Electron-phonon interactions in HTSC cuprates

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The phonon mechanism was discarded early in the study of high-temperature superconductivity (HTSC). But this premature judgment is based on the conventional electron-phonon coupling, while the electron-phonon coupling in strongly correlated systems can be very different. Theories predict that it is strongly dependent on the momentum, energy and the eigenvector. In particular it is predicted that the Cu-O bond-stretching LO mode interacts strongly with charge [1]. We carried out a series of inelastic neutron scattering measurements on single crystals of $YBa_2Cu_3O_{6.95}$. Measurements were made using the triple-axis-spectrometer at the HFIR of the Oak Ridge National Lab. as well as the time-of-flight spectrometer the ISIS of the Rutherford-Appleton Laboratory. We found that the Cu-O bond-stretching LO mode, in particular toward the zone edge, shows anomalous dependences on composition and temperature. The results suggest strong electron-phonon coupling for this mode, in agreement with the recent photoemission results [2]. They also suggest charge inhomogeneity at two lengthscales, atomic and nanometer scale. At the atomic scale short-range dynamic CDW with cell-doubling [3] is suggested, and at the nano-scale they suggest that underdoped samples are made of nano-scale regions of optimally doped and undoped states. These findings challenge the present theories on the origin of HTSC. Since the e-p coupling is highly directional the phonon mechanism is not in conflict with the spin mechanism for the d-wave superconductivity. It is possible that the phonon is the missing link in the HTSC theory.

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