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The electronic structure change induced by stripe phase formation in cuprates

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Abstract

It has been suggested that the stripe phase shows 1D charge transport in the CuO_2 planes instead of the 2D characteristics of the Zhang–Rice band. X-ray absorption near edge spectroscopy (XANES) has been used to study the electronic structure of the stripe phase compounds $La_{2-x}Sr_xCuO_4$, and $La_{2-x-y}Nd_ySr_xCuO_4$ for x around 1/8. The measurements were performed at both 300 and 28 K to examine the possible electronic structure change above and below the temperature of the stripe phase formation.

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The 1/8 anomaly in the La-based cuprates had been puzzling since the high-T_c era until the explanation of the stripe phase formation was finally proposed [1]. The stripe phase is the static order of spins and holes. It is believed that the one-dimensional (1D) spin-charge modulations exist in the two-dimensional (2D) CuO_2 planes. There is still much to learn about the stripe phase. It has been suggested that the stripe phase shows 1D charge transport in the CuO_2 planes instead of the 2D characteristics of the Zhang–Rice band. This scenario was supported by the resistivity and Hall measurements in the related compounds [2]. However, the studies of the corresponding 2D–1D electronic structure change are still in absence except a photoemission work [3]. X-ray absorption near edge spectroscopy (XANES) has proven to be an effective tool to investigate the hole states in the complex compounds [4]. In this paper, we report the preliminary results of XANES on $La_{2-x}Sr_xCuO_4$ and $La_{2-x-y}Nd_ySr_xCuO_4$, and aim to shed light on the possible electronic structure changes of the stripe phase.

$La_{2-x}Sr_xCuO_4$ and $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ samples were prepared by the standard solid state reaction. X-ray diffraction patterns indicate no impurity phase in both kinds of compounds. At room temperature, $La_{2-x}Sr_xCuO_4$ is tetragonal for $x = 0.12$–0.16, and $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ is orthorhombic for $x = 0.1225$–0.13 in this study. Fig. 1 shows resistivity $\rho(T)$ for $La_{2-x}Sr_xCuO_4$ and $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ samples. For $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$, the kinks of $\rho(T)$ at about 80 K for all samples are manifestations of the low-temperature orthorhombic (LTO) to low-temperature tetragonal (LTT) structure phase transition. LTT could help stabilize the stripe phase and suppress superconductivity in samples [2].

If the 2D charge transport in CuO_2 planes does change to the 1D transport due to the stripe phase formation, there ought to be a corresponding electronic structure evolution. To study the electronic structure of the stripe phase compounds, XANES was performed on the two samples with the lowest T_c in each set of the samples shown in Fig. 2(a) and (b), respectively

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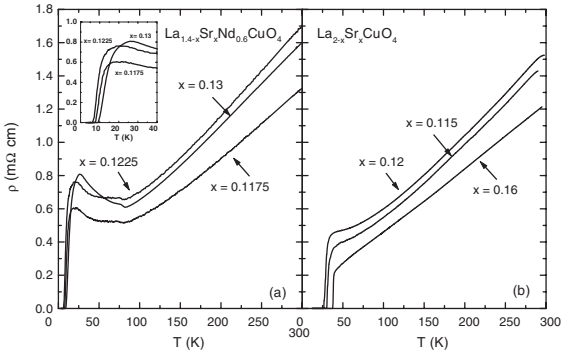

Fig. 1. $\rho(T)$ of (a) $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ and (b) $La_{2-x}Sr_xCuO_4$.

($x = 0.12$ for $La_{2-x}Sr_xCuO_4$ and $x = 0.1225$ for $La_{1.4-x}$-$Nd_{0.6}Sr_xCuO_4$). In order to investigate the possible changes due to the stripe phase formation, the spectra were taken at 300 and 28 K, respectively. The results of XANES are shown in Fig. 2. The spectral weight around 528.5 eV corresponds to the Zhang–Rice (ZR) states when the stripe phase is absent. The spectral weight around 530.5 eV for $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ and around 530 eV for $La_{2-x}Sr_xCuO_4$ is associated with the upper Hubbard band (UHB). At the first glance, the spectra look similar either with or without the stripe phase for both samples. According to infrared spectroscopy, the electromagnetic response of both $La_{2-x}Sr_xCuO_4$ and $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ is similar, although a low frequency peak in the far-infrared conductivity of $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ was observed while not in that of $La_{2-x}Sr_xCuO_4$ [5]. However, the spectral weight of UHB is significantly enhanced at 28 K (Fig. 2(a)) for $La_{1.4-x}$-$Nd_{0.6}Sr_xCuO_4$, which indicates the weakening of the original ZR states. Furthermore, the peak associated with ZR band in Fig. 2(a), tends to split into two peaks at 28 K, suggesting a possible electronic structure change. This change has to be further confirmed by spectra with better resolution, which are currently under way.

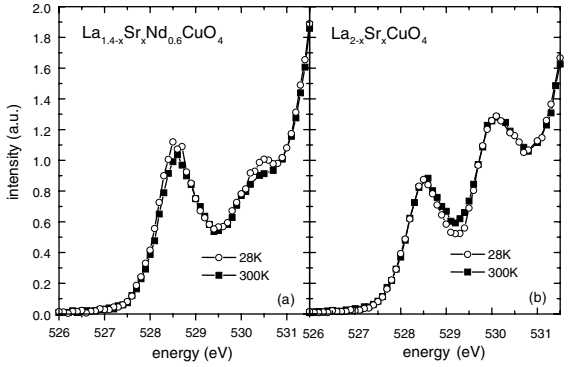

Fig. 2. XANES of (a) $La_{1.4-x}Nd_{0.6}Sr_xCuO_4$ and (b) $La_{2-x}Sr_xCuO_4$ with $x = 0.1225$ and 0.12 in (a) and (b), respectively. Data at 28 K might manifest the stripe phase formation or fluctuations.

In summary, some intriguing results of XANES on possible stripe phase samples were observed. These changes in XANES could be due to the stripe phase fluctuations.

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