Fluctuating Cu-O-Cu Bond model of high temperature superconductivity in cuprates

D.M. NEWNS, C.C. TSUEI, IBM T.J. Watson Research Center — Twenty years of research have yet to produce a consensus on the origin of high temperature superconductivity (HTS). However, several generic characteristics of cuprate superconductors have emerged as the essential ingredients of and/or constraints on any viable microscopic model of HTS. Besides a $T_c$ of order 100 K, they include a $d$-wave superconducting (SC) gap with Fermi liquid nodal excitations, a pseudogap with $d$-symmetry and the characteristic temperature scale $T^*$, an anomalous doping-dependent oxygen isotope shift, nanometer-scale gap inhomogeneity, etc. The isotope shift implies a key role for oxygen vibrations, but conventional BCS single-phonon coupling is essentially forbidden by symmetry and by the on-site Coulomb interaction $U$. Hence the present work invokes nonlinear coupling of planar oxygen vibrations to the Cu-Cu hopping integral $t$. A dominant Fluctuating Bond field emerges involving oxygen vibrational square amplitudes and associated Cu-Cu $t$'s - in a pattern of quadrupolar symmetry around a given Cu site. Such fluctuations in Cu-Cu bonds mediate $d$-wave pairing, leading to a $d$-wave SC gap, and an explanation of the anomalous isotope shift. A quadrupolar CDW generates a $d$-wave pseudogap related to $T^*$. Other salient features of HTS are also explained by our model. This work is to appear in Nature Physics.