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Strong-coupling theory of high-temperature superconductivity beyond BCS

ALEXANDRE ALEXANDROV, Loughborough University, United Kingdom

We have extended the BCS theory to the strong-coupling regime, where carriers are small lattice polarons and bipolarons. Attractive electron correlations are caused by an almost unretarded electron-phonon interaction (EPI) sufficient to overcome the direct intersite Coulomb repulsion in this regime. Here I present our recent theoretical results, which in conjunction with a number of experimental observations provide a definite answer to the fundamental question on a key pairing interaction in high-temperature superconductors. Theoretical studies using advanced numerical (QMC) techniques have shown that purely repulsive models do not account for high- temperature superconductivity [1]. On the other hand our recent QMC studies have found that even a relatively weak finite-range EPI induces substantial d-wave superconducting order in strongly-correlated Mott-Hubbard insulators [2], while the strong EPI provides superlight small bipolarons, which bose-condense at high temperatures [3]. I propose that the true origin of high-temperature superconductivity is found in a proper combination of strong electron-electron correlations with the significant finite-range EPI, so that charge carriers are small mobile polarons and bipolarons in cuprate superconductors. We have shown that the conventional EPI explains the unconventional symmetry of the superconducting order parameter both in the weak-coupling (BCS) and in the strong-coupling (bipolaronic) regimes [4]. Bipolarons account for the normal state diamagnetism [5], unusual ARPES [6], superconducting and normal state (pseu)dogaps in the tunnelling spectra of cuprates [7].

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