In-situ 高分解能 ARPES でみる (Ga,Mn)As の価電子帯電子状態

Valence-band electronic structure of (Ga,Mn)As studied by high-resolution ARPES

Carrier-induced nature of ferromagnetism in a ferromagnetic semiconductor, (Ga,Mn)As, offers a great opportunity to observe novel spin-related phenomena as well as to demonstrate new functionalities of spintronic devices [1]. Many experimental observations in (Ga,Mn)As have been well explained by the model based on the exchange interaction among localized Mn moments mediated by itinerant holes, the so-called p-d Zener model, in which holes reside in the GaAs host-like valence band. On the other hand, several spectroscopic studies suggested that the Fermi level ($E_F$) is pinned in the impurity band inside the bandgap formed by Mn doping. Despite intensive studies, no conclusive consensus has been reached yet.

In this talk, we report an in-situ high-resolution ARPES study on epitaxially-grown (Ga,Mn)As thin films [2]. To overcome the possible surface problems, MBE-grown films were directly transferred to the ARPES vacuum chamber without being exposed to the air. For Ga$_{0.95}$Mn$_{0.05}$As with Curie temperature $T_C$ of ~100 K, we observed a holelike valence band at the $\Gamma$ point as seen in Fig. 1. The Fermi level $E_F$ is located in the valence band, as evident from the clear Fermi-edge cutoff. Comparison with a tight-binding calculation (gray dashed line) and also with ARPES result of nonmagnetic n-type GaAs demonstrate the hole-doped nature of the valence-band states for Ga$_{0.95}$Mn$_{0.05}$As. We also observed a disorder-induced soft Coulomb gap at $E_F$ as well as the close link between the $T_C$ and the metallic spectral weight at $E_F$. We discuss these experimental results in comparison with theoretical models proposed to explain the ferromagnetism in (Ga,Mn)As.


Fig. 1 (a) Near-$E_F$ ARPES spectra of Ga$_{0.95}$Mn$_{0.05}$As ($T_C = 101$ K) around the $\Gamma$ point [2]. (b) ARPES-intensity plot of (a). Dashed curves are calculated band dispersion within tight-binding approximation. (c) Same as (b) for n-type GaAs.