2C/2008S2

Electronic structure of $V_{1-x}W_xO_2$ thin films investigated by soft x-ray photoelectron spectroscopy

Enju SAKAI[1,2], Kohei YOSHIMATSU[1], Keisuke SHIBUYA[3], Hiroshi KUMIGASHIRA[1,4,5], Masashi KAWASAKI[3,6,7], Yoshinori TOKURA[3,7,8], and Masaharu OSHIMA[1,2,5]
[1]Department of Applied Chemistry The University of Tokyo, Bunkyo-ku, Tokyo, 1138656, Japan
[2]CREST, Japan Science Technology Agency (JST),Bunkyo-ku, Tokyo 113-8656, Japan
[3]CMRG, Advanced Science Institute, RIKEN, Wako 351-0198, Japan
[4]PRESTO, JST, Kawaguchi, Saitama 332-0012, Japan
[5]SRRO, The University of Tokyo, Bunkyo-ku, Tokyo 113-8656, Japan,
[6]WPI Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan,
[7]Department of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan
[8]Multiferroics Project, ERATO, JST, Tokyo 113-8656, Japan

Introduction

There is a considerable interest in controlling the metal-insulator transition temperature (T_{MI}) of VO_2 from the viewpoint of both device applications and basic understanding of the metal-insulator transition (MIT). The substitution of W ions for V ions in VO_2 films ($V_{1-x}W_xO_2$) shows an interesting behavior of the T_{MI} [1]. In a lower doping region ($x \leq 0.08$), the T_{MI} decreases with increasing x, leading to a metallic conductivity at almost all the temperatures in a narrow doping region at around $x = 0.08$. With further increasing x, another insulating phase appears: the T_{MI} monotonically increases again in the higher doping region ($0.08 \leq x \leq 0.33$). The re-entrant behavior strongly suggests that there are different effects of W doping on the lower and higher doping regions.

Experimental

$V_{1-x}W_xO_2$ ($0 \leq x \leq 0.33$) thin films with thicknesses of 30–40 nm were grown on Nb-doped TiO_2 (001) substrates by a pulsed laser deposition method [1]. Soft-x-ray photoelectron spectroscopy (PES) measurements were performed at BL-2C to reveal the effect of W doping on the electronic structure of VO_2 thin films.

Results and discussion

Figure 1 shows the PES spectra near the Fermi level (E_F) of $V_{1-x}W_xO_2$ films taken at metallic and insulating states, respectively. For x = 0–0.08 films, a peak at E_F and a broad satellite structure around 1.5 eV are observed for the metallic phase, while a prominent peak at 1.0 eV for the insulating phase. It should be noted that the satellite structure at the metallic phase has a different binding energy from the prominent peak of the insulating one. The spectral changes across the MIT are essentially the same as those of bulk VO_2 [2], indicating that the Peierls-like gap formation is the dominant origin of MIT in this doping region. On the other hand, highly doped samples ($x \geq 0.17$) exhibit the typical behaviour of the Mott insulator: a clear spectral weight transfer from a coherent peak at E_F to an incoherent peak around 1.2 eV across the MIT. These results suggest that the origin of the MIT is different between lower and higher W doping regions.

References

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

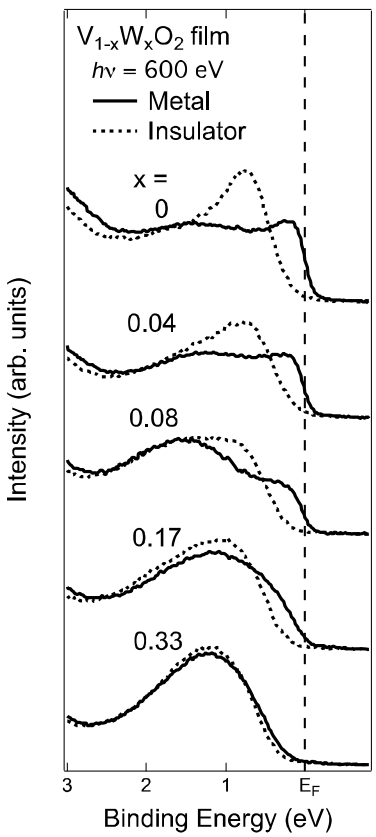

Figure 1: PES spectra near E_F of $V_{1-x}W_xO_2$ thin films