Selfconsistent Eliashberg theory of superconductivity in unconventional superconductors

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The Migdal-Eliashberg theory provides a framework for precise calculations of superconductivity in real materials. Although originally formulated for electron-phonon (EP) coupling on the basis of Migdal's theorem [1], the framework can be extended to include spin and charge fluctuations. We employ this framework in the anisotropic, multiband and full-bandwidth formulation to study the superconductivity of a monolayer FeSe on the $SrTiO_3$ (STO) substrate as well as the temperature dependence of the quasiparticle bands. Solving the coupled equations selfconsistently, and with focus on the interfacial EP coupling, we compute a $T_c \approx 60$ K, and a nearly constant Fermi surface with respect to temperature and predict a nontrivial temperature evolution of the global chemical potential [2]. The Cooper pairing mechanism and unusual gap symmetry of bulk FeSe and FeSe on STO have been much debated and display signatures of spin fluctuations (SFs) (see [3]). Including EP coupling, as well as spin and charge fluctuations in multichannel calculations we find, without SFs an *s*-wave gap symmetry and when SFs are present, a nodeless *d*-wave gap, yet the gap magnitude and T_c is due to the interfacial EP coupling [4].

To investigate further the origin of unconventional superconductivity, we extend the framework by including EP vertex corrections beyond Migdal's approximation in nonadiabatic selfconsistent calculations [5]. It is commonly believed that the EP interaction cannot cause a sign-changing gap symmetry. Using only an isotropic EP interaction we show that vertex corrections lead to a *d*-wave order parameter for the high-Tc cuprates and the heavy-fermion $CeCoIn_5$, whereas for Fe-based superconductors we obtain an $s_{\pm}$ gap symmetry, which proves that EP interaction cannot be excluded as a mediator of unconventional superconductivity [6]. Focusing on the high Tc-cuprates, we include both vertex corrections and SFs in multichannel calculations. We find the characteristic $d_{x^2-y^2}$ gap symmetry and a reasonable order of magnitude for T_c $(50 - 120$ K). Both EP and SF mechanisms support an unconventional *d*-wave symmetry, yet the EP interaction is chiefly responsible for the Cooper pairing and high T_c, while SFs have a suppressing effect on the gap magnitude and critical temperature.

References

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