# Mathematical Model of Channel Current in FET-Based Nanobiosensors

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*Abstract* – **field effect transistor (FET)-based sensor for biomolecules detection has been simulated.**

*Keywords* – **nanobiosensor, field effect transistor, carbon nanotube, nanowire.**

## I. INTRODUCTION

Among one-dimensional (1-D) materials carbon nanotubes (CNTs) and nanowires (NWs) are extremely interesting as the active material for biological and chemical sensors. CNTs and NWs are directly comparable to the size of the target molecules, thatmakesthem well suitable for electronic detection of biomolecules or other analytes. CNTs and NWs-based biosensors have higher sensitivity at room temperature and faster response than conventional FET-based sensors.

One of the most promising applications of carbon nanotubes or nanowires is biosensors based on field-effect transistors (FETs). Field effect transistor (FET)-based sensors have attracted lots of attentions because of their high sensitivity and compatibility with biomolecules [1].

It is important to study FET-based nanobiosensors and improve their sensitivity, because until now there is no accepted model, which could completely describe the physics of biosensors based on field effect transistors (FETs) with low-dimension structures.

In this paper, we attempt to create the mathematical model of channel current in FET-based nanobiosensors.

## II. MATHEMATICAL MODELING OF CHANNEL CURRENT IN CNTFET

The device physics is not completely clear and there are a couple of approaches to the description. In this reason current in the channel is different described by various authors. We used our own approach, obtained the following equations.

According to the CNT ballistic transport theory, the current in the channel can be calculated using the Fermi–Dirac statistics [2].

Current, which flows through the nanotube, can be calculated by Eq. (1):

$$I_{CNT} = \frac{2 \cdot q \cdot k \cdot T}{p \cdot \mathbf{h}} \left[ F_0 \left( x_S \right) - F_0 \left( x_D \right) \right] \qquad (1)$$

$$I_{CNT} = \frac{4 \cdot q \cdot k \cdot T}{h} \cdot \left( \ln \left[ 1 + e^{\frac{q \cdot V_{CNT} - E_C}{kT}} \right] - \ln \left[ 1 + e^{\frac{q \cdot V_{CNT} - E_C - q \cdot V_{ds}}{kT}} \right] \right)$$

where k is Boltzmann constant, h is Planck's constant,Vds is voltage between drain and source, Ec is the energy of the conduction band and Vcnt is potential on the surface of the nanotube[3].

Potential is calculated by Eq. (2):

$$\mathrm{V_{CNT}} = \begin{cases} \mathrm{V_{GS}}, \mathrm{V_{GS}} < \Delta_1 \\ \mathrm{V_{GS}} - \dfrac{a(\mathrm{V_{GS}} - \Delta_1) + \sqrt{(a(\mathrm{V_{GS}} - \Delta_1))^2 + 4e^2}}{2}, \mathrm{V_{GS}} \geq \Delta_1 \end{cases} \qquad (2)$$

whereVz is gate voltage, e - smoothing parameter, α – predefined parameter Eq. (3)

$$a = a_0 + V_{DS} \cdot a_1 + V_{DS}{}^2 \cdot a_2 \qquad (3)$$

$$a_0 = 0.758 - 0.124 \cdot \mathrm{d} + 0.018 \cdot \mathrm{d}^2$$

$$a_1 = -0.325 + 0.181 \cdot \mathrm{d} - 0.137 \cdot \mathrm{d}^2 + 0.024 \cdot \mathrm{d}^3$$

$$a_2 = 0.143 - 0.137 \cdot \exp^{\frac{-\mathrm{d}+1.1075}{0.9744}}$$

where d – nanotube diameter, nm.

Parameters which describe CNTFET biosensors work are presented and discussed.

## III. CONCLUSION

Mathematical model of channel current in CNTFET-based biosensors has been developed.

It is important to develop a general efficient approach to the carrier transport solving. Simulations will help to understand the device physics and explain of experimental data.

The present work can be further improved by inclusion in model the ballistic transport,the equations of the Schottky barrier, scattering of charge carriers mechanism, velocity saturation effects, mobility considerations in carbon nanotubes, ect.

## REFERENCES

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