Tunnelling between a superconductor and a hopping insulator: charge transport through the interface and energy relaxation in charge qubits

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The lecture reveiws the theory of low-temperature charge transfer between a superconductor and a hopping insulator — semiconductor in the regime of hopping conductance, or insulator with electron traps. The main result is that that the charge transfer can be governed by the coherent two-electron tunneling process — time reversal reflection, where electrons tunnel into superconductor from the localized states in the hopping insulator located near the interface and get converted into Cooper pairs. This process is an analog to the well-known Andreev reflection.

The lecture will summarize results of two projects: (i) Time reversal interface resistance between a hopping insulator and superconducting leads (in collaboration with V. I. Kozub, A. A. Zyuzin, and V. Vinokur). In this work we have shown that there exists a non-trivial interplay between the time-reversal processes and hopping through the percolation cluster in the bulk, the time reversal interface resistance provides interesting information on both interface and bulk charge transfer. In mesoscopic structures it can exceed the bulk hopping resistance. (ii) Energy relaxation in Josephson charge qubits (in collaboration with L. Faoro, J. Bergli, and B. Altshuler). Here we have shown that the time-reversal tunneling of Cooper pairs to pairs of defects provides an explanation of recent experimental results on energy relaxation in Josephson qubits.