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CALCULATION OF CURRENT-VOLTAGE CHARACTERISTICS OF A SINGLE-ELECTRON TRANSISTOR WITH DISCRETE SPECTRUM OF ENERGIES IN THE ISLAND

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The paper contains the results of calculation of current-voltage characteristics (CVC) of a single-electron transistor with discrete spectrum of energies based on the extended orthodox theory. The calculation of curves is carried out with the aid of the Monte-Carlo procedure. The transistor model describes the transport of electrons and holes in the device. The numerical results show that the fine structure of the CVC depends strongly on the density of states and on distance between the levels of carriers' energies in the island.

It is well known that if dimensions of tunnel junctions decrease, the Coulomb interaction between the tunneling electrons in the system composed of two series-connected junctions is a factor and the tunneling of the carriers is correlated [1]. As a result, the current-voltage characteristics (CVC) of such structures are unstable, which has been observed in many experiments [2]. Then the question arises: how the properties of the system of two series-connected tunnel junctions will change if the dimensions of such system are gradually decreasing until the spatial quantization of carriers' energy spectrum is noticeable. Note that in the system of two series tunnel junctions the island usually consists of metal or a semiconductor.

The purpose of this paper is description of the model and calculation results of CVC of a single-electron transistor with discrete levels of energies in the island based on the extended orthodox theory. The model of such a transistor is an extension of the model of a single-electron transistor with continuous spectrum of carriers' energies in the island [3].

The schematic diagram of the single-electron transistor with a discrete set of carriers' energies in the island is presented in Fig. 1. It consists of two series-connected tunnel junctions characterized with resistances R_1, R_2 and capacitances C_1, C_2. Voltages V_1 and V_2 feed the junctions. The island is connected to the central electrode via capacitance C_0. The voltages of the sources U and $V = V_1 + V_2$ are equal to the bias voltage across the gate electrode, and to the voltage applied to the series-connected tunnel junctions. E_F^S and E_F^D are the Fermi quasi-levels at the outer electrodes of the series-connected tunnel junctions.

When the island dimensions become comparable with de Broglie wavelength, quantization of carriers' energy in the island becomes noticeable. We shall limit ourselves by considering the transport of carriers in a system meeting the following conditions:

1) resistances of the tunnel junctions meet the inequality $R >> 6.4 \cdot 10^3\ \Omega$;

2) tunneling through tunnel junctions occurs when the inequality $k_B T << e^2/2C_S$ is met, where k_B is the Boltzmann constant, T is the environment temperature, C_S is the total capacitance of the system; and e is the electronic charge;

3) the energy $k_B T$ satisfies the inequalities $k_B T >> h(\Gamma^l + \Gamma^r)$ and $k_B T \le \Delta$, where h and Δ are Planck's constant and the distance between the nearest levels of energies in the island, while Γ^l and Γ^r are velocities of carriers' tunneling from the island through the left and right tunnel junctions;

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