Radioelectronics and Communications Systems
Vol. 47, No. 2, pp. 20–24, 2004

Izvestiya VUZ. Radioelektronika
Vol. 47, No. 2, pp. 27–34, 2004
UDC 621.382.2.029.64

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

V. I. Kanevskii and K. N. Pak

Chungbuk National University, Republic of Korea

The paper contains the results of calculation of current-voltage characteristics of a single-electron transistor with continuous spectrum of energies based on the orthodox theory. The calculation of curves is carried out with the aid of the Monte-Carlo procedure.

The single-electron transistors represent a promising line of development of microelectronics. They are used for creation of new so-called "single-electron" networks operating at extremely low voltages and with extremely low power consumption. During the last decade, considerable efforts went into the studies of the principles of operation of this type of transistor, and a notable advance was made in this sphere [1]. The technology of fabrication of such transistors has gone through a number of phases during its development — from individual metal islands operating at the helium temperatures, to complete devices functioning at room temperature [2].

The purpose of this work is to describe the model and the results of the current-voltage characteristic (CVC) calculation of a single-electron transistor with a continuous spectrum of carriers' energies in the island based on the orthodox theory [3].

Modeling of carriers' transport in the transistor dwells on analysis of the equivalent network of this device. The network includes two tunnel junctions, an island, and a controlling electrode (gate), each characterized by some capacitance and resistance. The CVC calculation is performed by the Monte-Carlo method [4]. By the way, there are more accurate procedures, describing the carrier transport in a single-electron transistor — based on self-coordinated treatment of a system of nonlinear equations including the Schrodinger, Poisson, and carriers' motion equations [5]. These methods permit to describe in detail the carrier transport in a transistor, but they are hardly suitable for calculation of networks containing several devices under consideration. Note that carriers' transport in these networks is a fundamentally stochastic process, which depends on the conditions of the tunnel junctions comprising the main part of such a network [6, 7].

Consider the equivalent network of a single-electron transistor presented in Fig. 1. The bias of two connected in-series tunnel junctions is provided by a voltage source V, while the bias of the gate electrode is attained with the aid of a voltage source U. Provided that the electron charge has a positive sign, the polarization charges of the first junction Q_1, second junction Q_2, of the gate capacitance Q_0, and the full charge Q in the island, can be written as

$$Q_1 = C_1 * (V - V_2);\, Q_2 = C_2 * V_2;\, Q_0 = C_0 * (U - V_2),$$
$$Q = Q_2 - Q_1 - Q_0 = N * e + Q_{\mathrm{IND}}, \qquad (1)$$

REFERENCES

1. D. A. Averin and K. K. Likharev, Possible Applications of Single Charge Tunneling, Chapter 9 in Single Charge Tunneling: Coulomb Blockade Phenomena in Nanostructures (Ed. by H. Grabert and M. H. Devoret), NATO ASI Series B: Physics, Vol. 294, Plenum Press, 1992.

2. A, Nakajima, T. Futasugi, K. Kozemura, T. Fukano, and N. Yokoyama, Appl. Phys. Lett., Vol. 70, No. 13, pp. 1742–1744, 1997.

3. K. K. Likharev, IBM J. Res. Develop., Vol. 32, pp. 144–158, 1988.

4. S. A. Roy, Simulation Tools for the Analysis of Single Electronic Systems, PhD Thesis, University of Glasgow, 1994.

5. D. Jovanovic and. J.-P. Leburton, Phys. Review B., Vol. 49, No. 11, pp. 7474–7483, 1989.

6. S. Amakawa, H. Majima, H. Fukui, M. Fujishima, and K. Hoh, IEICE Trans. Electron., Vol. E81-C, No. 1, pp. 21–29, 1998.

7. Z. Yu, R. W. Dutton, and R. A. Kiehl, IEEE Trans. on Electron. Devices, Vol. 47, No. 10, pp, 1819–1825, 2000.

8. M. Amman and K. Mullen, J. Appl. Phys., Vol. 65, No. 1, pp. 339–346, 1989.

9. A. Scholze, A. Schenk, and W. Fichtner, IEEE Trans. on Electron. Devices, Vol. 47, No. 10, pp. 1811–1818, 2000.

10. K. K. Likharev, IEEE Trans. on Magnetics, Vol. MAG-23, No. 2, pp. 1142–1145, 1987.

11. A. E. Hanna and M. Tinkham, Phys, Review B., Vol. 44, No. 11, pp. 5919–5922, 1991.

12. K. P. Hirvi, M. A. Paalanen, and J. P. Pekola, J. Appl. Phys., Vol. 80, No. 1, pp. 256–263, 1996.

13. J.-J. Kim, J.-O. Lee, J. Kim, K. H. Yoo, J. W. Park, and J. B. Choi, J. of the Korean Phys. Soc., Vol. 33, No. 6, pp. 750–754, 1998.

20 October 1003