

ELECTRONIC STRUCTURE OF HEAVY FERMION SUPERCONDUCTORS

The discovery of superconductivity in heavy fermion (HF) compounds has stimulated the studies of this class of materials [1]. Recently, a “high- T_C ” superconductivity of $T_C = 18$ K was discovered in PuCoGa_5 [2], indicating that there remains an unexplored class of exotic superconductors in HF compounds. In these compounds, the superconductivity coexists or competes with magnetic ordering, and this is the most characteristic feature of HF superconductors. It has been proposed that these properties originated from the dual character of f electrons, i.e., their localized and delocalized characters [3]. However, their detailed electronic structures have not been studied yet, and the nature of f electrons as well as the mechanism of the superconductivity originating from such electrons are not well understood. To reveal the electronic structures of HF superconductors, we have performed angle resolved photoemission spectroscopy (ARPES) experiments for typical HF superconductors, namely, UPd_2Al_3 and CeIrIn_5 . UPd_2Al_3 shows an antiferromagnetic transition at $T_N = 14$ K, and undergoes a transition into the superconducting state at $T_C = 2$ K. CeIrIn_5 is a HF superconductor with $T_C =$

0.4 K. Although it does not show the magnetic ordering, $\text{CeRh}_{1-x}\text{Ir}_x\text{In}_5$ exhibits both superconductivity and antiferromagnetic (AF) ordering in $0.3 < x < 0.6$ [4], suggesting that the ground state of CeIrIn_5 is very close to the magnetic ordering state. The Fermi surfaces of both compounds, at low temperatures were investigated by dHvA experiments, and they were well explained by the band structure calculations [5,6]. Therefore, it is considered that f -electrons have strong itinerant character in these compounds. Photoemission experiments were mainly performed at SPring-8 beamline **BL23SU**. $4d$ - $4f$ resonant ARPES experiment for CeIrIn_5 was performed at Hiroshima Synchrotron Radiation Research Center (HiSOR) BL-1.

Figure 1 shows the f -derived angle-integrated photoemission (AIPES) spectra of UPd_2Al_3 and CeIrIn_5 . The U $5f$ spectrum of UPd_2Al_3 was obtained by subtracting the photoemission spectra measured at $h\nu = 400$ eV and $h\nu = 800$ eV, and the Ce $4f$ spectrum of CeIrIn_5 was obtained using $3d$ - $4f$ resonant photoemission ($h\nu = 881.2$ eV). Both spectra have two pronounced components as indicated by the triangles in the figure. One is located around E_F , and the other is located on the deeper binding energy side. The relative intensities and the positions of this broad satellite differ markedly between UPd_2Al_3 and CeIrIn_5 . These satellites originate from the electron correlation effects, which cannot be taken into account by band structure calculations. The Ce $4f$ spectrum of CeIrIn_5 is essentially understood within the framework of the single impurity model, suggesting that Ce $4f$ electrons in this compound are dominated by the localized character. On the other hand, the U $5f$ spectrum of UPd_2Al_3 is dominated by the strong quasi-particle peak located near E_F , and the intensity of the correlated feature is much weaker than that of CeIrIn_5 .

Figure 2 shows ARPES spectra of UPd_2Al_3 measured for A-H-L direction at $h\nu = 465$ eV and ARPES spectra of CeIrIn_5 measured for Γ -X direction at $h\nu = 122$ eV. For both directions of Brillouin zone, Fermi surfaces with large contribution from f states are expected in band structure calculations. In these spectra, the contribution from U $5f$ states or Ce $4f$ states is dominant. For UPd_2Al_3 , some dispersive bands were clearly observed in the ARPES spectra, suggesting that the U $5f$ states have strong itinerant character. On the other hand, the ARPES spectra of CeIrIn_5 have the double peak structure arising from the spin-orbit interaction. In contrast to the case of

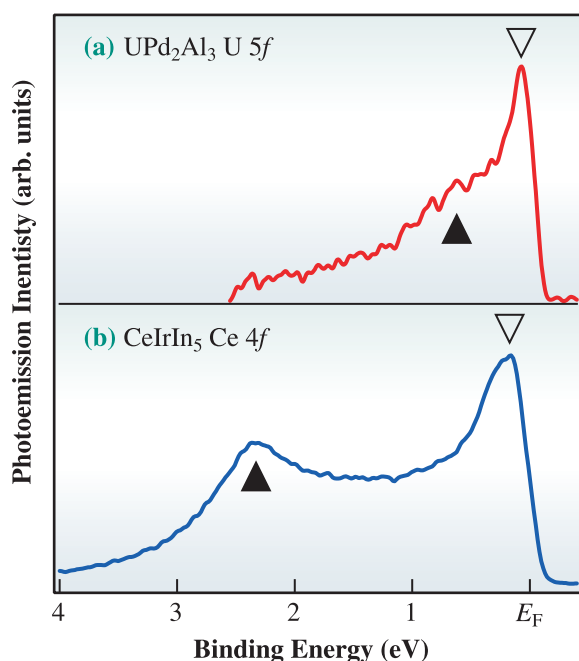


Fig. 1. (a) U $5f$ spectrum of UPd_2Al_3 and (b) Ce $4f$ spectrum of CeIrIn_5 .

UPd₂Al₃, their momentum dependence is very small, suggesting that the 4*f* electrons are dominated by the localized character. A detailed analysis of ARPES spectra suggests that the peak near E_F has a small energy dispersion of ~30 meV [7], and that this might be the origin of the observed itinerant nature of Ce 4*f* states in this compound. Therefore, we have observed the very different natures of *f* electrons in

UPd₂Al₃ and CeIrIn₅. For UPd₂Al₃, although a correlated feature exists, the itinerant nature dominates the spectra. Meanwhile, for CeIrIn₅, the localized nature dominates the spectra, and the contribution from itinerant states is very small. The present results bring us a step closer to understanding the of dual natures of *f* electrons in HF superconductors [8].

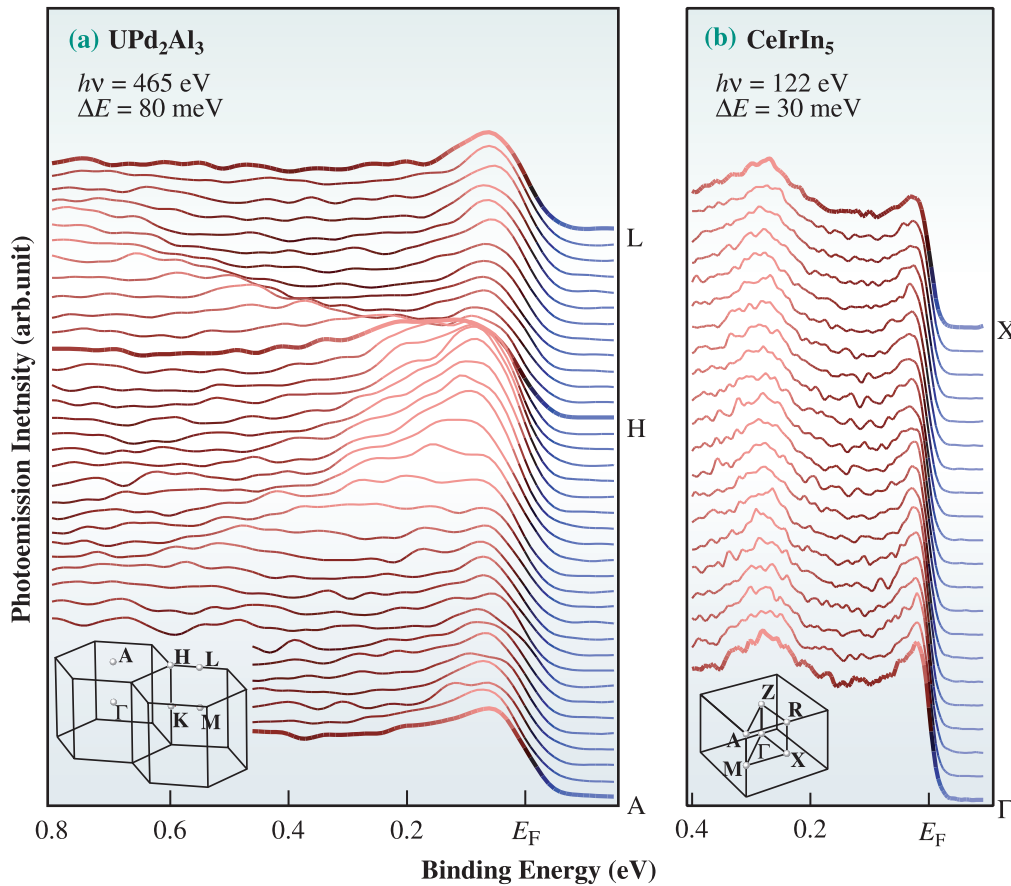


Fig. 2. (a) ARPES spectra of UPd₂Al₃ measured at $h\nu= 465$ eV and (b) ARPES spectra of CeIrIn₅ measured at $h\nu= 122$ eV.

Shin-ichi Fujimori

SPring-8 / JAEA

E-mail: fujimori@spring8.or.jp

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