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Gap inhomogeneity in $Bi_2Sr_2CaCu_2O_{8+\delta}$ revealed by laser micro-ARPES

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Since the discovery of the high-T_c superconductivity in copper oxides (cuprates), the cuprate superconductors have been extensively investigated experimentally and theoretically. Nevertheless, the mechanism of the high-T_c superconductivity has not been clarified yet. The order parameter, the superconducting gap, of the high-T_c superconductivity has been particularly investigated. Angle-resolved photoemission spectroscopy is known as the powerful tool to prove the superconducting gap in a momentum-resolved manner, which fingerprinted the d-wave gap symmetry. On the other hand, scanning tunneling spectroscopy/microscopy allows to observe the superconducting gap, and the nano-scale inhomogeneity was in the real-space was reported in $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) [1]. However, such real-space inhomogeneity has not been fully considered in the conventional ARPES studies due to its poor spatial resolution (~ mm scale). To overcome this problem and study the evolution of the superconducting gap in the real- and momentum-space, we have performed high-resolution micro-ARPES experiments on underdoped Bi2212 (T_c = 65 K) using a micro-focused laser ($h\nu$ = 6 eV) at the Hiroshima Synchrotron Radiation Center, Hiroshima University.

Figure 1(a) shows the ARPES image of the underdoped Bi2212 taken along the nodal direction (see inset) in the superconducting state (T = 20 K). We have then measured such a clear band dispersion from the nodal to the off-nodal direction (see inset) and evaluated the momentum dependence of the gap. In addition, we have also examined the real-space dependence of the superconducting gap by performing the same measurement while slightly changing the measurement position on the sample surface. Figure 1(b) compares the momentum dependence on the gap magnitude taken from the two different measurement positions (A and B). We found that the gap magnitude and its momentum dependence are clearly different in spite of the small difference (less than 0.1 mm) on the measurement position. To examine the momentum dependence quantitatively, we fit the experimental results by the gap function [2]: $\Delta(\theta) = \Delta^N \sin 2\theta + (\Delta^* - \Delta^N)(3\sin 2\theta - \sin 6\theta)/4$, where the Δ^N is the nodal gap (superconducting gap), the Δ^* is the antinodal gap (pseudogap), and the θ is the Fermi surface angle. The fitting analysis showed that the antinodal gap for position A is larger than one for position B, while the nodal gap for position A is smaller than one for position B. In other words, our results suggest the inverse correlation between the superconducting gap and the pseudogap. In this talk, we will discuss the observed real-space and momentum-space dependence on the superconducting gap and the pseudogap in detail.

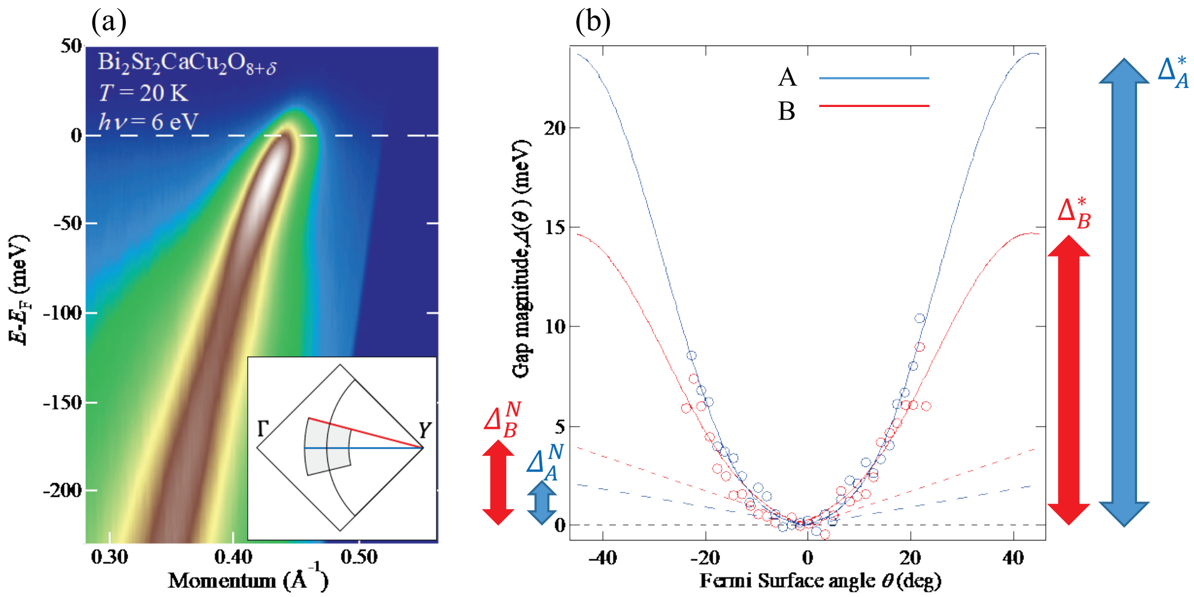

FIGURE 1. (a) ARPES image of underdoped Bi2212 (T_c= 65 K) taken along the nodal direction, where the inset shows the schematic diagram of the Fermi surface due to the antibonding band of Bi2212 (Blue line: nodal direction, red line: off-nodal direction). (b) The momentum dependence of the gap magnitude taken at the two different measurement positions (A and B). The arrows on both sides indicate the magnitude of the nodal and antinodal gap.

REFERENCES

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