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Bulk electronic structure of $Ca_{1-x}Sr_xRuO_3$ studied using epitaxial thin films

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Introduction

Metal-insulator transition has been extensively studied because of its fundamental importance as well as its close relationship to interesting phenomena such as high-temperature superconductivity in cuprates and colossal magnetoresistance in manganites [1]. $Ca_{1-x}Sr_xVO_3$ (CSVO) is a typical bandwidth control system but remains metallic for the entire x range. With Ca doping, ultra-violet photoemission spectra of CSVO have shown the spectral weight transfer from the coherent part to the incoherent part [2], while using high photon energies there were no spectral weight transfer [3]. Very recently, a more bulk-sensitive measurement of the same system using a UV laser as a light source indicated that spectral weight transfer indeed occurs [4]. The problem therefore remains highly controversial and further studies are strongly required. In the present work we have observed clear spectral weight transfer in another bandwidth-control system $Ca_{1-x}Sr_xRuO_3$ (CSRO) after decomposition of the spectra into surface and bulk components [5].

Experiment

CSRO thin films were fabricated in a laser MBE chamber connected to a synchrotron radiation photo-emission system at BL-2C of Photon Factory [6]. The films were deposited on Nb-doped TiO_2-terminated $SrTiO_3$ (001) substrates [7] at 900 °C at an oxygen pressure of 0.1 Torr. The fabricated CSRO films were transferred into the photoemission chamber under an ultrahigh vacuum of 10^{-10} Torr. The PES spectra were taken at room temperature with the total energy resolution of about 200 ~ 500 meV depending on photon energy.

Results and Discussion

We have measured PES spectra at 400 eV and 900 eV as shown in Fig. 1. As we are interested in the Ru 4*d* band, the tail of the O 2*p* band has been subtracted. In order to obtain the bulk and surface components of the Ru 4*d* band, we have followed the procedure of Ref. [8]. The measured photoemission spectra are assumed to be expressed as $I(E) = \exp(-s/\lambda)I_{bulk}(E) + [1 - \exp(-s/\lambda)]I_{surface}(E)$, where s is the thickness of the surface layer, λ is the photoelectron mean-free path, and I_{bulk} and $I_{surface}$ denote the spectra of the bulk and surface regions, respectively. We have used the mean-free paths of λ_{900} = 18 Å and λ_{400} = 6 Å at $h\nu$ = 900 and 400 eV, respectively and the surface layer thickness of 4 Å, the dimension of the unit cell. As shown in Fig. 1, the incoherent part of the bulk component thus obtained is weaker than that of the raw spectra, and manifests itself as a shoulder rather than a separate feature from the main structure near E_F. Nevertheless, there is still spectral weight transfer from the coherent part to the incoherent part with Ca doping.

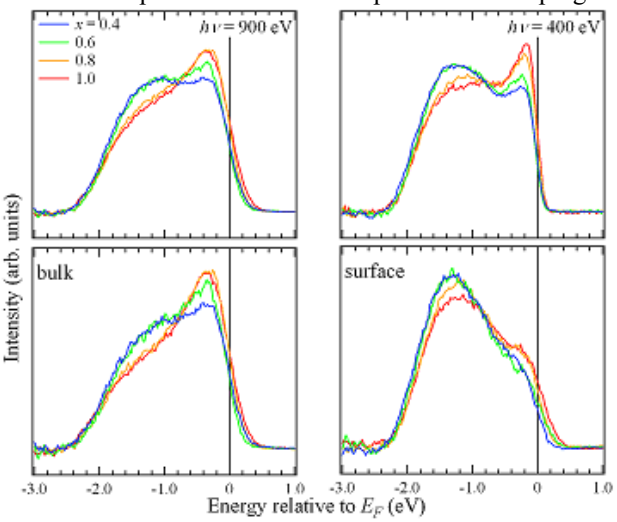

Fig. 1: Ru 4*d* band of $Ca_{1-x}Sr_xRuO_3$. Top: Data taken at $h\nu$ = 400 and 900 eV. Bottom: The bulk and surface components deduced from different energies.

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