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Study the Electrical Performance of Carbon Nanotube Field Effect transistor (CNTFET) with mixed I-V characteristics

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ABSTRACT

The I-V characteristics of carbon nanotube field effect transistor (CNTFET) are explored. As the CNFET is a new transistor that can create the tremendous progress in the field of nano electronics and integrated circuits design due to its excellent electrical properties. This device can overcome the limitations that were found in the Si MOSFET.It performance of carbon nanotube depend on the gate insulator thickness and the length of carbon nanotube. So in this paper, we simulate the structure, operation and the I-V characteristics like output characteristics, mobile charge, quantum capacitance, insulator capacitance, average velocity and qm/id ratio by changing the values of nanotube diameter and gate insulator thickness in detail.

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INTRODUCTION

The transistor has simple function, although it is considered one of the most sophisticated devices created by mankind. The 10 (Jang, Y.T. C.H. Choi, 2013) transistors have been fabricated annually and play a crucial role in computers, cell phones, power relays and variety of other electronic devices.

A transistor plays a key role in the field of electronics. By the passage of time, the dimensions and performances of devices are improved. Nanotechnology is also achieving breakthroughs in thermo electrics which have suffered from problems of low efficiencies for decades. As the device scale enters the nanometer range and novel device structures are introduced, it becomes essential to revisit the physical data of a device and develop new simulation frameworks to analyze the experimental data and project the device performance (Kim, Ra seong, Mark S., 2011).

As Gordon Moore predicted in 1965 that the number of transistors in chips are duplicates every 18 months. Complementary metal oxide semiconductor (CMOS) is less suitable for near future nano-scale regime.

For getting the higher computing power, small size, very low power usage of integrating circuits leads to a pressing need to downscale semiconductor devices(ITRS Roadmap, 2001).However if we make the size of the MOSFETs small then we have to face a number of problems like high power consumption, short channel effect and gate leakage current.

The credit for the discovery of carbon nanotube (CNT) was goes to Lijima in (1991) after the discovery of carbon nanotube, researchers have done a lot of work in exploring the structural properties and possible applications in engineering field. The engineering applications for nano electronics devices have been analyzed since the exposition of the first carbon nanotube transistor (CNTFET) in (Tans, S.J., A.R.M. Verschueren, 1998).

The CNT's are suitable for nano electronics applications due to their excellent electrical properties like high resistive to electron migration, low bias transport, high k-get insulator, high conductance, high mobility, chemical inertness and Fermi level pinning.

In order to the improve the efficiency of transistor ,a number of techniques have been developed like scaling of nanotube channel, good material for source/drain constants (Javey, A. J. Guo, 2003), high k-gate dielectric insulator (Javey, A., H. Kim, 2002; Wind, S.J., J. Appenzeller, 2001) and construction of self align.

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1-Caron Nanotube Field Effect Transistor (CNTFET):

The maximum possible bulk mobility is achieved by severely reducing the phase space for scattering of CNT's. For high on-current of CNT transistor low scattering probability and high mobility are very important. In the same way, low scattering along with the strong chemical bonding and high thermal conductivity leads to metallic CNT's to extremely high current densities (Benfdila, A., M. Berd, 2012).

In MOSFET structure, we used the silicon as a channel material but we used the single carbon nanotube or a collection of carbon nanotube as channel in carbon nanotube field effect transistor (CNFET) (Sanjeet Kumar Sinha, Saurabh Choudhry, 2012) The carbon nanotube shows a very interesting perspective as it can serve as a link between electronics and photonics. This will lead to integrated circuits(IC).

There are two types of CNTFET, the first one is single-walled carbon nanotube field effect transistor (SWCNT) and the second one is multi-walled carbon nanotube (MWCNT). The structure of single-walled CNT is like a hollow cylinder that has a shape like of a hexagonal. The diameter of carbon atoms are 0.3nm to few nm and length of 10 centimeters. There are also multi-walled CNT with concentrically stacked shells, but while multi-walled CNT's are mostly used for the improvement of electromechanical properties of composite data and also for field emission equipments, SWCNTs are much more suitable for transistor design because they have small size and excellent electrical characteristics.

The electronic properties of CNT's make them suitable not only for transistors but also for others applications as gas sensor (Suehiro, J. G. Zhou, 2003), high frequency diodes (Manohara, H.M., E.W. Wong, 2005), light emitting diodes (Muelleer, T. M. Kinoshita, 2010)[, and efficient photovoltaic devices (Gabor, N.M., Z. Zhong, 2009).Owing to their high strength and low density CNT's are more attractive for nano-electromechanical systems(NEMS)(Sazonoya, V., Y. Yaish, 2004), thin conducting sheets(Zhang, M., S. Fang, 2005) or in composite materials (Schadler, L.S. S.C. Giannaris, 1998).The high aspect ratio of CNT's is also a suitable property for tips of scanning probe microscopy (Hafner, J.H., C.L. Cheung, 2006) and field emitter for flat panel displays (Jang, Y.T. C.H. Choi, 2003) while the large surface to volume ratio can be exploited for hydrogen storage in fuel cells (Dillon, K.M., Jones, 1997) or capacitors (Futaba, D.N., K. Hata, 2006).

2. ***Observation and experiments:***

The FETTOY tool that is used to simulate the I-V characteristics of MOSFET.It simulates the carbon nanotube field effect transistor, silicon nano wire, single and double gate MOSFET. By using this tool the characteristics of CNFET are explored for different structural design and voltage. CNFET are simulated under some conditions like the value of gate and drain control specification should be less then or equal to 1.The performance of CNFET depends on gate insulator thickness and length of carbon nanotube.

The thicker the oxide layer and the bigger diameter have less voltage through the insulator and more current density. The value of gate insulator thickness is changed from 1.5 nm to 5.5 nm and diameter of the carbon nanotube is varied from 1nm to 5 nm. Drain current is increased with the increase of gate control and drain control parameters. It shows that the saturation region depends on diameter, not like MOSFET that depend on the channel pinch off.

In this paper, we have investigated some electrical properties of CNFET like transfer characteristics, mobile charge, quantum capacitance, insulator capacitance, gm/id ratio and average velocity.

2.1 Drain Current vs. Gate Voltage:

The relation between drain current vs. gate voltage for gate insulator thickness and diameter of carbon nanotube is shown in fig 1 and 2 respectively. The drain current is decreases with the increase of gate voltage. The gate thickness affects the value of drain current. The drain current decreases with the increase of gate thickness. Its mean the drain current is inversely proportional to gate thickness. The drain current increases with the increase of nanotube diameter.

2.2 Mobile charges vs. Gate Voltage:

The relation between mobiles charges vs. gate voltage for gate insulator thickness and nanotube diameter is shown in fig 3 and 4.We noted that the curve is increasing with increase the gate voltage and then reached a point that the curve has no effect with the increasing the gate voltage and it remains same. Mobile charges have indirect relation with gate voltage; the mobile charge has low value at high gate voltage. With decreasing the value of gate voltage the value of mobile charge increases. It is also observed that the value of mobile charge decreases with the increase of gate insulator thickness.

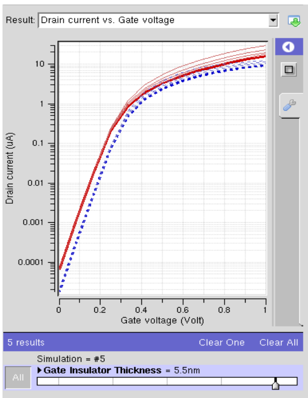

Figure 1

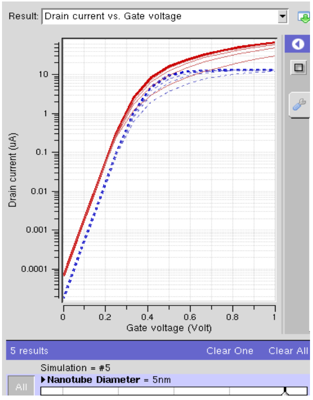

Figure 2

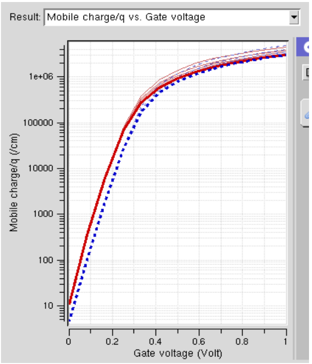

Figure 3

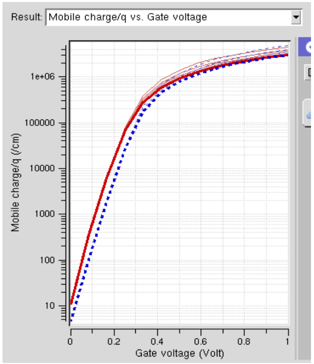

Figure 4

2.3 Quantum Capacitance vs. Gate voltage:

The relation between quantum capacitance vs. gate voltage for gate insulator thickness and nanotube diameter is shown in fig 5 and 6 respectively. The quantum capacitance decreases with the increase of gate insulator thickness. Its mean that quantum capacitance is inversely proportional with gate insulator thickness.

The value of quantum capacitance is increases with the increase of gate voltage, by changing the value of gate insulator thickness there is little interval decrement in the value of quantum capacitance but in fig 6 the by changing the value of value of nanotube diameter, there is large interval decrement in the value of quantum capacitance.

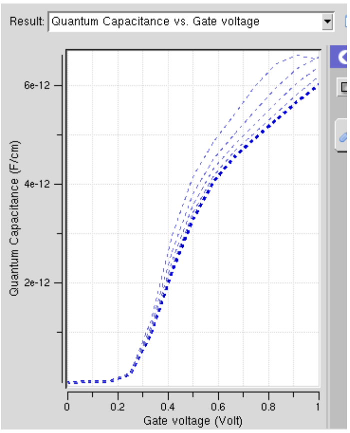

Figure 5

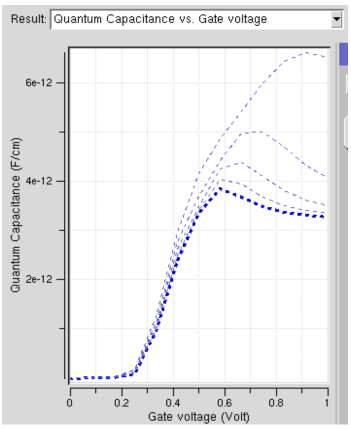

Figure 6

2.4 QC/ Insulator capacitance vs. Gate voltage:

The relation between QC insulator capacitance vs. gate voltage for gate insulator thickness and nanotube diameter has been shown in fit 7 and 8 respectively. The value of QC insulator capacitance increases with the increase of gate voltage. QC/insulator capacitance increases with the increase of gate insulator thickness. Its mean the QC/insulator capacitance is directly proportional to gate insulator thickness.

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But in fig 8, the relation between QC/insulator capacitance vs. gate voltage for nanotube diameter has been shown. The value of QC/ insulator capacitance is decreases with the increase of gate voltage. By increasing the value of nanotube diameter the value of QC/insulator capacitance is also decreased.

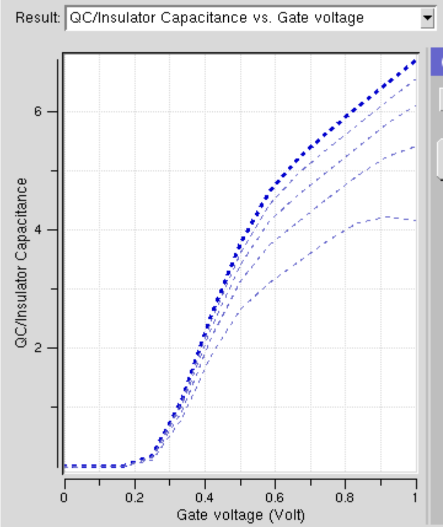

Figure 7

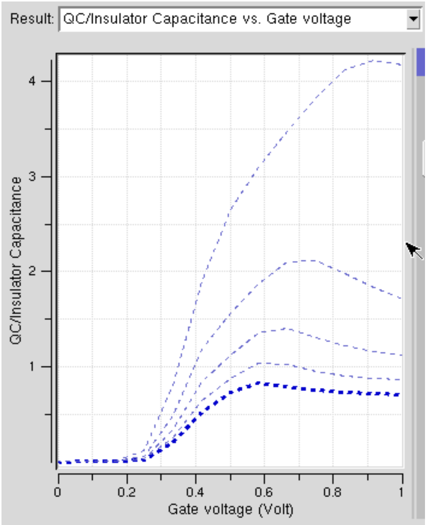

Figure 8

2.5 Average velocity vs. Gate voltage:

The relation between average velocity vs. gate voltage for gate insulator thickness and nanotube diameter has been shown in fig 9 and 10 respectively. The value of average velocity is decreases with the increase of gate voltage. It is also noted that the average velocity decreases with the increase of gate insulator thickness.

For nanotube diameter the average velocity is increases with the increase of gate voltage. By increasing the value of nanotube diameter average velocity is also increased. It means that the average velocity is directly tonanotube diameter.

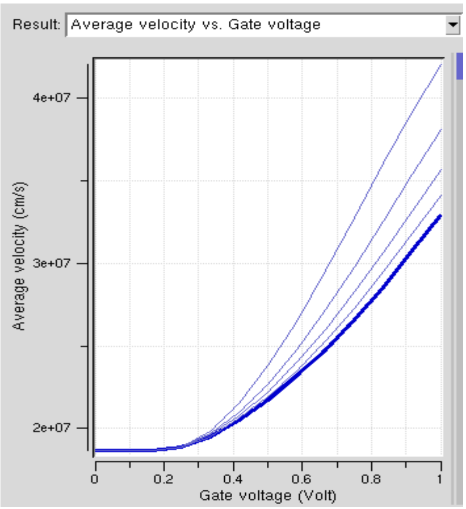

Figure 9

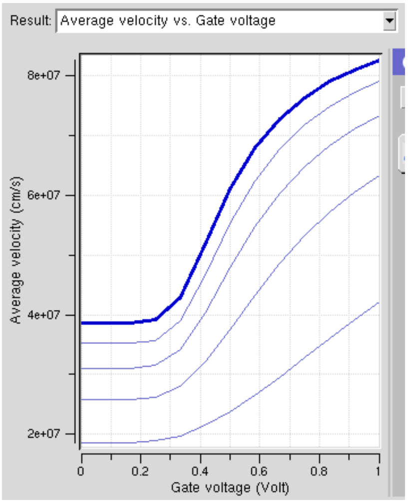

Figure 10

2.6 gm/Id ratio vs. gate voltage:

The relation between gm/id ratio vs. gate voltage for gate insulator thickness and nanotube diameter has been shown in fig 11 and 12 respectively; the value of gm/id ratio is decreases with the increase of gate voltage for gate insulator thickness and carbon nanotube diameter. For getting the higher value of transconductance the value of gate insulator thickness should be very low.

Conclusion:

In this paper, we have studied the carbon nanotube, types, and electrical properties like drain current, average velocity, mobile charges and quantum capacitance that make it very useful for future nanotechnology and physical properties of it. We have simulated the diameter of carbon nanotube and gate insulator thickness with different values for the electrical properties of carbon nanotube FET. The explored characteristics of CNTFET make it liable in transistor application memory cells, medical equipments and field emission displays.

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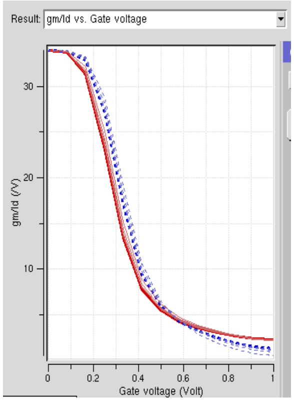

Figure 11

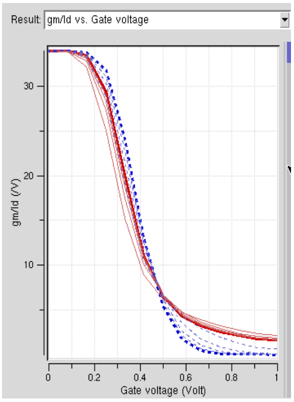

Figure 12

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