Electronic Structure of Ferromagnetic Semiconductor Ge$_{1-x}$Fe$_x$ Studied by Soft X-ray Angle Resolved Photoemission Spectroscopy

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Ge$_{1-x}$Fe$_x$ (GeFe) is a p-type ferromagnetic semiconductor. Since GeFe can be grown on Ge and Si substrates by low temperature molecular beam epitaxy, it has an advantage of being compatible with conventional Si-based electronics [1]. By doping boron atoms, one can control the resistivity and carrier concentration independently [2]. The Curie temperature seems to be dependent on Fe concentration fluctuation, and the more Fe atoms are inhomogeneously distributed, the higher the Curie temperature becomes [3,4].

In order to gain more insight into the origin of the ferromagnetism in GeFe, we have investigated its electronic structure by soft x-ray angle-resolved photoemission spectroscopy (ARPES). The experiment was performed at BL23SU of SPring-8 on samples with 6.5% Fe whose $T_C$ was 100 K. Figure 1 shows the second derivative plot of the obtained ARPES spectra taken along $\Gamma$-K-X line with the photon energy of 885 eV at the temperature of 20 K. Here, blue dots represent the peak positions of the energy distribution curves reflecting the band structure. The heavy hole, light hole, and split off bands can be clearly seen, and the valance band maximum seems to be located close to the Fermi energy, which is consistent with the p-type conduction of GeFe. Note that the bands without dispersions originate from photo-electrons losing the information of the momentum at the surface, and not from the Fe 3$d$ states. By using photons in the Fe $L_3$ edge absorption region, it is found that the Fe 3$d$ states have finite contribution to the density of states at $E_F$.

References