

Electronic structure of the core/shell-formed diluted magnetic semiconductor Fe-doped ZnO nano-particles

Takashi KATAOKA^{*1}, Yuta SAKAMOTO¹, Masaki KOBAYASHI¹, Gyong Sok SONG¹,
Atsushi FUJIMORI^{1,2}, Taichi OKUDA³, Ayumi HARASAWA³, Akito KAKIZAKI³,
Debjani KARMAKAR⁴, S. K. MANDAL⁵, Indra DASGUPTA⁶

¹ Department of Physics and Department of Complexity Science and Engineering,
University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan

² Synchrotron Radiation Research Unit, Japan Atomic Energy Agency,
Sayo-gun, Hyogo 679-5148, Japan

³ KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

⁴ Max-Planck-Institute, Stuttgart, Heisenbergstraße 1, D-70569 Stuttgart, Germany

⁵ Department of Physics & Meteorology, Indian Institute of Technology, Kharagpur 721302, India

⁶ Indian Association of the Cultivation of Science, Kolkata 700032, India

Introduction

There is growing interest in diluted magnetic semiconductors (DMS), where magnetic ions are doped into the semiconductors, due to the possibility to utilize both charge and spin degrees of freedom in the same material, which allows us to design a new generation of spin electronic devices with enhanced functionalities. Theoretical studies on the basis of Zener's p - d exchange model have shown that transition-metal-doped wide-gap semiconductors such as ZnO are promising candidates for room temperature ferromagnetic DMS [1] and a number of experiments on the ZnO-based DMS have revealed ferromagnetic properties at room temperature [2].

Recently, Karmakar *et al.* [3] have reported room temperature ferromagnetism in Fe-doped ZnO nano-particles and proposed that the ferromagnetism is originated from exchange interaction in the core/shell structure of the underlying nano-particle system. Based on magnetic measurements, they proposed that some randomized surface spins are superimposed on the core-dominated ferromagnetism. It is indispensable to clarify the core/shell electronic structures of the system. In order to discuss the electronic states in the shell-layer region of the nano-particles, we have performed resonant photoemission spectroscopy (RPES) on the $\text{Zn}_{0.9}\text{Fe}_{0.1}\text{O}$ nano-particles.

Results and Discussions

Figure 1 (a) shows the valence-band photoemission spectra of the $\text{Zn}_{0.9}\text{Fe}_{0.1}\text{O}$ nano-particles as a function of photon energies in the Fe $3p$ - $3d$ core excitation region and Fig. 1 (c) shows the magnified view of the valence-band maximum region. For the valence-band photoemission spectra, all binding energies (E_B) are referenced to the Fermi level E_F . Figure 1 (b) shows the Fe $3p$ - $3d$ absorption spectrum near the Fe $3p$ - $3d$ core excitation threshold of the $\text{Zn}_{0.9}\text{Fe}_{0.1}\text{O}$ nano-particles measured by the total electron yield method. In Fig. 1 (b), one can see that a peak appears at 58 eV, representing the Fe $3p$ - $3d$ absorption. For α - Fe_2O_3 (Fe^{3+}), the peak is found at 58 eV [4]. For FeO (Fe^{2+}), on- and off-resonance energies are reported to be 57 and 53 eV, respectively [5].

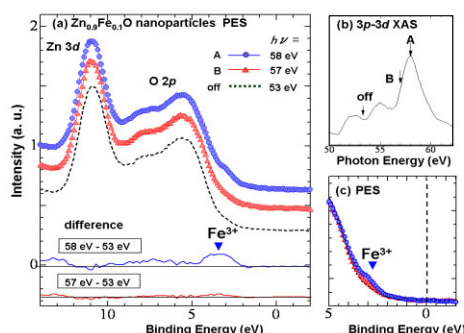


Fig. 1. Valence-band photoemission spectra of $\text{Zn}_{0.9}\text{Fe}_{0.1}\text{O}$ nano-particles. (a) A series of photoemission spectra taken with photon energies in the Fe $3p$ - $3d$ core excitation region. Difference curves at the bottom represent the Fe $3d$ PDOS. (b) Fe $3p$ - $3d$ absorption spectrum recorded in the total electron yield mode. (c) Magnified view of the valence-band maximum.

From this comparison, we conclude that $3p$ - $3d$ absorption due to Fe^{3+} ions is mainly observed in this sample. In Fig. 1 (c), one can see that in going from $h\nu=53$ eV to 58 eV, the tail of the spectrum at $E_B \approx 3$ -4 eV grows in intensity. By subtracting the off-resonance spectrum ($h\nu=53$ eV) from the Fe^{3+} ($h\nu=58$ eV) and Fe^{2+} ($h\nu=57$ eV) on-resonant ones, we have obtained the Fe $3d$ PDOS for Fe^{3+} and Fe^{2+} as shown in the bottom panels of Fig. 1 (a). The 58-53 eV difference spectrum which yields the Fe^{3+} $3d$ PDOS reveals a feature at $E_B=3$ -4 eV. On the other hand, the 57-53 eV difference spectrum which yields the Fe^{2+} $3d$ PDOS reveals no clear feature. Taking these results into account, it is concluded that the Fe^{3+} ions are dominant on the surface region of the $\text{Zn}_{0.9}\text{Fe}_{0.1}\text{O}$ nano-particles.

References

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* kataoka@wyvern.phys.s.u-tokyo.ac.jp