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Observation of three-dimensional Fermi surfaces in the iron pnictides superconductor $BaFe_2(As_{1-x}P_x)_2$

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Introduction

Symmetry of the superconducting order parameter is crucial information for understanding the mechanism of Cooper pairing in the novel superconductors. Most of the experimental results on Fe-pnictide superconductors indicate that the superconducting gaps open on the entire Fermi surface [1], in contrast to the *d*-wave gap in the high-T_c cuprate superconductors. However, recent studies of $BaFe_2(As_{1-x}P_x)_2$ [2] show signatures of superconducting gap with line nodes in penetration depth, thermal conductivity [3], and NMR [4] results. In $BaFe_2(As_{1-x}P_x)_2$, the substitution of P for As suppresses magnetic order and induces superconductivity with maximum T_c~ 30 K at x~0.3. Isovalent substitution gives a good opportunity to reveal the character of the superconducting states, because one can produce the superconducting states without changing the number of Fe 3*d* electrons. Here, we expect that the shape of Fermi surfaces become more three-dimensional compared to nondoped $BaFe_2As_2$ because the inter-layer hopping would increase with P substitution. Therefore, it would be interesting to reveal the three dimensional electronic structure of this system. In order to clarify the three-dimensional electronic structure, we have performed an angle-resolved photoemission study of optimally doped $BaFe_2(As_{1-x}P_x)_2$ with x ~ 0.38.

Experimental condition

High-quality single crystals of the $BaFe_2(As_{1-x}P_x)_2$ with x=0.38 (T_c = 30 K) were grown using the flux method. ARPES measurements were carried out at BL-28A using a circularly-polarized light with photon energies ranging between 46 and 67eV. A Scienta SES-2002 analyzer was used with a total energy resolution of ~15 meV and a momentum resolution of ~ 0.02 π/a, where a =3.92 Å is the in-plane lattice constant. The crystals were cleaved *in situ* at T=10 K in an ultra-high vacuum ~5×10^{-11} Torr. Calibration of the Fermi level (E_F) of the samples was achieved by referring to that of gold.

Result and Discussion

Results of Fermi surface (FS) mapping in the k_x-k_y plane are shown in Fig. 1 (a) and (b). Intensity mapping for the hole FSs were performed at hν=46 eV (k_z ~ Γ) and 63 eV (k_z~ Z), while the electron FS around X point were taken at hν=67 eV (k_z ~ Z) and 52 eV (k_z~Γ). By assuming an inner potential V_0=13.5 eV, panels (a) and (b) approximately correspond to the k_x-k_y plane including the Z and the Γ point, respectively. We have observed at least two hole FS sheets around the Brillouin zone (BZ) center, and two electron FSs around BZ corner. While the outer hole FS around the Z point has nearly circular shape with Fermi momentum k_F ~ 0.5(π/*a*), the hole FS around Γ shows smaller k_F ~0.25 (π/*a*). This indicates that the hole FS has strong three-dimensionality as expected from the large inter-layer hopping caused by P substitution.

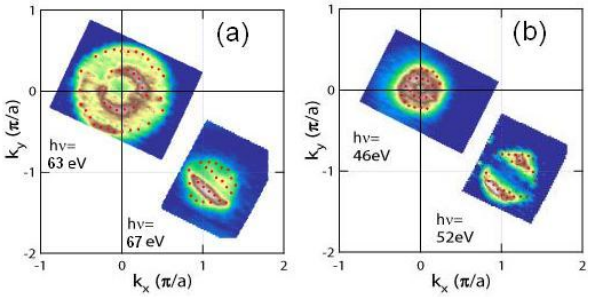

Fig. 1: Fermi surface mapping of $BaFe_2(As_{1-x}P_x)_2$ in the k_x-k_y plane. The ARPES intensity has been integrated over 10 meV around E_F. Panels (a) and (b) correspond to the k_z ~Z and k_z ~Γ, respectively.

References

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