

Abstract

The retarded nature of the effective electron-electron pairing interaction leading to the formation of Cooper pairs is accurately described by the microscopic Eliashberg theory. On the other hand, the successful Dynes phenomenology of the superconducting state can be justified if scattering on disorder is described within the coherent-potential approximation. Recently, we have developed a theory which unifies these two very different approaches to superconductivity. In this thesis, we generalize the resulting E-CPA theory by including also nominally Cooper-pair-breaking coupling between electrons and collective excitations in the system, and we apply the theory to two problems of current interest.

Firstly, we investigate the evolution of the spectroscopic characteristics of the Dynes superconductors with increasing temperature. The focus is on the Dynes parameter Γ , which quantifies the influence of all pair-breaking processes in the system. We show that the low-energy properties of the pairing glue are, in principle, visible in the dependence of the Dynes parameter Γ on temperature, provided that the system exhibits strong magnetic disorder. Furthermore, an attempt is made at explanation of an anomalously strong temperature dependence of Γ observed in recent experiments.

Secondly, the microscopic origin of the features observed in the energy gap function of strongly disordered materials in the vicinity of the quantum phase transition into the non-superconducting state is examined. We observe that part of the features observed experimentally in such systems can be modelled by the presence of nominally Cooper-pair-breaking modes. The possibility of extracting information about the coupling of electrons to such pair-breaking modes is studied, and for systems lacking magnetic disorder, we develop an algorithm which can find the minimal nominal pair breaking necessary to explain the given results of the tunneling experiments.

Keywords: *microscopic theory of superconductivity, dirty superconductors, coherent potential approximation, Eliashberg theory, quantum breakdown of superconductivity, Cooper pair breaking, tunneling spectroscopy;*