Abstract

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Title:	Identification of pair-generation and pair-breaking processes in superconductors by solving inverse problems
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Superconductivity arises when electrons bound to the so-called Cooper pairs undergo the Bose-Einstein condensation. The task of microscopic theory of superconductivity is to decide which processes create Cooper pairs, and vice versa, which processes break them. A number of mechanisms describing both types of processes have been proposed in the literature. The goal of the presented thesis is to identify, based on data from tunneling experiments, those processes that significantly affect particular properties of superconductors observed in two specific open problems.

The first problem concerns thin aluminum films in a parallel magnetic field at low temperatures. Aluminum is a conventional superconductor and its Cooper pairs are formed by the standard attractive phonon-mediated interelectron interaction. However, it turns out that the nature of the pair-braking processes, that must be elastic, is not known. At first, we solve the problem in the usual way, i. e. in the studied case we compare predictions of the theoretical model with the available tunneling data. We explicitly show that in a single-band model for electrons, there can exist four possible types of scattering: potential scattering, scattering on magnetic impurities, orbital interaction of electrons with magnetic field, and spin-orbital coupling. We investigate these scattering processes within two approximations: within the standard self-consistent Born approximation, but also within the coherent potential approximation, with the latter representing a generalization of the microscopic theory for Dynes superconductivity. Unfortunately, the resulting model is very complicated and does not allow to unambiguously identify the dominant scattering mechanisms in the aluminum films. In the presented work, we therefore also present an alternative approach by solving the inverse problem, i. e. a direct extraction of the density of states from the tunneling conductivity of superconductor – insulator – superconductor junction, together with preliminary results.

The second problem concerns the identification of mechanisms that lead to the quantum breakdown of superconductivity (QBS) in strongly disordered superconductors.

There are several competing mechanisms for this type of QBS: an increase of repulsive interactions that suppress the formation of Cooper pairs, superconducting phase fluctuations, as well as the increase of the spatial inhomogeneity of the electron wave functions. It is known that the gap function $\Delta(\omega)$ carries full information about the microscopic processes, which take place in superconductors. Unfortunately, in strongly disordered materials, the density of states in the normal state is not constant and therefore standard procedures for extraction of $\Delta(\omega)$ cannot be applied. We have therefore developed a new model-independent extraction method of $\Delta(\omega)$, whose inputs are only the measured superconducting and normal-state densities of states. We demonstrate the applicability of this procedure in detail on the tunneling data for thin films of TiN. A related problem has to do with the fact that the normal state of a superconductor is experimentally achievable, for example, by heating above the critical temperature. In this situation the tunneling conductance of the junction between the normal metal and the studied material is not directly proportional to the density of states in the studied material and can be considerably smeared by the temperature. Therefore, in this thesis, we also propose several methods which remove thermal smearing from the data, although their applicability requires further verification.

Keywords: microscopic theory of superconductivity, gap function, tunneling experiments, inverse problems