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Kink energy in the trilayer high-T_c cuprate superconductor $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$

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Introduction

To elucidate the mechanism of high-T_c superconductivity in the cuprates, it is necessary to identify characteristics of materials with higher T_c. $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi2223) which has three CuO_2 layers show the highest T_c (~110 K) in the Bi-based high-T_c cuprate superconductors [1].

In recent angle-resolved photoemission spectroscopy (ARPES) studies, kink in the quasi-particle (QP) dispersion due to strong electron-boson coupling is thought to be related to origin of superconductivity [2]. According to the strong-coupling BCS theory, the kink appears at energies Ω and Ω+Δ in the normal and superconducting states, respectively, where Ω is the energy of the boson mode and Δ is the superconducting gap [3, 4]. It is important to see how the electronic structure and the dispersion kink change in compounds with higher T_c such as Bi2223.

Experimental condition

Single crystals of optimally doped Bi2223 (T_c = 110 K) were grown by the floating zone technique. ARPES experiments were carried out using a SES-2002 analyzer at BL - 28A. The energy and momentum resolution was at 18 meV and ~0.5 deg, respectively. Measurements were performed at 10 K and 120 K.

Result and Discussion

Figure 1(a) and (b) shows the intensity plots in energy-momentum space of the ARPES spectra from the nodal to the anti-nodal region measured at 10 K and 120 K, respectively. The QP dispersion determined by taking the peak positions of the momentum distribution curves (MDCs) in shown by red dots in Fig. 1(a) and (b). Red arrows in the figure indicate the energy position of the kink in the dispersion. Here, the kink energy is defined by the energy position where the QP dispersion shows the largest deviation from the bare band indicated by straight blue lines. The energy position of the kink is plotted as a function of momentum on the Fermi surface (FS) angle (ϕ) in Fig 1(c). In the superconducting state, the energy of the kink shows nearly a constant value of ~70 meV on the entire FS. In the normal state, the kink energy becomes dependent on ϕ, varying from ~70 meV (ϕ ~45 degree) to ~45 meV (ϕ ~ 20 degree). This is similar to the previous ARPES result on Bi2212 [5], where the kink energy in the anti-nodal kink in the normal state was interpreted as due to the B_{1g} bond-buckling phonon, and the present result is consistent with this picture, although the crystal structures are different between Bi2212 and Bi2223.

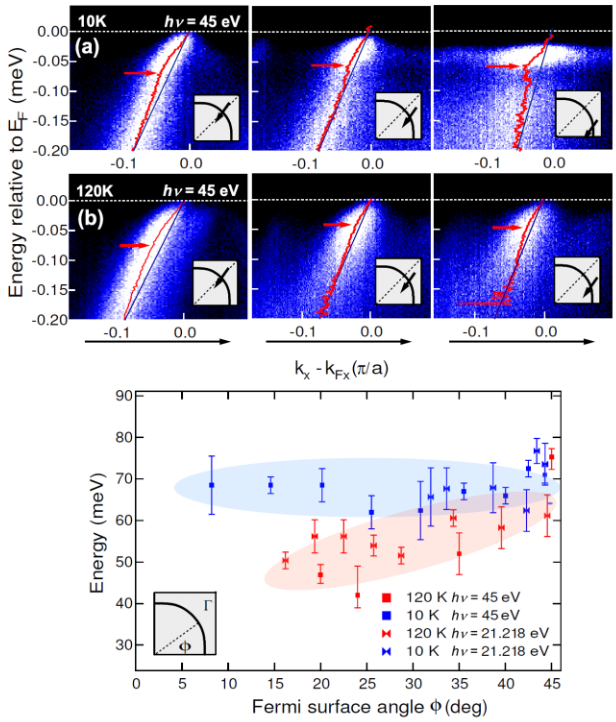

Figure 1: Kink in the ARPES spectra of Bi2223 in the superconducting (10 K) and normal (120 K) states. (a) ARPES intensity plots in *E-k* space showing the QP dispersions from the nodal to the antinodal region in the superconducting state. Horizontal arrows indicate the kink positions. Corresponding momentum cut is shown in the inset of each panel. (b) ARPES intensity plots in the normal state. Red dots and blue straight lines indicate the MDC peak positions and bare bands, respectively. (c) Kink energy in the superconducting and normal states as a function of FS angle (ϕ) defined in the inset.

Summary

The kink energy in the anti-nodal region changes from ~70 meV in the superconducting state to ~45 meV in the normal state, whereas the kink energy in the anti-nodal region ~70 meV does not changed with temperature. This behavior is consistent with electron-phonon coupling, if we assume that the B_{1g} bond-buckling phonon is coupled to the anti-nodal states in the superconducting state.

References

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