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Soft X-ray Angle Resolved Photoemission Study of the Diluted Magnetic Semiconductor $Ba_{1-x}K_x(Zn_{1-y}Mn_y)_2As_2$ Single Crystals

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1 Introduction

Diluted magnetic semiconductors (DMSs) have attracted considerable attention as a candidate for future spintronics devices after the discovery of ferromagnetism in Mn-doped GaAs (GaMnAs). A new series of DMS, $Ba_{1-x}K_x(Zn_{1-y}Mn_y)_2As_2$ (Mn-$BaZn_2As_2$), which is isostructural to the ``122"-type iron-based high-temperature superconductors, was successfully synthesized recently with the T_C as high as 230 K [1]. This material has an advantage that the Ba layer, where hole carriers are introduced, and the ZnAs layer, where magnetic elements are, are spatially separated. This property allows us to independently control the amount of carriers and that of magnetic element. Also, the equal chemical valence 2+ of the magnetic element Mn and the host Zn atoms does not cause low chemical solubility problem always present in GaMnAs and related DMSs, which makes it possible to obtain bulk specimens. Furthermore, interstitial sites for Mn ions in the ZnAs layers are energetically unstable and thus the Mn ions takes only substitutional ones, which significantly simplifies the theoretical treatment and experimental understanding of the carrier-induced ferromagnetism in this material.

2 Experiment

In the present work, we have performed x-ray absorption spectroscopy (XAS) and angle-resolved photoemission spectroscopy (ARPES) measurements on Mn-$BaZn_2As_2$ (x=0.3, y=0.15, T_C = 60 K) single crystals. The newly developed Beamline 2A is equipped with two undulators for vacuum ultraviolet (VUV) and soft x-ray (SX) light, respectively, enabling us to measure samples with a wide range of photons (from ~20 eV to ~1500 eV) at the same sample position.

3 Results and Discussion

The SX light increases the photoemission cross section from the As *4p* orbitals and the increased probing depth provides us with information about the bulk low-energy electronic structure. Figs. 1 (a) and (b) show ARPES spectra taken with $h\nu$ = 720 and 680 eV photons. The k_z positions approximately correspond to those of the Γ and Z point, respectively. The corresponding second derivative plots along the energy directions are also shown in Figs. 1 (c) and (d). Around the Γ point, we observe that two hole bands cross E_F, while around the Z point one hole and an electron band cross E_F. The appearance of multiple hole FSs and small electron pocket around the Z point in the hole-doped Mn-$BaZn_2As_2$ is consistent with the calculated band structure of the host semiconductor $BaZn_2As_2$ [2].

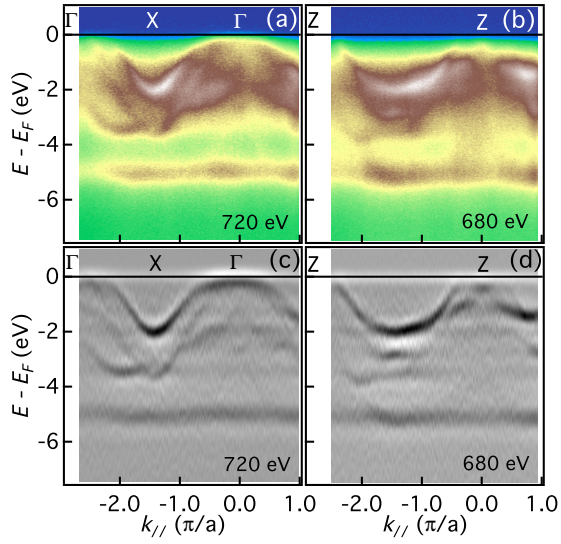

Fig. 1: (a), (b) Valence-band soft x-ray angle-resolved photoemission spectroscopy intensity plots taken with $h\nu$ = 720 and 680 eV photons. The k_z positions correspond to Γ and Z point, respectively. (c), (d) Corresponding second derivative plots.

References

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[2] H. Suzuki et al., Phys. Rev. B **91**, 140401(R) (2015)
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