

Modeling and Simulation of Carbon Nanotubes based FET for Cervical Cancer Detection

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ABSTRACT: Cancer diagnosis and treatment are of great interest due to the widespread occurrence of the diseases, high death rate, and recurrence after treatment. Carbon nanotubes are attractive for nanoelectronic biomedical applications due to its excellent electric properties and sensitivity. In this paper we investigated the property of carbon nanotubes, types and its modes, carbon nanotubes based field effect transistor construction, properties, input and output characteristics of CNTFET, finally we concluded based on the results obtain an array of CNTFET can be used as a biosensor for the detection of cervical cancer with high accuracy and early detection is possible and proper dosage of medicine can be given when the stage of cancer patient is known.

KEYWORDS: Carbon nanotubes, CNTFET, Cervical cancer detection

I. INTRODUCTION

Carbon Nanotubes look like a powder or black soot, but they're actually rolled-up sheets of graphene that form hollow strands with walls that are only one atom thick. Nanotubes, which are sometimes called buckytubes, were developed from the Fullerene, a structure that is similar to the geodesic domes. Nanotubes, which are grown in a laboratory, are strong and exhibit many thermal and electrical properties that are desirable to chip makers. Carbon nanotubes have the potential to be used as semiconductors, for example, potentially replacing silicon in a wide variety of computing devices. Nanotubes can be characterized by their number of concentric cylinders, cylinder radius and cylinder length. Some nanotubes have a property called chirality, an expression of longitudinal twisting. Multiple nanotubes can be assembled into microscopic mechanical systems called nanomachines [1]. Carbon nanotubes (CNTs) are tubular cylinders of carbon atoms that have extraordinary mechanical, electrical, thermal, optical and chemical properties. At the individual tube level, these unique structures exhibit: 200X the strength and 5X the elasticity of steel; 5X the electrical conductivity ("ballistic transport"), 15X the thermal conductivity and 1,000X the current capacity of copper; at almost half the density of aluminum. CNTs typically have diameters ranging from <1 nanometer (nm) up to 50 nm[2]. Fig.1 shows single wall CNT and Fig.2 shows Multi wall CNT. The extraordinary characteristics of carbon Nanotubes make them a promising candidate for applications in microelectronics [3]. A high-performance multichannel carbon-nanotube field-effect transistor (MC-CNTFET) has been built by applying an array of parallel nanowelded single-walled carbon Nanotubes (SWCNTs) as the channels. The SWCNT channel array with good directional and spatial control was obtained by the ac electric-field alignment of SWCNTs on a specially designed electrode. An ultrasonic nanowelding technique was utilized to achieve the reliable and highly transparent contacts between SWCNT channels and electrodes. Both p- and n-MC-CNTFETs fabricated exhibit high performance[4]. The structure of the conventional CNTFET (C-CNTFET) provides a MOSFET-like behavior similar to that of a MOSFET but with ballistic transport. The source and drain regions are heavily doped, which provides barrier-height modulation by application of the gate potential[5].

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II. RELATED WORK

The operation of the conventional CNTFET has source-drain distances shorter than 150 nm, the carrier transport is expected to be essentially ballistic. Hence, from the description of current flow through the CNTFET, several aspects of the evaluation of the CNTFET potential in circuit context have been developed. The major one consists of the development of a computationally efficient physics-based compact model where the self-consistent loop in CNTFET operation is handled through analytical development, depending on the CNT diameter or chirality vector [6]. The implementation of band to-band tunneling (BTBT) mechanisms into the compact model of a conventional carbon nanotube transistor FET featuring a MOSFET-like operation has been proposed[7]. The use of transistors with multiple threshold voltages is widely utilized in today's CMOS circuits to improve performance. The threshold voltage can be changed by applying different bias voltages to the bulk terminal of the CMOS transistors. The threshold voltage of CNTFET is determined by the CNT diameter. Therefore, CNTFETs with different threshold voltages can be accomplished by growing CNTs with different diameters (chiralities). The threshold voltage of the CNTFET can be controlled easily by changing the chirality vector of the CNTs, a dual-diameter CNTFET SRAMcell configuration with different threshold voltages is designed, which is made possible by using different diameters for the p-type and n-type CNTs in the cell. The best chirality for the PCNTFETs was selected to achieve high stability, fast write time, and low power consumption [8]. The transport properties of carbon nanotube field-effect transistors (CNTFETs), with a no equilibrium Green's function (NEGF) method having Tunneling leakage currents with respect to gate voltages are known effects for MOSFET-like CNTFETs (MOSCNTs)[9]. A novel design technique for ternary logic gates based on CNTFETs is proposed and compared with the existing resistive-load CNTFET logic gate designs. Especially, these proposed ternary logic gate design technique combined with the conventional binary logic gate design technique provides an excellent speed and power consumption characteristics[10]. A new CNTFET model developed in which the drain current, the gate capacitance, and the delay can be found[11]. The excellent electro thermal properties of the SWCNTs, and have great potential for the development of active devices with low power dissipation and good reliability at high-operating temperature[12]. DWCNT array-built MOSFET-like CNTFET has been proposed for future development of CNT transistors with high performance[13]. The DG-CNTFET is effective in controlling the ambipolar conduction that is inherent to Schottky barrier (SB) CNTFETs using two independent gates, namely, the primary gate and the polarity gate. Whereas the primary gate serves to turn the device on and off, the polarity gate can be used to configure the device in either the p-type or the n-type mode of operation[14].

II. CNTFET STRUCTURE AND MODEL

CNT can be viewed conceptually as graphene (a single atomic layer of graphite) 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 (Figure 1) and multi-wall CNTs (Figure 2). The single-walled CNT can be either metallic or semiconducting depending on the chirality (i.e., the direction in which the graphene sheet is rolled). The diameter of the CNT is also determined by the chirality [11]. CNTFET is a three-terminal device consisting of a semiconducting nanotube bringing two contacts (source and drain), and acting as a carrier channel, which is turned on or off electrically via the third contact (gate)[15]. Carbon nanotubes offer some remarkable characteristics for microelectronics applications. Scattering free current transport allows high current densities and improved signal delays for long wires. Selective catalyst mediated CVD-growth of CNTs is the most suitable method for CNT vias. CNTFETs with semiconducting nanotubes are promising candidates for transistor devices with superior characteristics as compared to silicon MOSFETs[16]

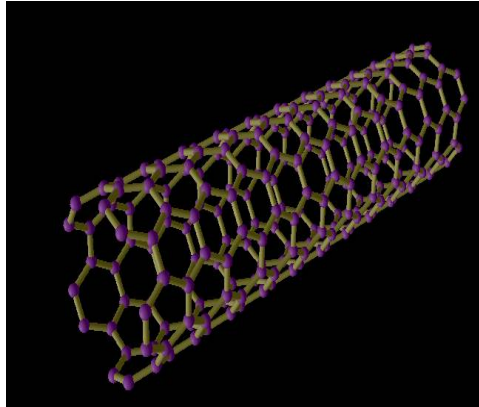


Fig.1 Single wall Carbon nanotube

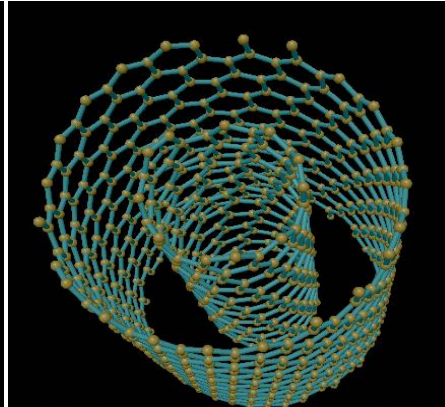


Fig.2 Multi wall Carbon nanotube

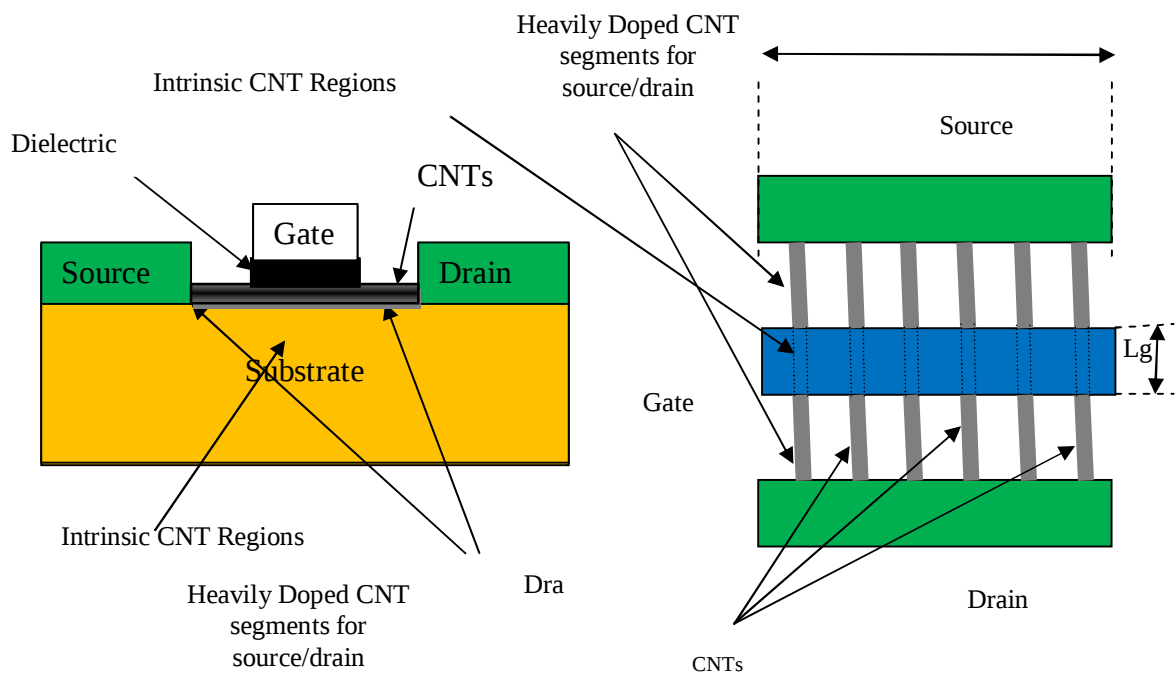


Fig.3 Structure of CNTFET

Figure 3 shows the structure of CNTFET and its different regions. Between the source and drain heavily doped CNT segments are connected. The length of the gate is specified as L_g as shown. For CNTFET the chiral vectors (n, m) nanotubes with $n = m$ are metallic; for $n - m \neq 3 \times \text{integer}$, the nanotubes are semiconducting with band gap proportional to $1/d$. For $n - m = 3 \times \text{integer}$, the nanotubes would be quasi-semiconducting with a small band gap proportional to $1/d^2$. The sensitivity of electrical properties on structural parameters in unique for CNTs, which opens up numerous opportunities in nanotube systems. The diameter of the zigzag nanotube, d is given by equation (1)

$$D = \frac{n\sqrt{3a_{cc}}}{\pi} \quad \text{-----} \quad (1)$$

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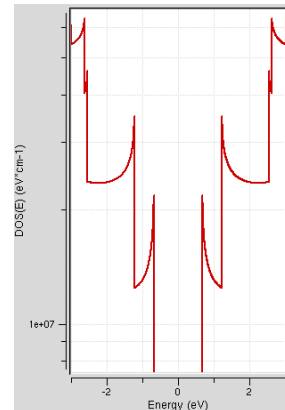
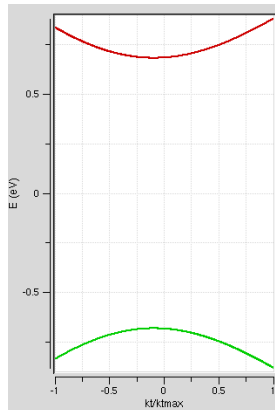
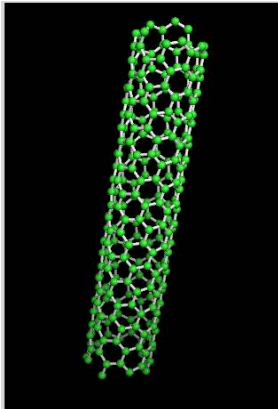


Figure 4(a)

Figure 4(b)

Figure 4(c)

Figure 4(a),4(b),4(c)Structure of CNTFET, Lowest energy sub band and Density of states Vs Energy for chiral vector $n=2, m=7$

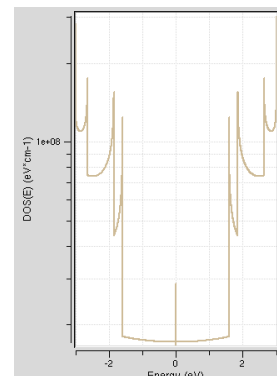
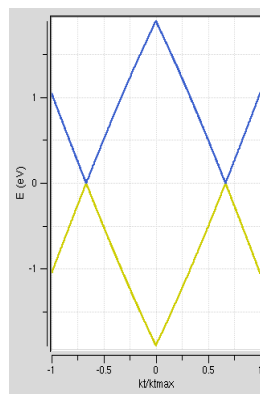
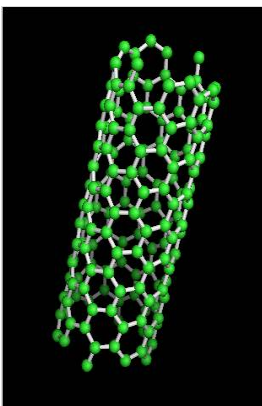


Figure 5(a)

Figure 5(b)

Figure 5(c)

Figure 5(a),5(b),5(c)Structure of CNTFET, Lowest energy sub band and Density of states Vs Energy for chiral vector $n=2, m=8$

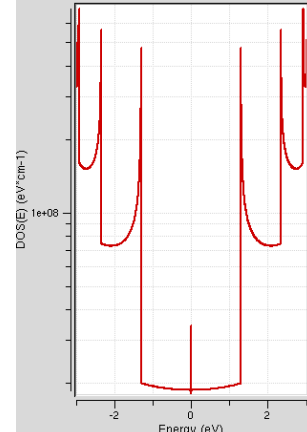
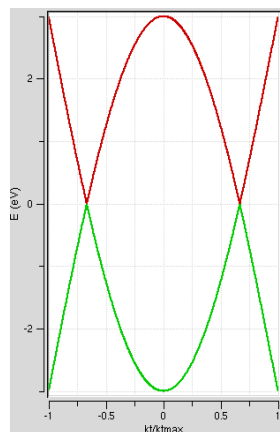
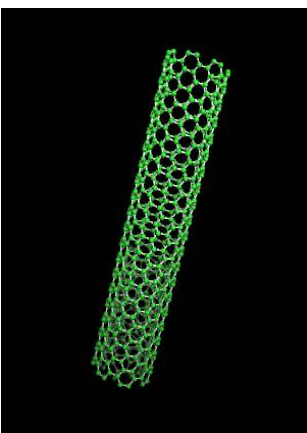


Figure 6(a)

Figure 6(b)

Figure 6(c)

Figure 6(a),6(b),6(c)Structure of CNTFET, Lowest energy sub band and Density of states Vs Energy for chiral vector $n=7, m=7$

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In order to study the electrical properties, carbon nanotubes is simulated in different modes. Figure 4(a),4(b),4(c)Structure of CNTFET, Lowest energy sub band and Density of states Vs Energy for chiral vector $n=2$, $m=7$. Figure5(a),5(b),5(c)Structure of CNTFET, Lowest energy sub band and Density of states Vs Energy for chiral vector $n=2$, $m=8$ and Figure6(a),6(b),6(c)Structure of CNTFET, Lowest energy sub band and Density of states Vs Energy for chiral vector $n=7$, $m=7$.

III. CNTFET SIMULATIONS

The electrical properties of a single wall carbon nanotube offer the potential for molecular-scale electronics, a typical semiconducting single-wall carbon nanotube is 1.4nm in diameter with a 0.6eV band-gap (the band-gap is inversely proportional to the diameter). Recent Carbon Nanotube Field Effect Transistors (CNFETs) have a metal carbide source/drain contact and a top gated structure as in figure 8 with thin gate dielectrics.

a)CNTFET Properties

To measure the actual performance of a CNTFET and for properties, CNTFET should be understood by the I-V characteristics. It is important to know the characteristics of a single CNT based transistor.

Table 1 Device parameters for simulation (CNTFET model)

Oxide thickness	4 nm
CNT diameter	1.2-1.8 nm
Source / Drain doping levels	0.59 eV-0.75 eV
Power supply	0.9 V
Mean free path: Intrinsic CNT	200 nm
Mean free path: Doped CNT	15 nm
Gate/Source/Drain length	32 nm
Work function(Contact & CNT)	4.5 eV
Interconnect capacitance	0.22fF/ μ m

b)Input Characteristics

The input characteristics curve is drawn between the input voltage V_{gs} and the output drain current. The simulation result for both CNTFET's with 32 nm MOSFET is shown in figures 7(a) & (b) . The ON current is increasing linearly with the input voltage V_{gs} . The CNT will provide the high channel mobility so automatically current will increase and linearity is more. The current is drastically increasing in CNTFET with increasing of number of tubes.

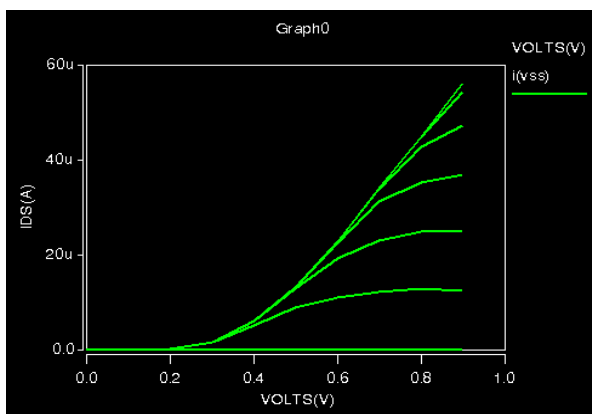


Figure 7(a) Input characteristics of NCNTFET

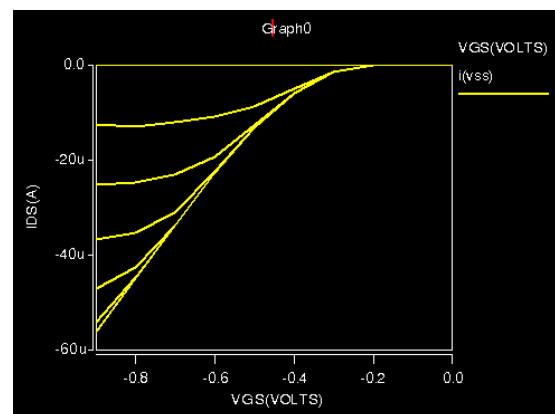


Figure 7(b) Input characteristics of PCNTFET

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c) Output Characteristics

The output characteristic curve is drawn between the drain to source voltage (V_{ds}) and drain current (I_{drain}) for the constant different source to gate voltages (V_{gs}). This characteristic curve gives the pinch-off, linearity and the effect of drain resistance. Figures 8 (a) &(b) shows the output characteristics of CNTFET and 32nm MOSFET transistors. The current of the CNTFET can be increased by increasing the number of tubes in a CNTFET at room temperature. The leakage power is also reduced due to the high stability in saturation current and due to back gate control saturation current decreased with high performance.

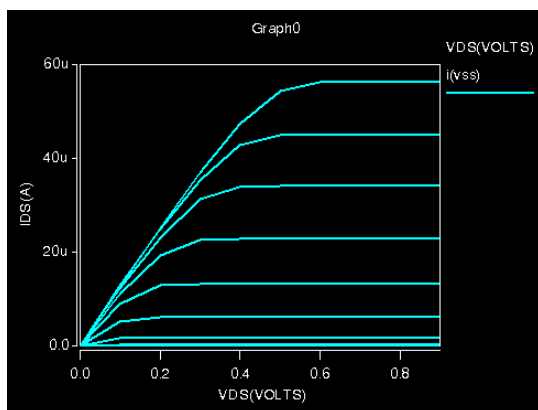


Figure 8(a) Output characteristics of NCNTFET

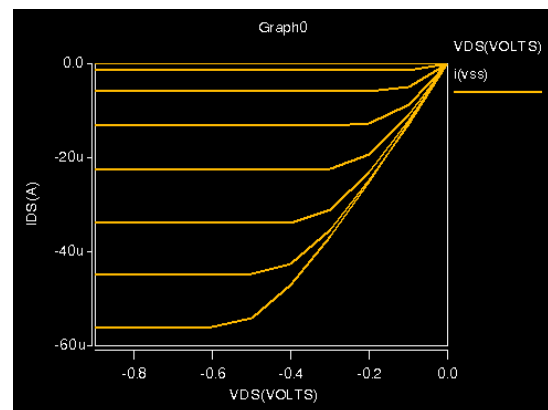


Figure 8(b) Output characteristics of PCNTFET

IV CNTFET AS BIOSENSOR FOR CERVICAL CANCER DETECTION

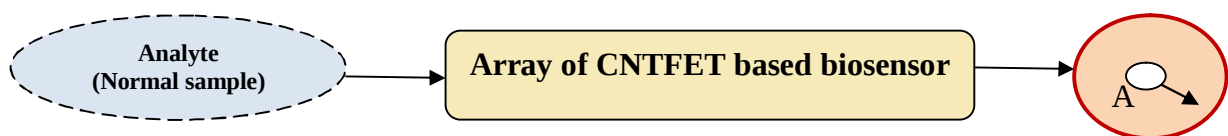


Figure 9 CNTFET arrays used as biosensor, response for normal sample

Cancer diagnosis and treatment are of great interest due to the widespread occurrence of the diseases, high death rate, and recurrence after treatment. Based on the study of CNTFET, Here an array of CNTFET based sensor is implemented. Figure 9 shows the response A for the normal analyte and figure 10 shows the system with response of B in which the variation is observed, the amount of variation of current in the system is the intensity of cancer affected by the human. In this method, the stage and intensity of cancer can be identified.

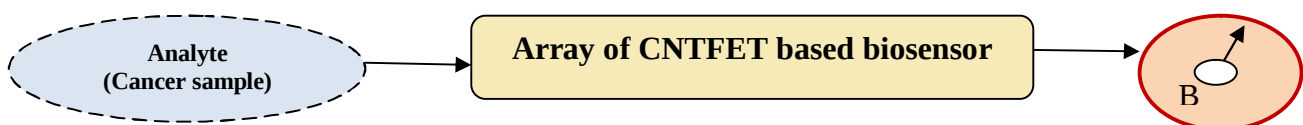


Figure10 CNTFET arrays used as biosensor, response for cancer sample

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V CONCLUSION

In this paper, we simulated and studied the electrical properties of CNT and characteristics of CNTFET, from the obtained result, we concluded that CNTFET can be used as biosensor for the identification of cervical cancer, in order to increase the sensitivity of the response, a system consist of an array of CNTFET can be used, by comparing the response obtained from the normal analyte and cancer analyte, the intensity of the cancer causing agent can be analyzed and the variation of current flow is proportional to the intensity of cancer cell in the analyte.

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