Angle-Resolved Photoemission Study on Strongly Correlated Electron Materials

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Strongly correlated electron materials has attracted more attentions in the last few decades because of their unusual and fascinating properties such as high-$T_c$ superconductivity, giant magnetoresistance, heavy fermion and so on. Those unique properties can offer a route toward the next-generation devices. We investigate the mechanism of the physical properties as well as the electronic structure of those materials by using angle-resolved photoemission spectroscopy (ARPES), a powerful tool in studying the electronic structure of complex materials, based on synchrotron radiation.

Selected Publications


* carrying out graduate research on Cooperative Education Program of IMS with Osaka University
† carrying out graduate research on Cooperative Education Program of IMS with Nagoya University
1. Suppression of Superconducting Gap on Ba$_{1-x}$K$_x$Fe$_2$As$_2$ Observed by Angle-Resolved Photoemission Spectroscopy

Iron-based superconductors have a complex phase diagram with the antiferromagnetic, structural, and superconducting (SC) transition phases as well as high-$T_c$ cuprates superconductors. Recently, nematicity, defined as broken rotational symmetry [a trigonal ($C_3$)-to-orthorhombic ($C_2$) structural transition], has shed light on the understanding of the mechanism on the iron-based superconductivity in the underdoped regime. In hole-doped BaFe$_2$As$_2$ (Ba122) system, thermal expansion, specific heat, and neutron diffraction measurements of Ba$_{1-x}$Na$_x$Fe$_2$As$_2$ and Ba$_{1-x}$K$_x$Fe$_2$As$_2$ (K-Ba122) at a certain hole concentration have revealed the magnetic order without Cu symmetry breaking in the underdoped regime. Measured of Ba$_{1-x}$Na$_x$Fe$_2$As$_2$ with $x$ = 0.25 and 0.3 at the $kF$'s of the $\alpha$ and $\gamma$ bands are shown in Figures 1(c1)–(2d) for comparison. While the SC peak ($x$ = 0.3) is far from the $E_F$, indicating that the SC gap is observed on the $\alpha$ and $\gamma$ FSs, we found that the SC peak of $x$ ~ 0.25 moves towards $E_F$, which indicates the decrease or almost close of SC gaps for the $\gamma$ band.

Figure 2 gives the detailed SC gap distribution of the electron bands designated as $\epsilon$ and $\delta$ for the inner and outer electron FSs, respectively. To precisely determine the SC gap size and its momentum dependence, we have performed an ARPES study at several $k_F$ and $k_z$ points of the $\epsilon$ and $\delta$ bands. For the $k_z$ direction, while the SC gap for the $\delta$ band shows an isotropic gap [Figure 2(g)], the EDC peak position reflecting the SC gap for the $\epsilon$ band does not seem to be constant, namely, the peak position as shown by a gray circle decreases in going from the A to M points [Figure 2(i)]. This indicates that an anisotropic SC gap is exhibited along the $k_z$ direction for the $\epsilon$ FS.

The present ARPES study indicates that the $T_c$ suppression of K-Ba122 ($x$ ~ 0.25) corresponds to the suppressed SC gap on the $\gamma$ FS and the $k_z$ dependent SC gap on the $\epsilon$ FS. According to the previous ARPES study, the SC gap size on hole FSs was almost identical in optimally doped K-Ba122, which was interpreted by the $s^\pm$-wave SC gap symmetry due to orbital fluctuations. Though SC gaps on the $\alpha$ and $\beta$ FSs of K-Ba122 ($x$ ~ 0.25) are identical, that on the $\gamma$ FS seems not to be explained directly by the orbital fluctuation. The SC gap might be suppressed in the presence of the $C_4$-magnetic fluctuation, assuming that the presence of the $C_4$ symmetry of the electronic structure with disappearance of the orbital order. We also find that the ARPES intensity plots of K-Ba122 ($x$ = 0.21, 0.3) at the $E_F$ band show the band folding of the electron-like band, which is known to be observed below the SDW transition temperature in the underdoped regime, but disappears in $x$ ~ 0.25 sample (not shown). Probably recently reported antiferroic electronic instability is suppressed around $x$ ~ 0.25 because of the $C_4$-magnetic phase fluctuation. Thus, the experimental evidence indicates that the SC gap on the $\gamma$ FS of K-Ba122 ($x$ ~ 0.25) is strongly influenced by the $C_4$-magnetic phase.

2. Development of Micro-Focused Beam ARPES

A soft X-ray beamline BL5U has been open for users from 2016 and used as high energy resolution ARPES beamline. By introducing a final focusing mirror close to the sample position (~50 mm), the synchrotron light whose original size was 400 (H) × 120 (V) is successfully focused to 23 (H) × 40 (V) μm. ARPES study on small samples or inhomogeneous samples is now available.

References