Percolative Theories of Strongly Disordered Ceramic High Temperature Superconductors

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Optimally doped ceramic superconductors (cuprates, pnictides, ...) exhibit transition temperatures Tc much larger than strongly coupled metallic superconductors like Pb, and exhibit many universal features that appear to contradict the BCS theory of superconductivity based on attractive electron-phonon pairing interactions. These complex materials are strongly disordered and contain several competing nanophases which cannot be described effectively by parameterized Hamiltonian models, yet their phase diagrams also exhibit many universal features, not only in the normal state, but in the superconductive state as well. Here we review the rapidly growing body of experimental results which suggest that these universal features are the result of marginal stabilities of the ceramic electronic and lattice structures. These dual marginal stabilities favor both electronic percolation of a dopant network, and rigidity percolation of the deformed lattice network. This double percolation model has previously explained many features of the normal-state transport properties of these materials and is the only theory that has successfully predicted strict lowest upper bounds for Tc in the cuprate and pnictide families. Here it is extended to derive an angular energy gap equation, which rationalizes angularly averaged gapTc ratios, and shows that these are similar to those of conventional strongly coupled superconductors.