Conductance and conductance fluctuations of mesoscopic superconductor/normal metal-samples

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The interplay between Andreev reflection at the interface between a superconductor (S) and a normal metal (N) and the phase coherence of the charge carriers in the normal metal adjacent to S strongly modifies the transport properties of mesoscopic SN systems. Because of the phase coherence in N the strong modification of the spectral conductance of these SN systems is a quantum interference effect. Universal conductance fluctuations are also expected to be strongly influenced by the proximity effect. Furthermore, in real mesoscopic SN structures reduced interface transparencies and geometrical constraints give rise to another quantum interefence effect, the mechanism of reflectionless tunneling. This process of coherent multiple Andreev reflections caused by the backscattering of quasi particles towards the SN interface results in an increase of the interface transparencies and thus in conductance maxima at low energies.

We measured the differential conductance of gold nanowires in contact with a normal conducting reservoir (gold) and a superconductor (niobium) as a function of applied voltage and magnetic field. Apart from the usual 2-contact geometry we also investigated samples in 3- and 4-contact geometry without current across the SN interface. The spectral conductance of samples with high interface transparency clearly displays the characteristic energy dependence of the reentrance effect. The Fermi velocity mismatch between gold and niobium leads to a finite normal reflection probability of the quasi particles at the SN interface. Considering the effect of reflectionless tunneling enabled us to successfully describe the experimentally observed magnetoresistance for magnetic fields exceeding the correlation field. A quantitative description of the experimental data within the quasiclassical theory was obtained taking into account the transparency of the interface.

The proximity effect also modifies universal conductance fluctuations in mesoscopic SN structures. For normal metal wires with two normal leads and one or two superconducting reservoirs which are attached in transverse direction the fluctuation amplitude is predicted to be reduced in comparison to the pure normal conducting case. Measurements on samples with two superconducting reservoirs are in quantitative agreement with the predictions. However, measurements of conductance fluctuations in samples with only one superconducting reservoir in transverse direction reveal an enhanced fluctuation amplitude. In samples with one N and one S lead on the one hand, the conductance fluctuations are enhanced by a factor much larger than theoretically expected. This huge fluctuation amplitude can again be attributed to the reflectionless tunneling mechanism. On the other hand, for some of the 2-contact samples conductance fluctuations caused by individual mobile defects could be investigated as random telegraph signals in the time domain. Here, the theoretically predicted enhancement of the fluctuation amplitude could be experimentally confirmed.