論文の内容の要旨

Superconducting gap in the iron-based superconductor $BaFe_2(As_{1-x}P_x)_2$
studied by angle-resolved photoemission spectroscopy

（角度分解光電子分光による
鉄系超伝導体$BaFe_2(As_{1-x}P_x)_2$の超伝導ギャップの研究）

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The discovery of the iron-based high critical transition temperature (T_c) superconductors has aroused a new wave of investigations on the high T_c superconductors. The key point of the investigations on the high T_c superconductors is the pairing mechanism, which is reflected by the superconducting gap symmetry. Other than the cuprate superconductors, the gap symmetry of the iron-based superconductors has been controversial in many iron-based superconductors. To solve this problem, using angle-resolved photoemission spectroscopy (ARPES), we investigated the isovalent doped $BaFe_2(As_{1-x}P_x)_2$, in which no charge doping is involved.

The analysis method of the superconducting gap is important. Therefore, prior to judging what the spectrum detected by ARPES corresponds to, we analyzed the possible orbitals of the available spectrum by calculating the polarization dependent photoemission response using the electric dipole selection rules. According to the comparison between experimental and calculated results, the orbital character of the Fermi surface in $BaFe_2(As_{1-x}P_x)_2$ was determined.

Moreover, the bands and Fermi momentums (k_Fs) were determined through the fitting of each momentum distribution curve (MDC) using a Lorentzian-Gaussian function. After that the energy distribution curves (EDCs) were selected based on k_F; the value of superconducting gap (Δ) on the k_F was given by the fitting of symmetrized EDCs to the Norman function.

The superconducting gap symmetry on the electron Fermi surfaces was analyzed at different k_F positions as obtained from the analysis above. Through ARPES measurements, we obtained the superconducting gap of $BaFe_2(As_{1-x}P_x)_2$ for a series of doping concentration, including the optimal doping (x = 0.3) and over doping (x = 0.34, x = 0.38, and x = 0.45). We mainly studied the superconducting gaps on the electron Fermi surfaces as well as those on the hole Fermi surfaces, and consider that the complexity of the superconducting gap symmetry in $BaFe_2(As_{1-x}P_x)_2$ comes from the competition of spin and orbital fluctuations.

In heavily doped materials (x = 0.45), we conclude that the spin fluctuation is dominant base on strongly anisotropic of superconducting gap and nodes on the edge of the Electron Fermi surface comparing with the previous theoretical study; with decreasing doping, for example, at x = 0.38, the effect of orbital fluctuation turns significant. In fact, the spin fluctuation also increases with decreasing doping; yet the orbital fluctuation increases faster, as suggested by the increasing of gap size and the decreasing of the anisotropic of superconducting gap symmetry with decreasing doping, which compared with the previous theoretical study. The orbital fluctuation becomes dominant when x < 0.34; near the optimal doping or even prior to that (slightly over doping region), the orbital fluctuation decreases abruptly while spin fluctuation continues increasing. The conclusion here has solved the contradiction appeared in some previous studies, and is consistent with the previous theoretical and experimental results, such as the theoretical superconducting gap calculation considering competition of spin and orbital fluctuations. It is found that the competition of spin and orbital fluctuations appears in the optimal doping and slightly over doping region, where one of two fluctuations becomes dominant depending on the doping concentration. We believe that the pairing symmetry changing from nodal s-wave to $s_{\pm}$-wave corresponds to the doping ration x = 0.45 to the optimal doping.

All the codes for analyzing the polarization dependent photoemission response, MDC/EDC, k_F, and superconducting gap were written by software IGOR.