High-Resolution Photoemission Study of Fine Electronic Structure in the Vicinity of the Fermi Level of High-T_c Superconductors(Abstracts of Doctoral Dissertations,Annual Report(from April 2001 to March 2002))

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High-Resolution Photoemission Study of Fine Electronic Structure in the Vicinity of the Fermi Level of High-T_c Superconductors

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In order to understand the mechanism of superconductivity in high-T_c(transition temperature) superconductors (HTSCs), there are several important issues to be solved. Typical examples are to clarify 1) the topology of Fermi surface (FS) in Bi-family HTSCs whether it is electron-like or hole-like, 2) the universality of $d_{x^2-y^2}$-like superconducting gap in hole-doped HTSCs, 3) the origin of pseudogap, 4) whether the mechanism of the supercodnctivity is the same between electron- and hole-doped HTSCs. To address these issues in more detail, it is necessary to improve the resolution of photoemission spectrometer. The purpose of present study is, firstly, to construct a new photoemission spectrometer and achieve the high resolution, and, secondly, to investigate the fine electronic structure in the vicinity of the Fermi level (E_F) of HTSCs by performing the photoemission spectroscopy (PES) so as to elucidate above issues.

I. Construction of High-Resolution Photoemission Spectrometer

Figure 1 shows schematic view of new high resolution photoemission spectrometer. The system consists mainly of electron analyzer, main chamber, preparation chamber, photon source, and pumping lines. Ultrahigh-resolution 2.1 meV has been achieved (shown in the inset of Fig. 1) by designing the μ-metal shield chamber, degaussing the analyzer, adjusting the voltage source cables, calibrating the settings of lens voltages as well as CCD camera. Other specifications of the spectrometer are listed below;

- Angular resolution: 0.2 deg
- Lowest temperature: 6.4 K
- Best pressure: 1.5×10^{-11}Torr

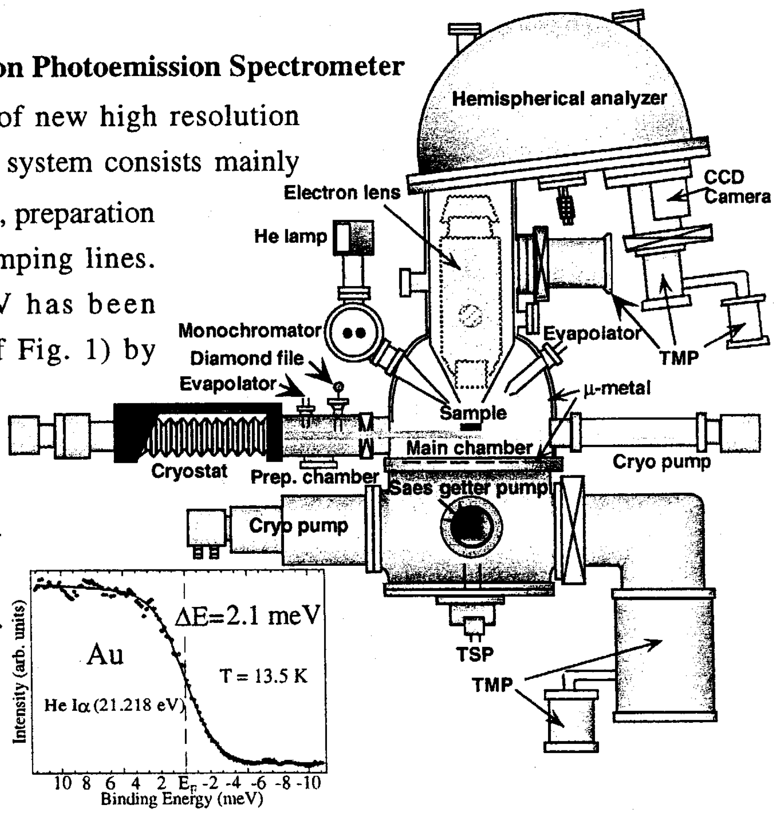

Fig. 1 Schematic view of high-resolution photoemission spectrometer, and PES spectrum of Au in the vicinity of E_F.

II. Topology of Fermi Surface in Bi-family HTSCs

Figure 2 shows angle-resolved PES (ARPES) spectral intensity at 25 K of Pb-substituted $Bi_2Sr_2CuO_6$ (Pb-Bi2201, T_c<4 K) in the vicinity of E_F. Bright area corresponds to the bands. We clearly find single band all over the measured momentum region, demonstrating that the present sample is actually superstructure free. At away from (π, 0) (lines A-J), the intensity shows remarkable dispersion, while that around (π, 0) (lines J-L) shows almost no dispersion. A finite intensity at (π, 0) unambiguously indicates a hole-like FS centered at (π, π) in Pb-Bi2201.

It is also observed that the hole-like FS stands irrespective of the doping ratio or the energy of photons. Similar hole-like FS has been found to exist in $Bi_2Sr_2CaCu_2O_8$ (Bi2212).

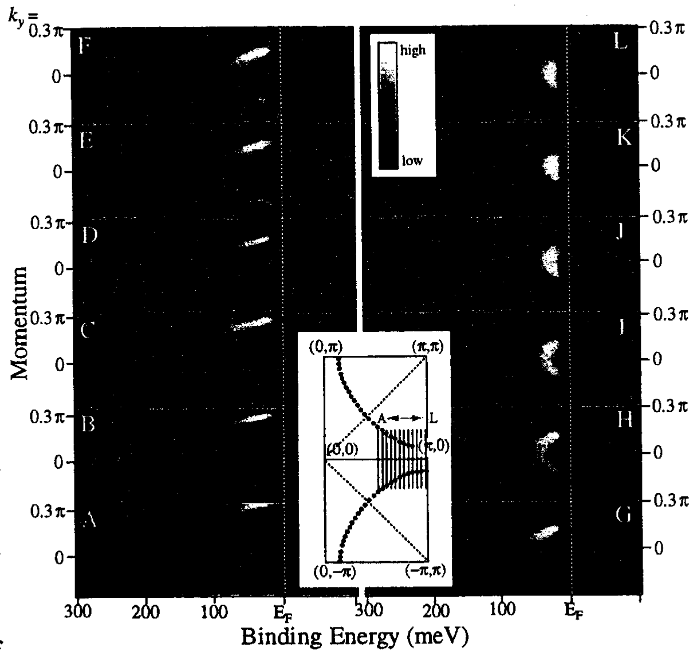

Fig. 2 ARPES intensity map of Pb-Bi2201(T_c<4 K) at 25 K measured along the lines in the Brillouin zone shown in inset.

III. Pseudogap in LSCO

High-resolution PES of $La_{1.85}Sr_{0.15}CuO_4$ (LSCO, T_c=38 K) has been performed. It is found that the pseudogap of 40 meV opens above T_c and it does not smoothly connect to superconducting gap (8 meV) below T_c. The energy scale of the pseudogap well corresponds to the characteristic temperature of magnetic susceptibility (400 K). This suggests that the observed pseudogap is formed by a development of antiferromagnetic correlation.

IV. Direct Observation of Superconducting Gap in Electron-Doped NCCO

Figure 3(a) shows ARPES spectra at 10 K of $Nd_{1.85}Ce_{0.15}CuO_4$ (NCCO, T_c=22 K) measured at two representative k-points. At Fermi vector (k_F) along (π, 0)-(π, π), we clearly find a leading edge shift in NCCO to higher binding energy with respect to the Au reference, showing that superconducting gap opens. On the other hand, leading edge along (0, 0)-(π, π) does not show any remarkable shifts. These clearly indicate that NCCO has an anisotropic $d_{x^2-y^2}$-like superconducting gap, as in the case of hole-doped HTSCs. Furthermore, size of the gap in NCCO is found to be much smaller than that of hole-doped Pb-Bi2201 (Fig.3 (b)), although the T_c's are similar between the two.

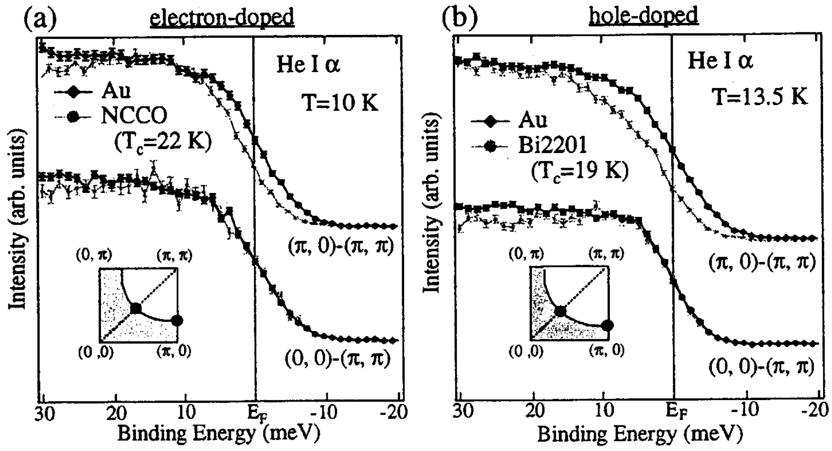

Fig. 3 Comparison of ARPES spectra in the vicinity of E_F at the superconducting state between (a) $Nd_{1.85}Ce_{0.15}CuO_4$(T_c=22 K) and (b) Pb-Bi2201(T_c=19 K). Spectra of Au are also shown as a reference.

V. Summary

Above experimental facts show that electron- and hole-doped HTSCs share common features in the topology of FS and the symmetry of superconducting gap. This indicates that essential framework of the superconductivity is the same between electron- and hole-doped HTSCs.