Local Lattice Distortions in $YBa_2Cu_3O_y$ Probed by XAS: Critical Fluctuation, Peudogap Opening and Stripe Ordering

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Introduction

Since the discovery of HTSC, numerous efforts have been taken to understand the mechanism of pairing. Up to now, however, attempts to *consistently and quantitatively* explain the mechanism of HTSC and normal-state properties have failed. This fact simply cast doubts on some of the fundamental assumptions. For instance, theories based on magnetic interactions (spin fluctuations) assume that HTSC occurs in a *homogeneous* two-dimensional CuO_2 planes. However, a number of experiments recently demonstrated that the CuO_2 plane is rather *inhomogeneous* in microscopic viewpoints. Common understanding is that the basal plane is characterized by two domains with distorted and undistorted local structures, which forms stripe-order under certain conditions. The present study was aimed at ilucidating mesoscopic-scale inhomogeniety and dynamical lattice anomalies in $Yba_2Cu_3O_7$.

Results and Discussion

In Fig. 1, the magnitude of FT for E//*c* geometry is shown as a function of temperature for the Cu-O pair. The magnitude for the Cu-O pair is not a smooth function of temperature showing deviation from a Debye-like behavior. Here, temperatures T_1 and T_2 indicate the two characteristic temperatures for the lattice anomalies found for the apical Cu-O correlations. A pronounced deviation from a normal phonon contribution begins at T_1 ~240-250 K followed by an upturn below T_2~140-150 K where T_2 ~T^*. The temperature range where the FT magnitude shows asymmetric pattern due to the distorted domain is indicated as an open box. The local lattice distortion indicating stripe ordering seems to occur at the crossover temperature T^*. This suggests that the phase separation and subsequent stripe ordering take place as the pseudogap is opened. Secondly, the high temperature anomaly occurs at T_1 where the elastic anomalies such as internal friction $Q^{-1}$and ion channeling were reported. In fact, these two experiments reported similar values for the temperatures (T_1, T_2) for lattice anomalies above T_c. The fact that only the Cu-O correlation has an unusual temperature dependence shows that *the unusual lattice response is due to the displacement of oxygen atoms*, in agreement with the recent report of LO phonon anomalies observed in neutron scattering involving half breezing mode of oxygen atoms. However, even more striking point is the fact that the FT magnitude peak intensity increases after the two domains are formed below T^*.

We report the temperature-dependent local lattice distortion (LLD) in $YBa_2Cu_3O_7$ single crystals using *ab*-plane and *c*-axis polarized Cu K-EXAFS. The results indicate that *the anomalous displacement occurs at oxygen sites*. The apical Cu-O and in-plane Cu-O correlation shows the evolution of asymmetric distribution indicating the oxygen atom displacement below tthe characteristic temperatures T_2~T^* (140-150 K) and T_1 (240-250 K). The asymmetric oxygen distribution appears below T^* in both orientations, indicating the stripe ordering occurs below the pseudogap opening temperature. Another unusual temperature dependence of LLD is the increase of mean-square relative displacement below T_1 followed by a suppression after the stripe order is formed. For optimum doping "quantum critical fluctuation" may exist at the cross-over temperature T^* leading to the quantum critical point at T = 0. When the fluctuation exceeds this limit, pseudogap opening and electronic phase separation seem to occur. At T_1 and T_2 giving the anomalies in MSRD, the elastic and lattice anomalies are observed. The present results demonstrate that stripe order and pseudogap opening are correlated [1]. We conjecture that *stripe ordering stabilizes the charge fluctuation*. Below T^*, in-plane optical conductivity changes from a single-component to two-component carrier regime, consistent with a charge and lattice stripe.

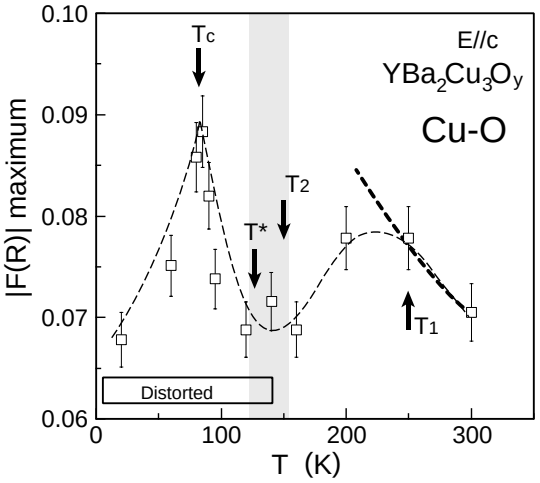

Fig.1 FT magnitude as a function of temperature.

References

[1] H. Oyanagi et al., Int. J. of Mod. Phys. B14 (2000) 3623.

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