ARPES studies of Fe pnictides: Nature of the antiferromagnetic-orthorhombic phase and the superconducting gap

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Interplay between antiferromagnetism, orthorhombic distortion, and superconductivity is the unique and essential feature of Fe-based superconductors. In particular, the nature of the “nematic”/pseudogap phase above the magneto-structural transition temperature T_S [1] has been controversial whether it is due to spin nematic order or orbital order. As for the orbital order, both possibilities of ferro-orbital and antiferro-orbital orders have been discussed. To gain further insight into this issue, we have performed temperature-dependent ARPES studies of band dispersions in undoped $BaFe_2As_2$ and its isovalent Ru-substituted compounds. The Fermi surface topology of $BaFe_2As_2$ in the antiferromagnetic-orthorhombic (AFO) phase was found to be fully consistent with the Shubnikov-de Haas result [2]. The anisotropic band dispersions between the Γ-X and Γ-Y directions, which were also observed in the previous ARPES study not only below T_S but also above it [3], suggest that ferro-orbital ordering persists above T_S. On the other hand, the Dirac cone, which results from band folding due to the AFO order, was also found to persist above T_S, indicating that antiferro-orbital order exists below T_S [4] and persists above it.

In the superconducting state, such interplay between antiferromagnetism, orthorhombic distortion, and orbital ordering is expected to result in a complex pairing mechanism, which should be reflected on the superconducting gap anisotropy. We have studied the gap anisotropy of the isovalent-substituted systems $BaFe_2(As,P)_2$, $SrFe_2(As,P)_2$, and $Ba(Fe,Ru)_2As_2$ as well as of the electron-doped $Ba(Fe,Co)_2As_2$. The gap anisotropy on the electron Fermi surfaces (FSs) [5] was found to depend on the system as well as on the chemical composition. The gap on the hole FSs was reduced around the Z point (i.e., near the Brillouin zone boundary) in some compounds but not in others. In $Ba(Fe,Ru)_2As_2$, two hole FSs exhibited the same shrinkage of the gap around the Z point. In order to interpret the material- and composition-dependent, complicated gap anisotropy, both spin and orbital fluctuations would have to be considered for pairing mechanism [6].

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