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Electronic structure of the five-fold oxygen-coordinated cuprate $SmLa_{1-x}Sr_xCuO_4$

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1 Introduction

While high-temperature superconductivity in cuprates occurs within the CuO_2 planes, superconducting properties depend significantly on apical-oxygen atoms placed right above or below the Cu atoms. For hole-doped six-fold oxygen coordinated cuprates, it is known that higher superconducting transition temperature T_c is realized with large apical oxygen distance from CuO_2 planes [1]. However, comparisons are often limited to materials with different types of crystal structure. Since properties of the block layer, which separates CuO_2 planes, could also affect superconducting properties [2], a thorough comparison of electronic structure within the same material class is desired.

In that perspective, so-called 214-type cuprates provide a unique platform. The local oxygen coordination around Cu can be varied from six-fold octahedral (T-type) to four-fold square planner (T'-type) ones. However, the T'-type cuprates cannot be easily doped with holes [3] and hence a comparison with the T-type counterpart is not straightforward. On the other hand, the T*-type cuprates with five-fold pyramidal oxygen coordination can be hole doped and thus are directly comparable with the T-type ones [4]. An optical conductivity study [5] has revealed a smaller charge transfer gap for the T*-type cuprates than the T-type counterpart, suggesting a smaller effective onsite interaction. While the electronic structure of the T-type cuprate $La_{2-x}Sr_xCuO_4$ (LSCO) is well documented [6], experimental reports on the T*-type ones are sparce. Aiming at making comparison with T-LSCO, we thus carried out an angle-resolved photoemission spectroscopy (ARPES) measurements of the T*-type cuprates.

2 Experiment

Single crystals of T*-type $Sm_{1-x}LaSr_xCuO_4$ (SLSCO, x = 0.25) were grown by the traveling solvent floating-zone method. The samples were O_2-annealed at 500 ◦C and 45 MPa for 72 hours. The sample showed superconductivity below T_c = 17 K. This value is consistent with the known trend in the doping range of x = 0.10 − 0.225 [7]. ARPES measurements were performed at BL28A of Photon Factory. Photon energies were set at hv = 105 eV and the total energy resolution at 35 meV. Samples were cleaved *in-situ* and measured at T = 20 K.

3 Results and Discussion

Figure 1 displays ARPES spectra obtained from T*-SLSCO (x = 0.25). While the quasiparticle dispersion reaches the Fermi level in the nodal direction (cut #1), the spectrum is gapped in the antinodal region (cut #3), yielding a Fermi arc. We fitted the (underlying) Fermi surface to the tight-binding model $\epsilon - \mu = \epsilon_0 - 2t[\cos(k_x a) + \cos(k_y a)] - 4t'\cos(k_x a)\cos(k_y a) - 2t''[\cos(2k_x a) + \cos(2k_y a)]$, where t, t', and t'' represent nearest, second-nearest, and third-nearest neighbor hopping parameters, respectively, and ϵ_0 is the center of the band relative to the chemical potential μ. The fitted Fermi surface area yield the hole doping level of 0.00, which is unrealistic considering the existence of the nodal quasiparticle. This inconsistency

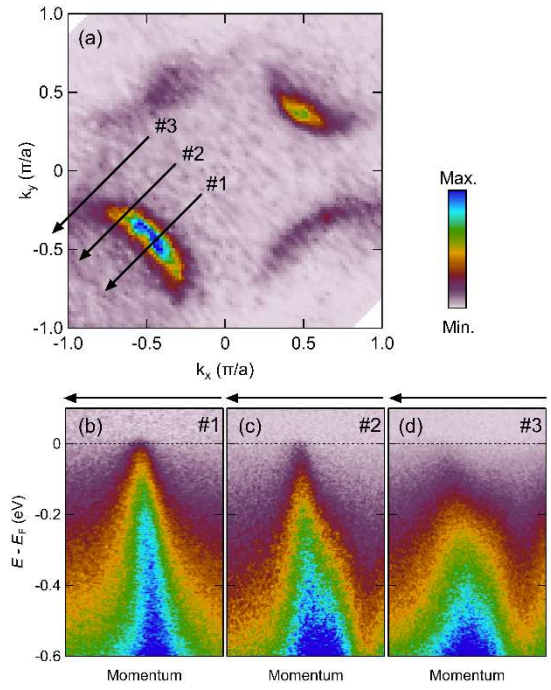

Fig. 1: ARPES spectra of T*-SLSCO (x = 0.25). (a) Fermi surface map obtained by integrating spectral intensity within ±20 meV around the Fermi level. (b)-(d) Energy momentum maps measured along cuts #1-#3 indicated in panel (a), respectively.

suggests the breakdown of the Luttinger's sum rule under the assumption of the large hole-like Fermi surface centered at (π, π). This is in contrast to the case of T-LSCO whose Fermi surface is known to obey the Luttinger's sum rule even in the heavily underdoped region [8]. The difference is likely associated with the difference of the oxygen coordination and hence the difference of on-site effective interaction.

References

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