THE INFLUENCE OF REGION SIZES ON THE CURRENT-VOLTAGE CHARACTERISTICS OF GRAPHENE-BASED FOUR-BARRIER RESONANT TUNNELING STRUCTURES

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Annotation. This article discusses the concept, essence and application areas of graphene-based four-barrier resonant tunneling structures (RTS). The purpose of this paper is to study the influence of various technological parameters on the electrical characteristics of RTS. The current-voltage characteristics of graphene-based resonant tunneling structures on silicon dioxide (SiO_2) and hexagonal boron nitride (h-BN) substrates are simulated for different widths of barriers and quantum wells. The calculations presented were carried out using a numerical model based on the Schrödinger equation.

Keywords. Resonant tunneling structures, current-voltage characteristics, graphene

When the Fermi level of the injection electrode coincides with the discrete level of a low-dimensional structure bounded by two potential barriers, there is a sharp increase in the tunnel current flowing through it, which is manifested on current-voltage characteristic by a section with a negative differential resistance, which is shown in Fig. 1. This phenomenon is called "resonant tunneling" [1].

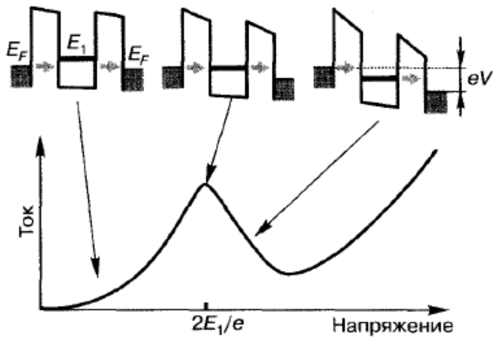


Fig. 1 - Energy diagram and current-voltage characteristic of a double-barrier RTS

If you continue to lower the energy level of E_1, then the charge carriers will no longer be able to tunnel with the conservation of energy and momentum, so they are delayed in the well. The current through the structure will begin to decrease, which will lead to the appearance of a section with a negative differential resistance on the current-voltage characteristic.

The numerical model based on the solution of the approximated one-dimensional Schrödinger equation and included in the nanoelectronic device simulation software system NANODEV [2,3] was chosen as the main model for calculating current densities. As a result of the approximation Tikhonov-Samarsky approach, the solution of the Schrödinger equation reduces to the solution of a system of linear algebraic equations. The result of calculation is the values of the wave function in the nodes of the spatial-discretization grid for a given energy of the incident particle and the applied voltage.

Figure 2 shows a four-barrier RTS based on bilayer graphene under investigation. This device includes potential barriers (d_{b1}, d_{b2}, d_{b3}, d_{b2}) and quantum wells (d_{w1}, d_{w2}, d_{w3}). In the simulation the barriers height (h) for RTS on a substrate made of SiO_2 and on a substrate made of h-BN are 3.58 eV and 3.137 eV respectively.

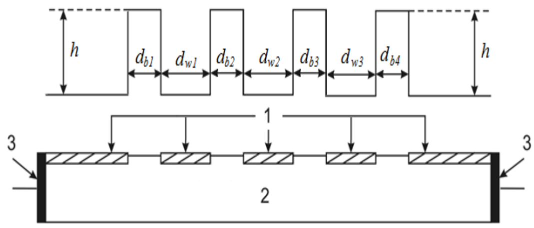


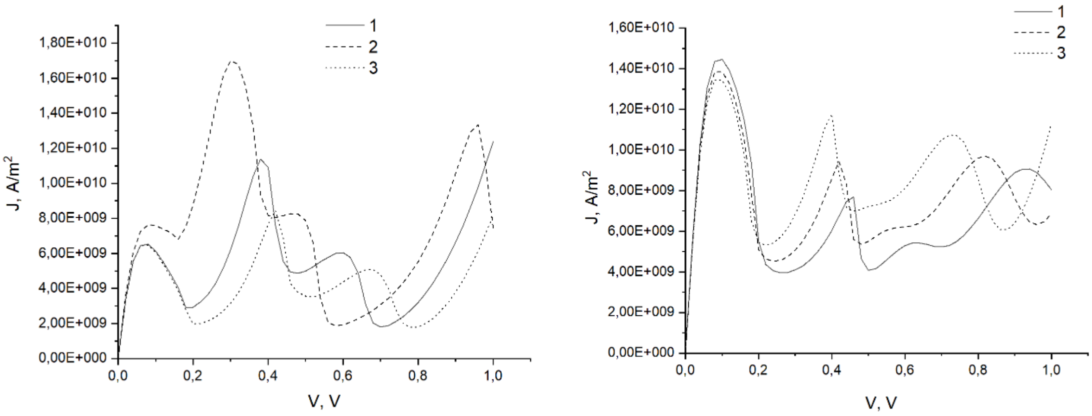
Fig. 2 - Four-barrier RTS and conduction band energy: 1 – graphene; 2 – substrate; 3 – contacts.

Table 1 shows the region sizes for which the current-voltage characteristics are simulated.

Table 1 - The region sizes of studied graphene-based RTS simulation

Substrate material	Width of barriers, nm			Width of quantum wells, nm		
	curve 1	curve 2	curve 3	curve 1	curve 2	curve 3
SiO_2	1,3	1,5	1,2	3,0	3,5	4,0
h-BN	1,2	1,3	1,4	3,0	3,5	4,0

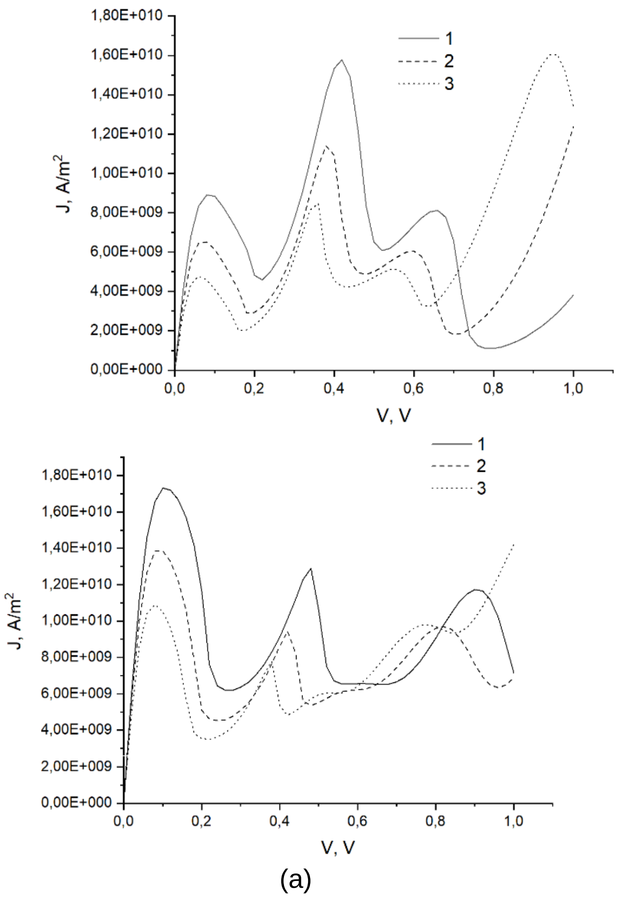
Figure 3 shows the current-voltage characteristics of the four-barrier RTS when changing the width of the barriers: on a substrate made of SiO_2 (Fig. 3a); on a substrate made of h-BN (Fig. 3b).



(a) (b)

Fig.3 - Current-voltage characteristic at different values of the barriers width

Figure 4 shows the current-voltage characteristics of the four-barrier RTS when changing the width of the quantum wells: on a substrate made of SiO_2 (Fig. 4a); on a substrate made of h-BN (Fig. 4b).



(a) (b)

Fig. 4 - Current-voltage characteristic at different values of the width of the quantum wells

It was found that the decrease in the width of the barriers leads to the decrease in the current density, as well as the increase in the voltage values of the second and third peaks. The current density decreases and the peaks shift to lower voltage values, as the width of the quantum wells increases.

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