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Observation of superconducting gap in underdoped $La_{2-x}Sr_xCuO_4$

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Introduction

In the studies of high-T_c cuprate superconductors, it has been a long standing issue whether the pseudogap is a distinct phenomenon from superconductivity or a gap due to incoherent superconducting fluctuations above T_c. In the underdoped cuprates, the momentum dependence of the gap size at low temperatures deviates from the simple *d*-wave form in the anti-nodal region [1], suggesting that ordering different from superconductivity affects the anti-nodal region. In the optimally doped $La_{2-x}Sr_xCuO_4$ (LSCO), a clear superconducting peak was observed around the momentum between the node and off-node [2], but not in the anti-nodal region. In order to get more insight into this issue, we have performed an angle-resolved photoemission study (ARPES) of underdoped LSCO and detected the superconducting gap in the anti-nodal and the off-nodal regions.

Experiment

ARPES measurements were performed at Beamline 28A of Photon Factory with a Scienta SES-2002 electron analyzer. The energy and angular resolutions were about 18 meV and 0.3 degree, respectively. Single crystals of LSCO (x=0.10, T_c=28K) were grown using the travelling-solvent floating zone method. Samples were first aligned *ex situ* using Laue diffraction, cleaved *in situ.* Measurements were performed at 15 K and 32 K.

Results and Discussions

Figures 1 (a) and (b) show ARPES spectra around the anti-nodal and the off-nodal directions as indicated in inset. In order to see superconducting and/or pseudogap opening, we have plotted integrated ARPES spectra taken at below and above T_c [Fig. 1 (c)(d)]. These spectra are divided by the Fermi-Dirac function broadened by the energy resolution. In panel (d), while the off-node spectrum below T_c shows a clear energy gap, that above T_c does not, indicating that the superconducting gap closes above T_c. On the other hand, as shown in panel (c), a dip of the intensity at E_F still survives above T_c, indicating the pseudogap. The contrasting behaviors between the off-node and the anti-node spectra are consistent with the recent observation of the superconducting/pseudo gap in $Bi_2Sr_2CaCu_2O_{8+\delta}$ [4]. The present result indicates that the superconductivity in the off-nodal region has a canonical (BCS-like) property.

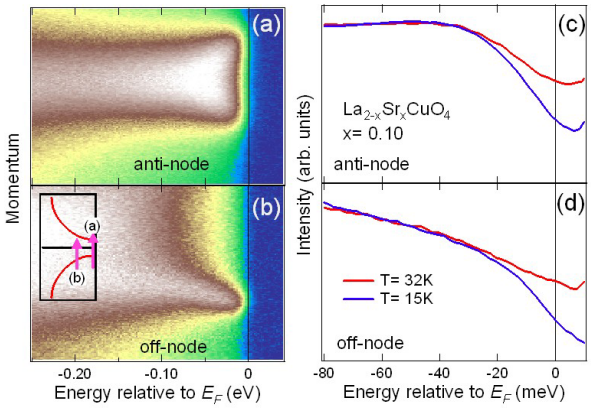

Figure 1: Photoemission spectra of LSCO (x=0.10). (a) (b) ARPES spectra taken at T=15K around the anti-nodal region and the off-nodal regions, respectively. (c)(d) Integrated ARPES spectra along the cut shown in the inset. These spectra have been divided by the Fermi-Dirac function broadened by the energy resolution.

References

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