IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Dual Metal Nanowire field effect transistor (NW-FET) based Labelfree biosensor.

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Abstract: In this paper a dual metal-nanowire field effect transistor based label free biosensor has been proposed and investigated. The influence of biomolecules on the biosensors electrical properties are analyzed. It is seen that proposed biosensor exhibits good sensitivity. The sensitivity variation of biosensors is analyzed in terms of current switching ratio i.e. I_{on}/I_{off}. The performance of the proposed biosensor is measured in terms of change in drain current after interaction with the biomolecules. It is seen that proposed biosensor's sensitivity is significantly high.

***IndexTerms*- NWFET , Dual Metal , Biosensor , Sensitivity.**

1. INTRODUCTION

Biosensors have drawn increasing attention in the field of medical and food security for label free detection of biomolecules. [1][2]. Labels are not used in label free biosensing technology for measurement. For sensing purpose, they employ the analyte's innate physical charactertics. FET-based biosensors have many advantages, such as CMOS compatibility, miniaturization, and excellent sensitivity, so research on FET-based biosensors has become essential and popular [3]. The early ion-sensitive FET biosensor only exhibits good sensitivity to charged biomolecules but cannot detect neutral biomolecules, which limited their applications [4], [5]. To overcome those drawbacks, a dielectrically modulated (DM) field-effect transistor (FET) based biosensor is proposed [6], [7]. By etching away part of the gate dielectric layer of the FET, a nanogap i.e. nanocavity for detecting biomolecules is formed between the gate and the channel. The electrical characteristics of the FET are also modulated in terms of threshold voltage, subthreshold swing, on-state current, and off-state current [9]. By analyzing the sensitivity parameter based on the above electrical characteristics, the target molecule can be identified [6], [8].

As transistors shrink to the nanometer scale, traditional planar FET devices will suffer severe short-channel effects, resulting in increased power consumption and decreased sensitivity of the DMFET-based biosensors [11].One way to solve the above problem is to use FINFET. In recent years, researchers have successfully manufactured biosensors based on FinFET and NW-FET [10], [11]. NW-FET has a larger gate than FinFET, which means a stronger gate control capability. Thus, NW-FET structure can suppress the short channel effects and improve the sensitivity of biosensors.

In this paper a DM-NW FET based biosensor is proposed. The research paper is divided into four sections. Section 1 covers the introduction, Section 2 covers the discusses the device structure and simulation. Section 3 discusses the result and section 4 summaries and draws the conclusion.

2. Device Structure

The proposed DM-NWFET based biosensor is designed and simulated. DM-NWFET device is illustrate in figure 1. The length of the channel is 30nm, the source and drain contacts are used with doping concentration of 10^{18} cm^3 . A uniform doping profile is specified in the simulation software. The simulation of the proposed device is performed by the SILVACO TCAD ATLAS tool. Moreover, the electrical characteristics of the proposed device are studied using the SILVACO ATLAS device simulator.

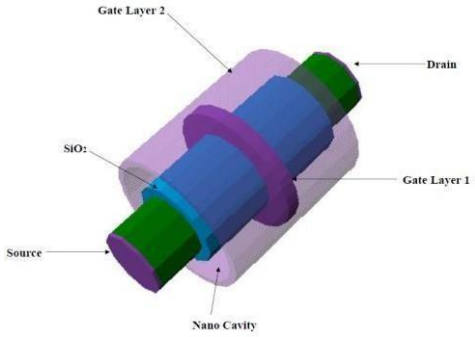


Fig.-1 3-D Dimensional view of DG-NWFET

The simulation results were evaluated using the Atlas-3D device simulation tool. The simulations include models for carrier recombination and carrier mobility generation. CONMOB model has been employed for doping versus mobility validation and BGN model has been used for high channel doping. The CONMOB model is used to calculate the effective mobility of carriers in the channel region of the NW-FET. This model takes into account the effect of impurities, interface roughness, and scattering mechanisms on carrier mobility. The mobility values calculated using the CONMOB model can be used to determine the device performance parameters such as drain current. The recombination of minority carriers in semiconductors has also been taken into account through the use of Shockley–Read–Hall (SRH) and Boltzmann transport equations.

3. Results and Discussion

Electrostatics Analysis is crucial to thoroughly characterize and comprehend the electrical behavior of the FET biosensor with varying dielectric constant and charge of the biomolecule to ensure proper functioning of the biosensor. Understanding the electrostatic interactions between the biomolecules and the FET surface provides insights into the sensitivity of the biosensor device and its ability to accurately detect the biomolecules.

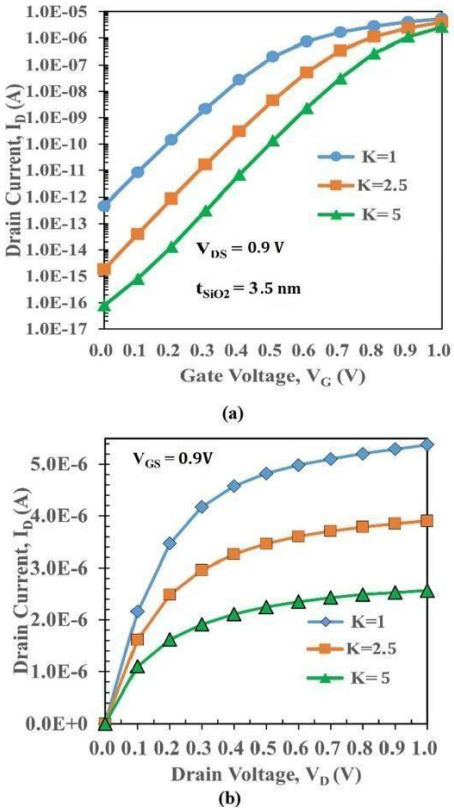


Fig. 2 a, I_D-V_G characteristic at V_{DS} = 0.9 and for Dry-Protein with dielectric constant variations. b, I_D-V_D characteristics at V_{GS} = 0.9 for Dry-Protein with dielectric constant variations.

Figure 2a examines I_D -V_G characteristics (drain current versus gate voltage) of the NW-FET biosensor for dielectric constants, K = 2.5 and K = 5 of Dry-Protein, assuming that they are neutrally charged. The subthreshold current dramatically decreases from 4 $\times 10^{-13}$ to 1 $\times$ 10^{-16} A/µm after immobilization of the biomolecules such as air whose K = 1 to K = 5 for the instance of Dry- Protein. This decrease in drain subthreshold current is caused by the efficient control of Dual Metal Gate over the channel and the decreased concentration of charge carriers within the channel area when the Dry-Protein biomolecules having high dielectric constants are immobilized into nanocavity region. Also, as seen from **fig 2(a),** I_{off} current at K= 1 is **4×10^{-13}**, K = 2.5 is **1.5×10^{-15}** and K=5 is **1×10^{-16}** . From **fig 2(b),** it is seen that drain I_{on} current at K= 1 is **5.2×10^{-6}** , and K= 2.5 is **3.7×10^{-6}** and at k= 5 is **2×10^{-6}.** Thus, the current switching ratio(Ion/off) at K= 1 is **1.3×10^{7}** , at K= 2.5 is **2.46×10^{9}** and K=5 is **2×10^{10}.** It is seen that as the dielectric constant of biomolecules rises the I_{on}/I_{off} ratio increases. As I_{on}/I_{off} ratio increases, the I_{on}/I_{off} sensitivity also increases. Hence, due to the immobilization of Dry-Protein biomolecules with the changing dielectric constant within the nanocavity, the I_{on}/I_{off} sensitivity increases which helps in the diagnosis of the various biomolecules.

4. Conclusion

The work done in this research paper demonstrates that Dual Metal structure has a persuasive effect on the sensing ability of the proposed biosensor. Dual Metal work function engineering allows greater Gate control over the channel and improved analog performance. The greater variation in the electrical parameters enables the development of incredibly sensitive biosensor. Also the device characteristic shows an evident variation with different target molecules, having different dielectric constants. Also, it is seen that I_{on}/I_{off} sensitivity increases with changing dielectric constant of biomolecules. I_{on}/I_{off} sensitivity (i.e. Current switching ratio) at K= 5 achieves a value of 2 $\times10^{10}$ while varying the dielectric constant (K) from 1 to 5.

Thus, the increase in I_{on}/I_{off} ratio provides the high sensitivity of NW-FET and accurate diagnosis of various biomolecules. Hence, with the advantage of high sensitivity, the DM-NWFET based biosensor is promising for biosensing applications.

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