Role of Hole Doping in High T_c Superconductors by XAS Technique

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Introduction

Charge carrier concentration in CuO_2 planes, plays an important role in high T_c superconductors (HTSC). The transition temperature (T_c) in HTSC is very sensitive to the hole concentration. We have achieved an increase in both (T_c) and the critical current density (J_c) of Hg-1223 through F substitution for oxygen. These improvements are due to optimizations of the hole concentration in the CuO_2 planes. In this work, we report results of the x-ray absorption near-edge structure (XANES) on Hg-Pb-1223 to study the effect of hole doping and on the electronic structure through anion substitution (F for O)

Experimental

Samples were prepared using the solid state reaction method. Characterizations and measurements of superconducting properties for samples with different hole densities were published elsewhere.[1-3]. The XANES measurements were performed at b.l 9.3.2 at the Advanced Light Source. Total electron yield mode of measuring the absorption spectrum was used. All the measurements were done with an ultra-high resolving power (~10000) with resolution better than ~100 meV.

Results

We have found that F enhances both J_c and T_c of this system [1-3]. We have attributed that to the gradual increase in the hole concentration in the CuO_2 planes of the originally slightly under-doped Hg-1223 system. These speculations were made based on the variation of the superconducting, electrical, magnetic and structural properties of the system as fluorine was introduced. In this study, we have directly measured the density of holes in various planes of this system by measuring the O K-edge and Cu $L_{2,3}$ edges as a function of fluorine content x.

Figure 1 is the Cu L_3 edge for the of samples as a function of x. The strong Peak A is attributed to transitions from $Cu(2p_{3/2,1/2})^{-1}3d^9$-$O2p^6$ ground state to $Cu(2p_{3/2,1/2})3d^{10}$ -O 2p excited state, where $(2p_{3/2})^{-1}$ denotes a $(2P_{3/2})$ holes. This will give rise to a copper final state of $[1s^22s^22p^53s^23p^63d^{10}4s^04p^0]$. This peak is a signature of Cu^{2+}[4]. The shoulder B at the higher energy side of the main feature A, is assigned to excitations of the $Cu(2p_{3/2,1/2})3d^9L$ ground states to the $Cu(2p_{3/2,1/2})^{-1}3d^{10}L$ exited states, where L denotes O 2p ligand hole, is a signature of Cu^{3+} states[5]. The wide feature C is attributed to Cu^{1+} state. The increase in the intensity of peak B and the decrease in that of C with increasing F content, are consistent with the observed O k edge behavior and with the improvements in the superconducting properties of this originally under-doped system.

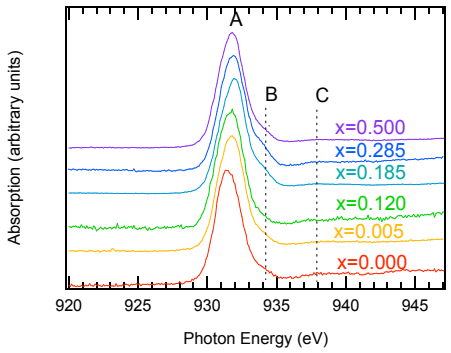

FIGURE 1. Cu L_3 edge of HgPb-1223/Fx.

Conclusions

We have found that the hole concentration in the Cu-O_2 planes of Hg-1223 increases with fluorine addition. As we have indicated earlier fluorine replaces the apical oxygen site in Hg-O plane, which has low occupancy.

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