H3. BOND-STRETCHING PHONON ANOMALY REFLECTING DYNAMIC CHARGE INHOMOGENEITY IN COPPEROXIDE SUPERCONDUCTORS

D. REZNIK[1,2], L. PINTSCHOVIUS[1], M. ITO[3], S. IIKUBO[3], M. SATO[3], H. GOKA[4*], M. FUJITA[4], K. YAMADA[4], G. D. GU[5], AND J.M. TRANQUADA[5]

[1] Forschungszentrum Karlsruhe, Institut für Festkörperphysik, P.O.B. 3640, D-76021 Karlsruhe, Germany
[2] Laboratoire Léon Brillouin, CE Saclay, F-91191 Gif-sur-Yvette Cedex, France
[3] Department of Physics, Division of Materials Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8602, Japan
[4] Institute for Material Research, Tohoku University, Katahira, Aoba-ku, Sendai, 980-8577, Japan.
[5] Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory, Upton, New York 11973-5000, USA

While many believe that antiferromag-netism is important for the high-temperature superconduc-tivity, there has been resurgent interest in the role of electron-lattice coupling. The Karlsruhe group, in collaboration with others, has been investigating electron-phonon coupling due to charge inhomoge-neities in copper oxide superconductors. This work focused on detailed measurements of optic oxygen modes believed to couple most strongly to dynamic charge inhomogeneity. The 1T spectrometer is ideally suited for such a study, as its performance is optimized for the high energies of these phonons. A collaboration with the theory group in Karlsruhe (K-P. Bohnen and R. Heid), made it possible to compare experimental results to predictions of band theory and thus separate the conventional Fermi-liquid physics from still poorly understood correlation effects.

Band theory works remarkably well for predicting electron-phonon effects in the recently studied conventional superconductors MgB_2 and YNi_2B_2C. They have a very strong electron-lattice coupling involving a particular phonon that was predicted by band theory and confirmed quantitatively by experiment. Our inelastic neutron scattering meas-ure-ments showed that there is a similarly strong anomaly in the Cu-O bond-stretching phonon in cuprate superconductors La^{2}-$_{x}Sr_{x}CuO_4$ (x = 0.07, 0.15) and in $YBa_2Cu_3O_{6+x}$ (x = 0.6, 0.95); however, this behavior is completely absent in band theory calculations. Instead, the anomaly is strongest in $La_{1.875}Ba_{0.125}CuO_4$ and $La_{1.48}Nd_{0.4}Sr_{0.12}CuO_4$, compounds that exhibit spatially modulated long-range charge and magnetic order, often called stripe order. It occurs at a wave vector corresponding to the charge order.

Stripe order is known to result from strong electron-electron correlations due to Mott physics. While the static stripe compounds are not superconductors, many believe that dynamic stripes play a crucial role in the physics of the cuprates and, possibly, in the mechanism of high T_c superconductivity. Existence of dynamic stripes is still controversial. Observation of a very similar anomaly in compounds with and without static stripes suggests that they may be present throughout the doping range associated with superconductivity (the anomaly is absent in undoped and overdoped non-superconductors).

More importantly, the phonon measurements conclusively demonstrated that a strong charge fluctuation, not predicted by band theory, is present in copper oxide superconductors and that it strongly couples to phonons. It follows that electron-phonon coupling may be important to understanding the superconductivity although its contribution to the mechanism is likely indirect.

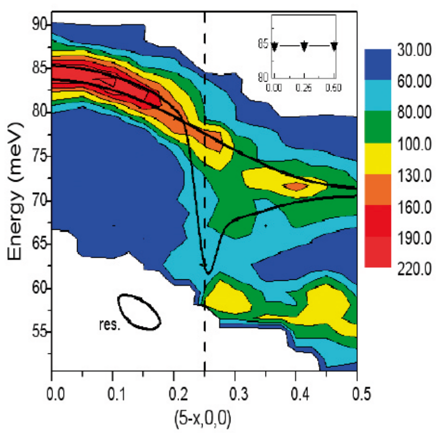

Figure 1. Color-coded contour plot of the intensities observed on $La_{1.875}Ba_{0.125}CuO_4$ at T = 10 K. The intensities above and below 60 meV are associated with plane-polarized Cu-O bond-stretching vibrations and bond-bending vibrations, respectively. Black lines are dispersion curves evaluated from two-peak fits to the data. The white area at the lower left corner of the diagram was not accessible in this experiment. The ellipse illustrates the instrumental resolution. The inset shows the dispersion in the [110]-direction. The dashed line represents the charge–ordering wavevector.

[1] D. Reznik, L. Pintschovius, M. Ito, S. Iikubo, M. Sato, H. Goka, M. Fujita, K. Yamada, G.D. Gu, and J.M. Tranquada, Nature 440, 1170 (2006).

[2] L. Pintschovius, D. Reznik, and K. Yamada, to appear in Phys. Rev. B