# APPROXIMATION OF THE POTENTIAL IN SHORT NANOTUBES LOCATED ON A METAL CATHODE TO FIND THE TRANSMISSION COEFFICIENT AND FIELD EMISSION CURRENT USING THE LANDAUER FORMULA

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According to theoretical work [1] and experimental studies of short carbon nanotubes (CNT) with a length of 80–300 nm [2], the mechanism of electron transfer in an array of vertically grown CNT is ballistic. In this case, the current can be obtained using the Landauer formula [3], for which it is necessary to know the coefficient of charge carrier passage through the CNT and the potential triangular barrier at the boundary with the vacuum. In this work, a model of approximation of the barrier by a step (Fig. 1) was proposed for calculating the transmission coefficient, the area of which is equal to the area of the triangular barrier, which significantly simplifies finding the wave function, and accordingly the transmission coefficient for this system. In Fig. 1, $L_1$ is the length of the CNT.

Based on the potential shown in Fig. 1, in the case of a short CNT located on a metal cathode and touching the other end with a vacuum, we will seek a solution for the wave function in four regions in the form of plane waves

$$\psi(z) = \begin{cases} A_1 e^{ik_1 z} + B_1 e^{-ik_1 z}, & z < 0, \\ A_2 e^{ik_2 z} + B_2 e^{-ik_2 z}, & 0 \le z \le L_1, \\ A_3 e^{ik_3 z} + B_3 e^{-ik_3 z}, & L_1 \le z \le L_2, \\ A_4 e^{ik_4 z} + B_4 e^{-ik_4 z}, & z \ge L_2, \end{cases} \tag{1}$$

where $A_1,\ A_2,\ A_3,\ A_4,\ B_1,\ B_2,\ B_3,\ B_4$ are the amplitudes of plane waves; $e^{ikz}$ and $e^{-ikz}$ are the wave functions describing the propagation of a particle along the z axis from left to right and from right to left, respectively.

The dependence of the transmission coefficient on the particle energy, obtained for a CNT of length $L_1 = 25$ nm, is shown in Fig. 2 for values of $1.5 \cdot 10^8$ V/m (solid line) and $1.7 \cdot 10^8$ V/m (dashed line). The transmission coefficient is similar to that obtained in [1] for cummulin and polyyne chains.

Also, within the framework of this model, the field emission current was calculated, which is similar to the current obtained in [1], which indicates the possibility of applicability of the Landauer formula for calculating the field emission current in short CNTs.

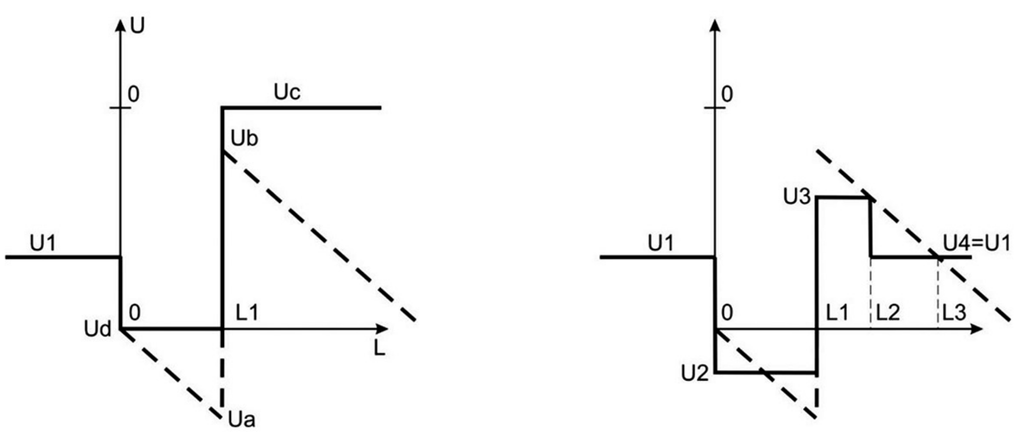


Fig. 1. View of a potential well and approximation of the potential distribution under the influence of a uniform electric field

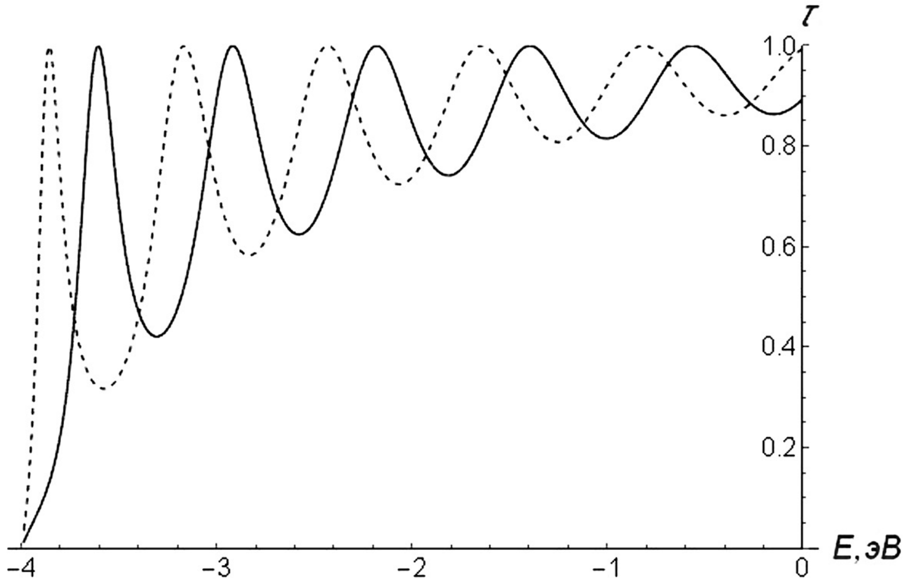


Fig. 2 Dependence of the transmission coefficient on the energy of the incident particle for different values of the longitudinal electric field

## References

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