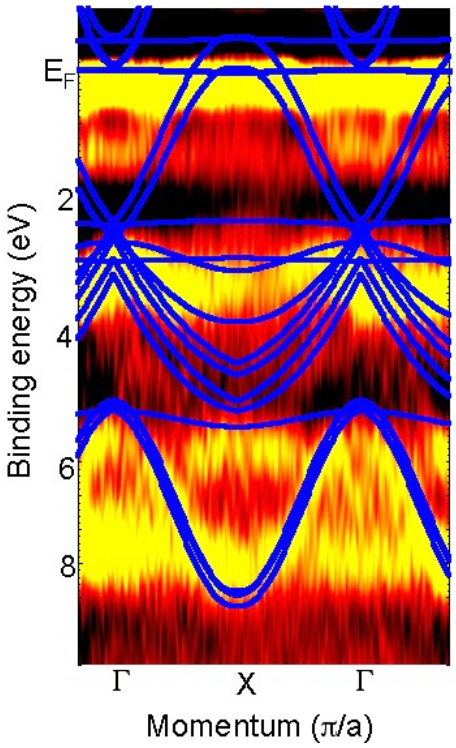

Figure 1: The band structure of SRO thin film along the Γ-X direction determined by the soft x-ray ARPES measurement.

References

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*yoshimatsu@sr.t.u-tokyo.ac.jp