Negative Differential Resistance and Other Features of Electron Transport in Different Hybrid Double-Barrier Supeconducting Structures

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Introdction

The study of hybrid structures containing superconductors and magnetic materials attracts great interest due to a number of important for fundamental and applied physics phenomena, such as spin-triplet electron pairing, the effect of giant magnetoresistance, anomalous superconducting and magnetic proximity effects, and others that have been studied in a large number of papers [1-5]. Very interesting phenomena can be realized in hybrid double-barrier structures S-IF-F-IF-N (S is a superconductor, F and N are ferromagnetic and normal metals, respectively, IF is a spin-active barrier), in particular, the negative differential resistance of the structure predicted in [6]. In this presentation, we discuss the results of the theoretical investigation the possibility of implementing a negative differential resistance and its asymmetric voltage dependence for the S-I-F-IF-N structure (I is a potential barrier). The features of electronic transport and the effect of the negative differential resistane in the double-barrier structures S-I-s-I-N, predicted in [7], are discussed.

Method

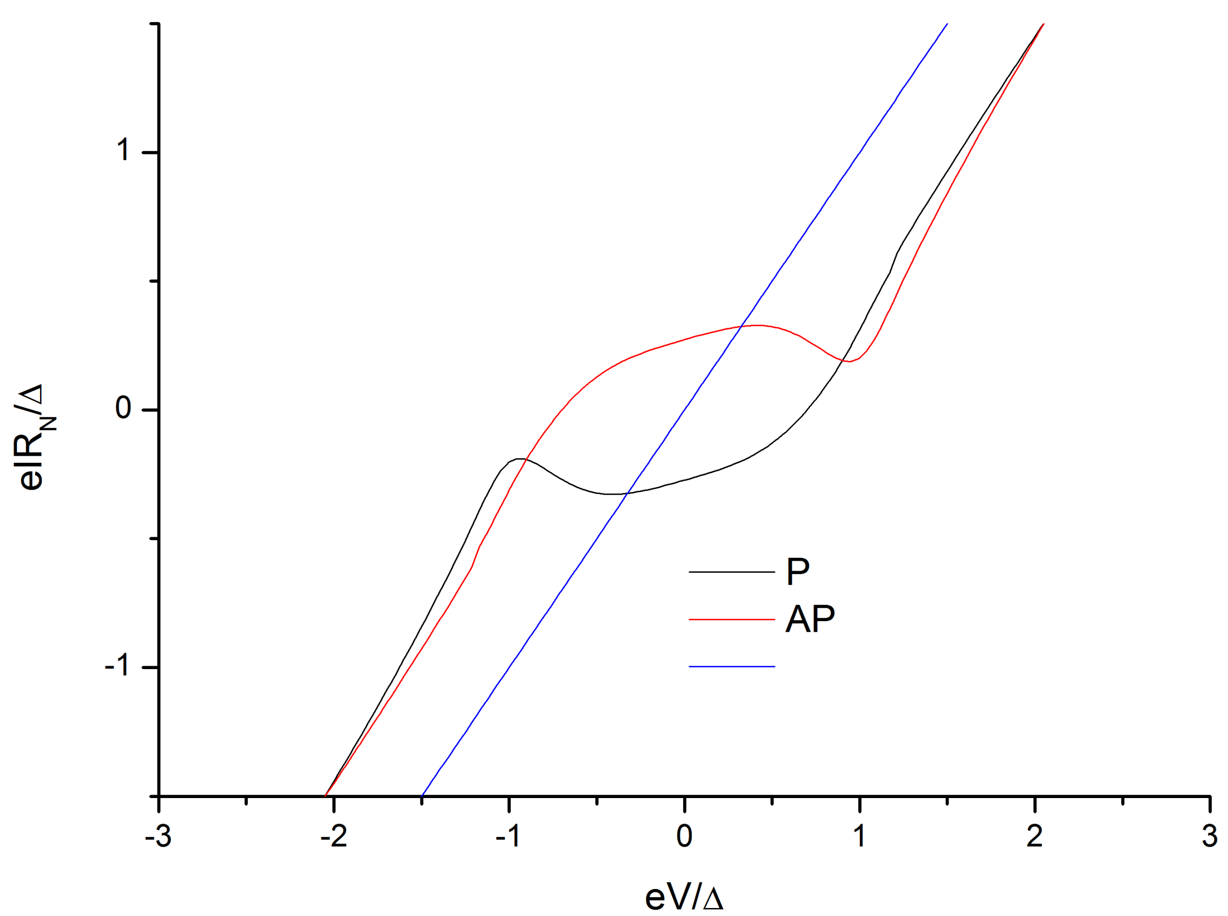
The method of quasiclassical Green's functions was used for matrix function

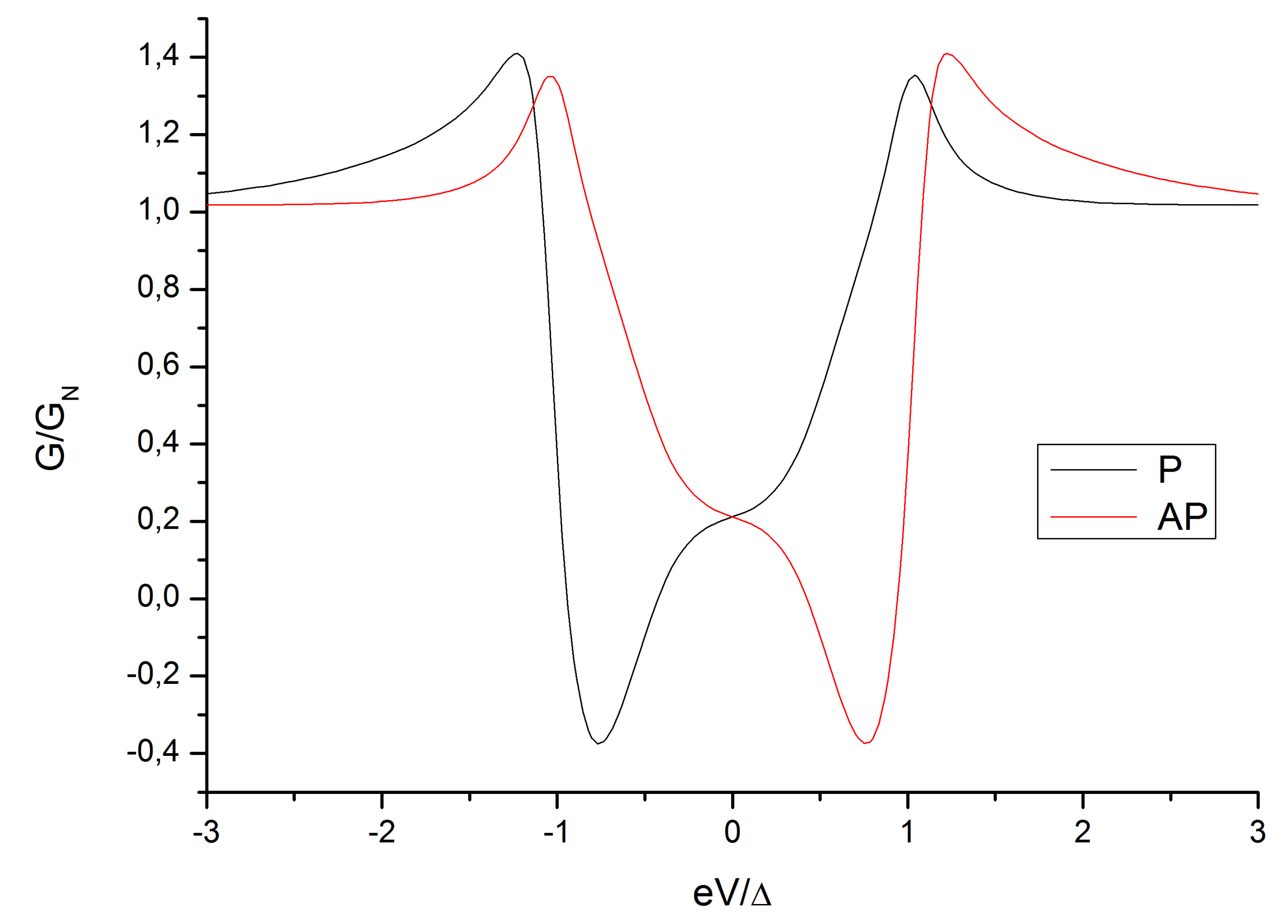
$$\check{G} = \begin{pmatrix} \hat{G}^R & \hat{G}^K \\ \hat{0} & \hat{G}^A \end{pmatrix}$$

where $\hat{G}^R, \hat{G}^A$, and $\hat{G}^K$ are, respectively, the retarded, advanced and Keldysh matrix Green's functions that were matched at the boundaries of barriers using boundary conditions. The case of diffusion electron transport is analyzed, for which equations are obtained and solutions are found for the case of a short F layer in the S-I-F-IF-N structure, allowing calculate current $I(V)$ and differential conductance $G(V) = dI(V)/dV$.

Figures

Below are the graphs of $I(V)$ and $G(V)$ dependences for the S-I-F-IF-N structure obtained for the special case of a short F layer, (for some parameters) in which a strong proximity effect is realized, while the $I(V)$ dependence has an N-shaped form, and the differential conductance, as well as the differential resistance in a certain voltage range turns out to be negative. Different plots correspond to parallel (P) and antiparellel (AP) orientations of the exchange fields in the F layer and the IF barrier. Characteristic features of $G(V)$ dependencies are their assimetrical voltage dependence and a radical change of these dependences upon passing from P to AP orientation.





S-I-s-I-N structure

Double-barrier structure S-I-s-I-N that contains sufficiently short superconducting s layer (in which strong superconducting proximity effect is realizd) is interesting by many reasons. In this structure negative differential conductance may be realized due to nonequlibrium state of the s layer in the presence of voltage and suppresion of the superconducting order paremeter in this layer [7]. In addition, this structure demonstrates non-classical Josephson behavior: despite the presence of a voltage at the barrier between two superconductors S and s, no current oscillations occur, that is the consequnce of nonequlibrium state of the slayer and strong superconducting proximity effect.

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