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Performance Analysis of Different High Performance Field Effect Transistor based Biosensors for Cancer Detection

[1]D. Kiran, [2]P.G.Gopinath

[1&2]Department of Electronics and Communication Engineering
Siddharth Institute of Engineering & Technology, Puttur, Tirupati District, Andhra Pradesh, India

Abstract : In this paper, we have studied the different types of latest Field Effect Transistor (FET) and its electrical characteristics. Based on the different cases and studies, we have identified the suitable FET which is going to use in Bio-Medical Applications. Now a days, detection of disease causing antigen is a big challenge, in order to overcome the difficulty, FET based biosensor is introduced to improve the sensitivity with respect to the disease causing antigen in micro/Nano level. Different types of transistor with different layers of material are introduced to identify the suitable transistor. All the simulations are performed in NANOHUB.ORG(OnlineTools) and performance are shown as simulation results, graphs and table.

Keywords: Performance Analysis, Field Effect Transistors, Biomedical Applications

I. Introduction

As MOS infrastructure continues to scale down deeper into the nanoscale, various non-ideal characteristics, substantially different from MOSFET are aroused. Carbon Nanotube (CNT), the rolled structure of graphene, renders itself to multi-disciplinary applications in nanoelectronic circuits and removes those effects. The field effect transistors consisting of CNT are called CNTFET and recently they have attracted the attention as possible building blocks of future nanoelectronics due to their distinctive structural, electrical and mechanical properties. These provide notable characteristics over MOSFET using the semiconducting properties of CNT like high carrier mobility, large MFP (mean free path), ballistic conduction, suitable contact resistance, fast switching speed and less heat dissipation.

In this proposed system we are going to analyse CNTFET is the best FET for detection of disease, in order to validate the properties of CNT. Though CNT has high cost and less reliability, it plays a vital role in nanoscale production due to its structural properties. They are three types of terminals. Source, gate and drain. Two types of gates are top gate and bottom gate, top gate act as a sensing device. In sensing device antibody is placed, while applying the samples if both antigen and antibody interacts, we can find whether the disease is caused or not and biopotential will increases. By this method we can easily identify the disease.

II .CNTFET STRUCTURE AND MODEL

CNT can be viewed conceptually as graphene sheets rolled up into concentric cylinders. The number of sheets is the number of walls and thus CNTs fall into two categories: single-wall CNTs (Figure1)and multi-wall CNTs(Figure2). The SWCNT can be either metallic or semiconducting depending on the chirality. The diameter of the CNT is also determined by the chirality. Figure3 shows structure of CNTFET and its different regions.

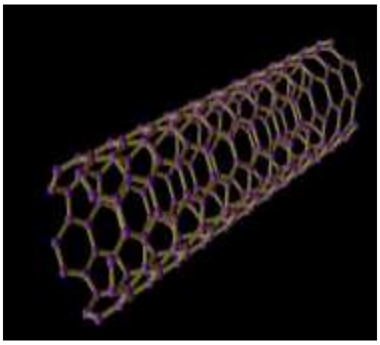


Fig1.SWCNT

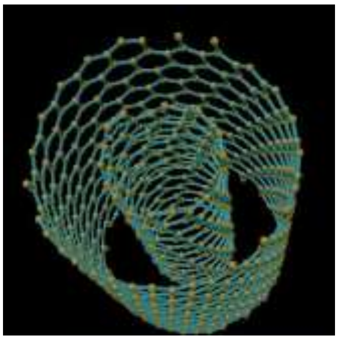


Fig2.MWCNT

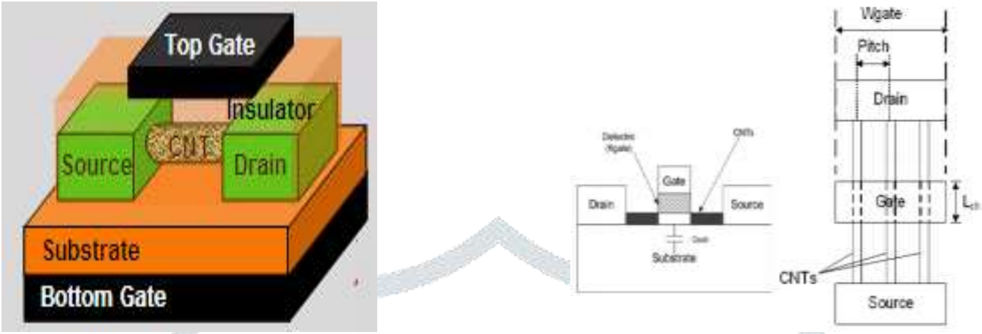


Fig3.Structure of CNTFET

Electrical properties of CNTFET

In order study the electrical properties,CNT is simulated in different modes. The electrical property of carbon nanotube from the below figure 4(a) shows drain currenr vs gate voltage. Here the curve is to be linearly increasing order, at the point of increasing, it decreases gradually. After reaching the voltage 1V.

From the below figure 4(b) shows drain current vs drain voltage. Drain voltage is constant to 1. Drain voltage is linearly increasing. From the figure4(c) shows average velocity vs gate voltage. Average velocity is a vector quantity and it can be defined as the displacement divided by the time. As the curve is linearly increasing from it. Figure 4(d) shows gm/id vs gate voltage. The electrical characteristic relating the current through the output of a device to the voltage across the input of a device. Transconductance is linearly decreasing with respect to the gate voltage.

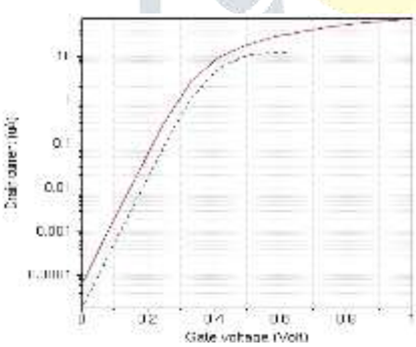


Fig4(a)Drain current vs Gate voltage

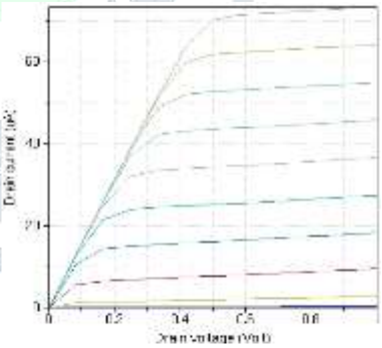


Fig4(b)drain voltage vs drain current

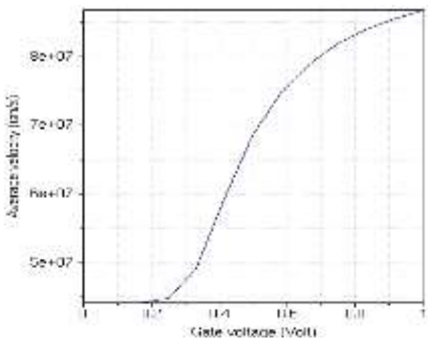


Fig4(c)average velocity vs Gate voltage

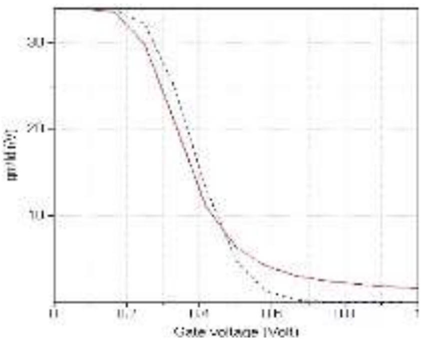


Fig4(d)gm/id vs gate voltage

III . SILICON NANOWIRE STRUCTURE AND MODEL

Silicon nanowires, also referred to as SiNWs, are a type of semiconductor nanowire most often formed from a silicon precursor by etching of a solid or through catalyzed growth from a vapour or liquid phase. Such nanowires have promising applications in lithium ion batteries and sensors

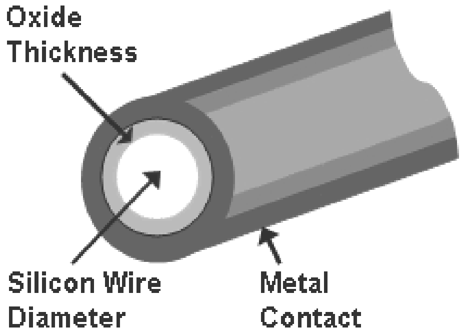


Figure 5. Structure of silicon nanowire

Electrical properties of Silicon Nanowire

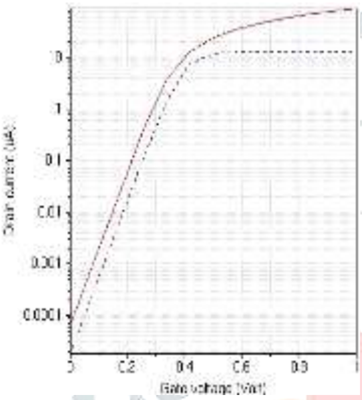


Fig 6(a) Drain current vs Gate voltage

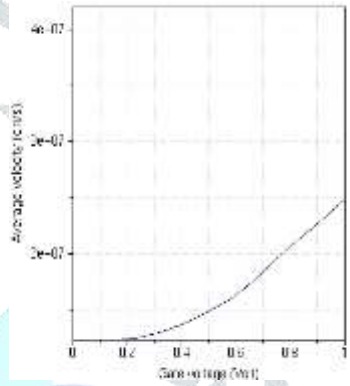


fig 6(b) average velocity vs gate voltage

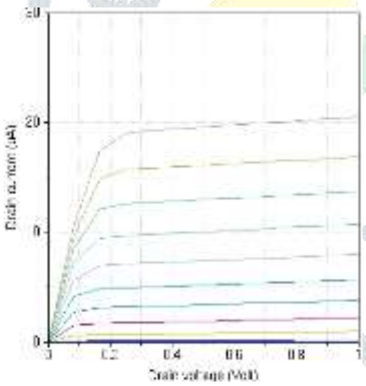


Fig6(c)drain cuurent vs Drain voltage

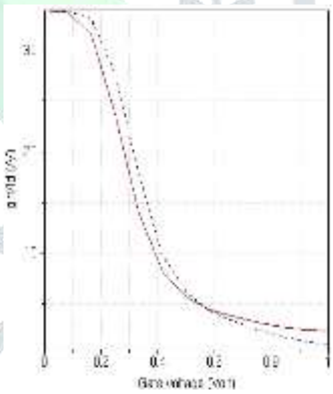


Fig6(d)gm/id vs gate voltage

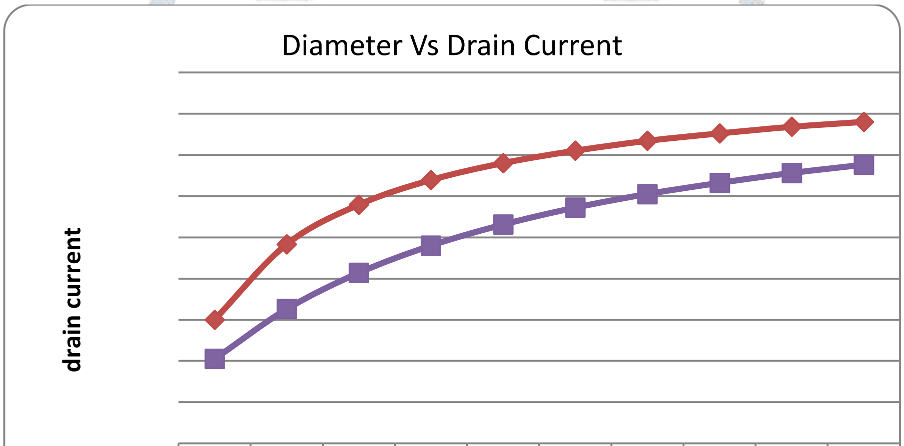
Figure6(a) shows drain current vs gate voltage. . Here the curve is to be linearly increasing order, at the point of increasing, it decreases gradually. From the figure4(c) shows average velocity vs gate voltage. Average velocity is a vector quantity and it can be defined as the displacement divided by the time. As the curve is linearly increasing from it. From the below figure 4(b) shows drain current vs drain voltage. Drain voltage is constant to 1. Drain voltage is linearly increasing. Figure 4(d) shows gm/id vs gate voltage. Transconductance is linearly decreasing with respect to the gate voltage.

IV. Comparison between Silicon Nano Wire MOSFET and Carbon Nanotube MOSFET

The simulated results and calculated values are compared and shown as graph. By changing the different values of transistors finally we analysed that CNT is a best tranistor. By comparing the different types of transistors. The below graph shown as variation of drain current vs diameter

Table 1Comparison of CNTFETand nanowire

S.No.	Diameter (nm)	Drain Current (I_d) at 1 Volts	
		Silicon Nanowire MOSFET (μa)	CNTFET (μa)
1.	1	20.5	30.0
2.	2	32.6	48.3
3.	3	41.4	57.9
4.	4	48.0	63.9
5.	5	53.1	68.0
6.	6	57.2	71.0
7.	7	60.5	73.4
8.	8	63.2	75.2
9.	9	65.6	76.8
10.	10	67.6	78.0



	1	2	3	4	5	6	7	8	9	10
CNT	30	48.3	57.9	63.9	68	71	73.4	75.2	76.8	78
Silicon	20.5	32.6	41.4	48	53.1	57.2	60.5	63.2	65.6	67.6

Figure 7. Variation of drain current vs diameter.

By analysing the different types of field effect transistor we conclude that CNT is a best transistor for the detection of diseases, in order to validate the properties of CNT. Now a days detection of diseases is very difficult so,we analysed the different types of latest field effect transistors in biomedical applications. To overcome the difficulty FET based biosensor is used. All simulations are performed in NANOHUB.

Design of biosensor array

The proposed design an array of biosensor since single sensor for the identification of disease does not give higher sensitivity. therefore it is essential to use an array of sensor to detect disease. The control unit consist of a user input that is connected to sensor array. The output of sensor array is current that flows from source to drain, at the output node the currents get added and the resulting current current is used to detect the disease.

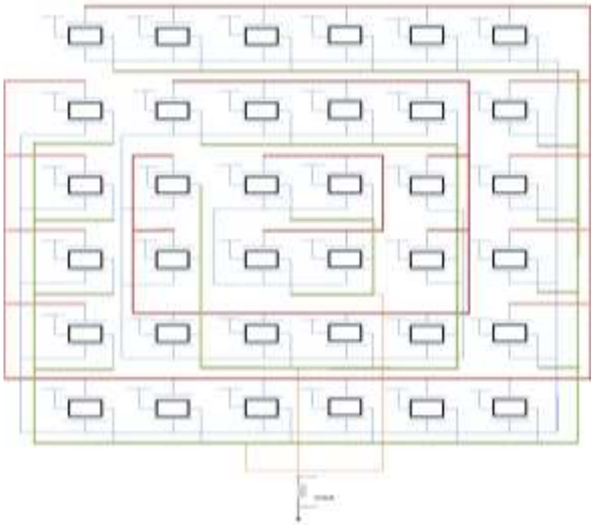


Figure 8.6x6 array of biosensor

The sample under the test is placed over the sensor array, as the analyte spread over the array, each of the biosensor capture the antigen present in the analyte and correspondingly there is electro potential created at each node and there is a corresponding current flow in the sensor.

figure 8 shown as 6x6 array of biosensor. To optimize the biosensor 6x6 array used. The sample under test is placed over the sensor array, each of the biosensor captures the antigen present in the analyte and correspondingly there is no electro potential created at each node and there is a corresponding flow in the sensor, As the analyte is placed over the array, the sensor nodes will drawn some current due to bio potential created by the electrons in the sample. When the sample is affected with cancer cell then, when an analyte sample is placed over the sensor its creates excess bio potential which leads to increase in current value drawn by the sensor.

Table 1 Performance Analysis

Sensor Model	Output Current	
	Single bioisensor	6x6 array biosensor
Silicon Nanowire FET	1.173 mA	1.578 mA
CNTFET	1.738 mA	2.203 mA
Performance Improvement		28 %

The table shows the results of affected sample with the single and 6x6 array biosensor of silicon nanowire FET and CNTFET. From this we can know that, CNTFET result shows the increase in output current with the comparison of silicon nanowire FET.

V Conclusion

In this paper we simulated and studied the electrical properties of CNT and characteristics of CNTFET and Silicon nanowire, from the obtained result, we concluded that CNTFET ii the best transistor ,it can be used as biosensor for the identification of disease, in order to increase the sensitivity of the response.

Carbon nanotube based sensor is an emerging technology which is used for diagnosing purpose. In this project we have proposed the different types of transistors which is used for the detection of diseases. Hence it gives high sensitivity and accuracy is increased. It is also implemented in hardware. So this technology wil be useful tool for the upliftment in biomedical field.

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