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Chemical pressure effects in electron-doped cuprates

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Introduction

Pressure effects in high-T_c superconductors (HTSCs) have attracted much interest due to the dramatic increase of T_c [1]. Hence, it has strongly been desired to study the pressure dependence of the electronic structures of HTSC's. However, it is hard to investigate the electronic structures under physical pressure by photoemission spectroscopy, which is the most powerful technique to investigate electronic structures. Here, we utilized chemical pressure induced by the lanthanide substitution in the electron-doped HTSCs $Ln_{1.85}Ce_{0.15}CuO_4$ (Ln = La, Pr, Nd, Sm, Eu). As the ionic radius of the Ln^{3+} ion becomes small in this system, both the lattice constant a and c monotonically decrease [2], indicating that the chemical pressure becomes large. We have performed an angle-resolved photoemission (ARPES) study of $Ln_{1.85}Ce_{0.15}CuO_4$ (Ln = Nd, Sm, Eu) and investigated how the electronic structure changes with chemical pressure.

Experiment

High-quality single crystals of optimally doped $Nd_{1.85}Ce_{0.15}CuO_4$ (NCCO), $Sm_{1.85}Ce_{0.15}CuO_4$ (SCCO) and $Eu_{1.85}Ce_{0.15}CuO_4$ (ECCO) were grown by the travelling solvent floating zone method. T_c of NCCO, SCCO, and ECCO were 22 K, 16 K, and 0 K, respectively. The ARPES measurements were performed at beamline 28A of Photon Factory, using incident photons with energy of 55 eV. We used a SCIENTA SES-2002 electron-energy analyzer and a five axes manipulator [3]. Samples were cleaved *in situ* under an ultrahigh vacuum of 10^{-9} Pa to obtain clean surfaces. We made the ARPES measurements at 10 K with the energy resolution of 15 meV.

Results and Discussion

Figures 1 shows the plot of ARPES intensity near E_F in NCCO, SCCO, and ECCO in the two-dimensional wave vector space. In Fig. 1, one can recognize that the curvature of the Fermi surface in NCCO is the largest among the three compounds. In order to quantitatively evaluate the difference of the curvature among the three samples, we performed a tight-binding analysis of the ARPES spectra. In this analysis, the parameter $-t'/t$ represents the curvature of the Fermi surface. We fitted the calculated band to the MDC peak positions as shown in Fig.1, and obtained $-t'/t$ = 0.20, 0.12, and 0.11 for NCCO, SCCO, and ECCO, respectively. This means that the curvature of the Fermi surface monotonically decreases from NCCO to SCCO to ECCO. That is, the higher the chemical pressure becomes, the smaller the curvature of the Fermi surface becomes.

According to the ARPES results of $La_{2-x}Sr_xCuO_4$ thin films, the reduced in-plane lattice constant a by compressive strain leads to a decrease of $-t'/t$ [4]. This trend is consistent with the present results of the electron-doped system. Therefore, from this report and our results, we consider that the small a-axis resulted in the small value of $-t'/t$ irrespective of whether chemical pressure or strain is used, and whether the doped carriers are holes or electrons.

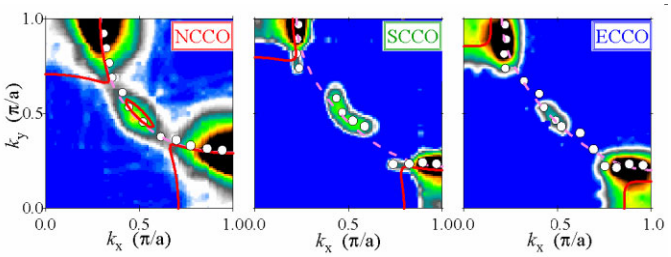

Figure 1: Plot of ARPES intensity at E_F in NCCO, SCCO, and ECCO in the two-dimensional wave vector (k_x, k_y) space. Energy distribution curves have been integrated within a 60 meV window around E_F. The data were taken over a Brillouin zone octant and symmetrized with respect to the (0,0) to (π, π) line. White dots show peaks in momentum distribution curves (MDCs), indicating the Fermi surface. Solid red curves and dashed pink curves show the Fermi surfaces obtained by tight-binding fit in the paramagnetic and antiferromagnetic states, respectively.

References

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