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Annealing effects in electron-doped cuprate $Nd_{1.85}Ce_{0.15}CuO_4$

Masaki IKEDA*[1], Teppei YOSHIDA[2], Atsushi FUJIMORI[1,2], Masato KUBOTA[3], Kanta ONO[3], Yoshihiro KAGA[4], Takao SASAGAWA[4,5], Hidenori TAKAGI[4]
[1]Department of Complexity Science and Engineering, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[2]Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[3]KEK-PF, Oho, Tsukuba, Ibaraki 305-0801, Japan
[4]Department of Advanced Materials Science, University of Tokyo, Kashiwanoha, Kashiwa, Chiba 277-8561, Japan
[5]Materials and Structures Laboratory, Tokyo Institute of Technology, Nagatsuta, Midori-ku, Yokohama, Kanagawa, 226-8503, Japan

Introduction

In electron-doped high-T_c superconductors (HTSCs), in order to induce superconductivity, it is necessary to anneal the samples after the Ce^{4+} substitution for the trivalent lanthanide ion, unlike the case of hole-doped HTSCs. Hence, in electron-doped HTSCs, one can adjust T_c not only by Ce concentration but also by the annealing process. Although the variation of physical properties with Ce substitution has been extensively investigated, with annealing process has not been explored much. Particularly, insufficient knowledge for the development of electronic structures by annealing process prevents us from clarifying how the annealing induces superconductivity. In order to resolve the above problem, we have performed angle-resolved photoemission spectroscopy (ARPES) studies for as-grown $Nd_{1.85}Ce_{0.15}CuO_4$ (ag-NCCO) and annealed $Nd_{1.85}Ce_{0.15}CuO_4$ (an-NCCO).

Experiment

High-quality single crystals of optimally doped $Nd_{1.85}Ce_{0.15}CuO_4$ were grown by the traveling solvent floating zone method. The T_c of an-NCCO was ~22 K while ag-NCCO did not show superconductivity. The ARPES measurements were performed at beamline 28A of Photon Factory (PF), Institute of Materials Structure Science, High Energy Accelerators Research Organization (KEK), using incident photons with 55 eV. We used a five-axis manipulator and a SCIENTA SES-2002 electron-energy analyzer in the angle mode. The measurements were made at ~10 K with energy resolution of 15 meV.

Results and Discussion

Figure 1 shows the plot of ARPES intensity near E_F in an-NCCO and ag-NCCO as a function of two-dimensional momentum [1]. The suppression of the intensity is seen near the hot spots, which are the intersecting point of the underlying Fermi surface and the antiferromagnetic Brillouin zone boundary. This is due to the (π, π) scattering of electrons as discussed in the previous ARPES studies [2]. Also, one can recognize that the spectral intensity around (π/2, π/2) in an-NCCO is stronger than that in ag-NCCO. This suggests that the gap may open around the nodal region in ag-NCCO, indicating strong effects of antiferromagnetism. The difference in the electronic structures around the nodal region may explain the results from other experiments. The low electrical resistivity of ag-NCCO compared with an-NCCO is due to the nodal gap opening in ag-NCCO. This may also demonstrate the results of optical studies where the pseudogap was not observed in an-NCCO but in ag-NCCO at low temperature [3]. That is, due to the wide gap opening region in ag-NCCO compared with an-NCCO, the pseudogap feature was clearly observed.

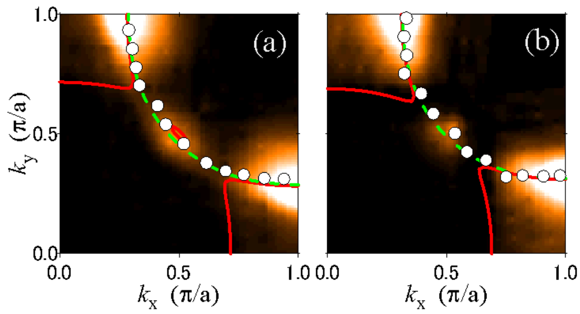

Figure 1: Plot of ARPES intensity at E_F for an-NCCO (a) and ag-NCCO (b) as a function of the two-dimensional wave vector (k_x, k_y). Energy distribution curves have been integrated within a ±30 meV window around E_F. White circles show peaks in momentum distribution curves. Red solid curves and green dashed curves show the Fermi surface obtained by tight-binding fit assuming the antiferromagnetic and paramagnetic states, respectively.

References

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* m_ikeda@wyvern.phys.s.u-tokyo.ac.jp