International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Carbon Nanotubes Field Effect Transistor: A Review

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Abstract: ***In this paper we have focused on the carbon nano tube field effect transistor technology. The advantages of CNTFET over MOS technology are also discussed. The structure and types of CNTFET are given in detail along with the variation of threshold voltage with respect to the alteration in CNT diameter. The characteristics curve between gate to source current and drain to source voltage is plotted. Various fixed and variable parameters of CNT are also focused.***

Keywords: CNTFET, Nano tube diameter, 3-D structure, MOSFET, I-V characteristics, fixed and variable parameters

1. Introduction

According to Moore's law, the numbers of transistors on an IC are increasing. This increased number of transistors results in the demand for decreasing the size of transistor and so the circuit size is also reduced. This gives birth to nanoscale technology. CMOS has flexible nature but still it faces many challenges in the field of nanotechnology. As the CMOS is scaled down then the power dissipation of the device is increased to a great extent. The leakage current also increases simultaneously. Short channel effect is another destructive challenge of MOSFET device. CNTFET has been announced as one of the most popular replacement for conventional MOSFET due to its similarities in terms of manufacturing process and electrical properties. In it the flow of electrons follow the ballistic transport.[1] Also the leakage current is very low. Thus CNTFET exhibits excellent performance characteristics over conventional MOSFET.

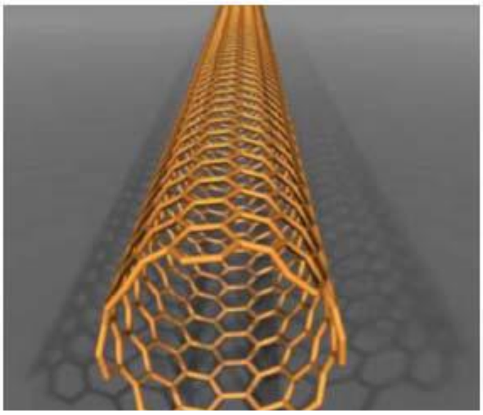

Figure 1: Graphine sheet forming CNT [2]

2. CNTFET Review

The important characteristic of CNTFET is its flexible behavior of changing the threshold voltage (V_{th}) by adopting different values of diameter for CNTs. [3] CNTFET is of 3 types: 1) Schottky Barrier CNFET (SB-CNFET): In this type the drain and source are directly connected to the channel.[4]. 2) MOSFET type CNFET (MOS-CNFET): In it the connecting source and drain of the impurities has been formed. 3) Tunneling CNFET (T-CNFET): This CNFET has an excellent cut-off characteristic. [7]. The structures of 3 types of transistors are shown in figure 2.

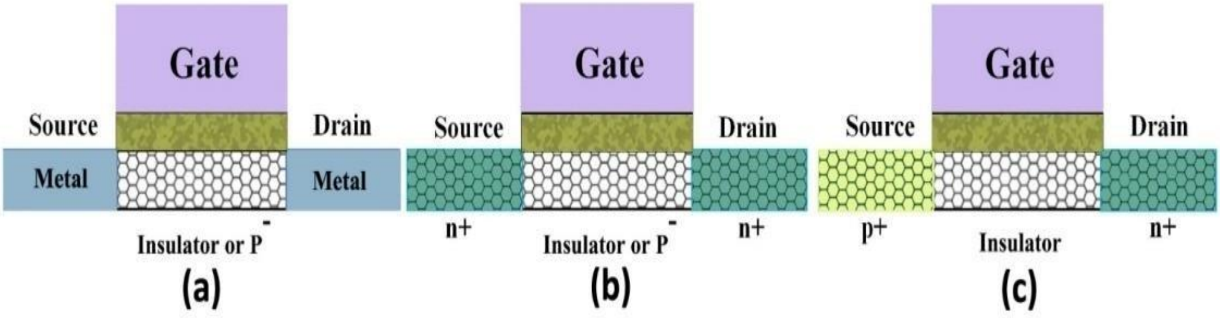

Figure 2: SB-CNFET (b) MOS-CNFET (c) T-CNFET [8]

The Leakage power is negligible when CNTFET is in turn off state. [9]. The structural and electrical characteristics are similar to MOSFETs, which facilitates the reuse of previous MOSFET based architectures and fabrication processes [10]. The structure of a MOSFET-like CNTFET is given in Fig 3. The main point of contrast is that in the CNTFET, the current flows through CNTs instead of the flow of holes and electrons through the physical channel in the substrate. The CNTs under the gate region are intrinsic to have semiconducting behavior and can be controlled by the input voltage of gate [11]. The fabrication of single-wall CNT (SWCNT) transistors came into existence in [9], [12]. A SWCNT is consists of a single hollow tube of rolled graphene sheet. This can either be metallic in nature or semiconducting in nature, depending on the values of vectors m and n.[13],[10],[14] This is possible only because of the angle of atoms arranged along the nanotube. This angle is represented by a 2-D vector known as the chirality vector .As shown in fig 4, CNTs can be rolled in 3 different ways, namely Armchair, chiral and Zigzag.[15].

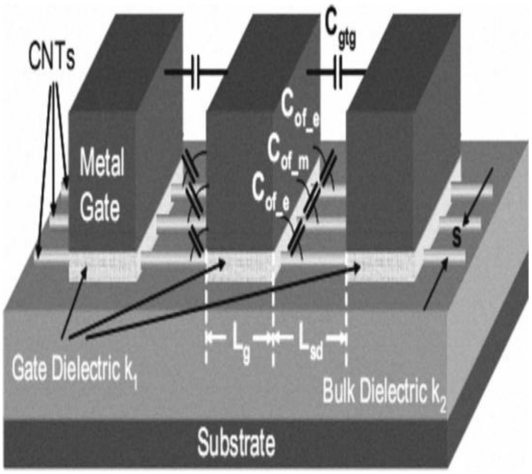

Figure 3: 3-D structure of CNTFET[16]

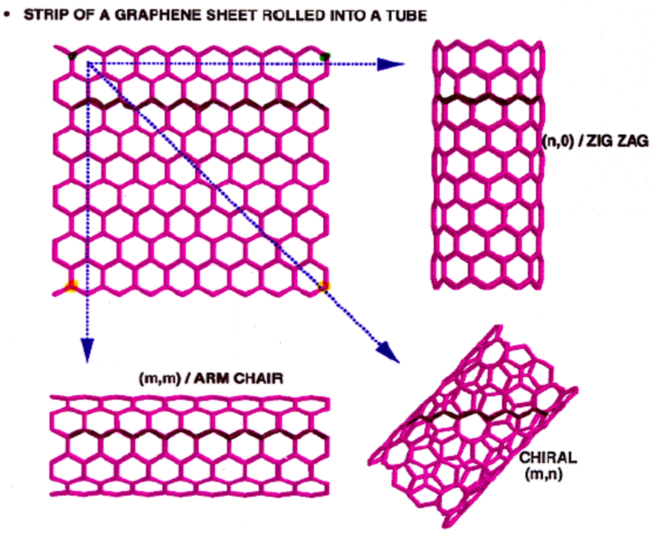

Figure 4: Types of CNTFET according to chirality

Diameter	Behaviour
$D_{CNT} = \frac{\sqrt{3}a_0}{\pi}\sqrt{n^2+m^2+nm}$, $a_0 = 0.142nm$	Rest of $[(n-m)/3] = 0 \rightarrow$ Metallic
	Rest of $[(n-m)/3] \neq 0 \rightarrow$ Semiconducting

Now the value of threshold voltage (Vth) [17] according to diameter D is given below:

$$Vth = 0.43 \div Dcnt(nm) \quad (1)$$

Based on the above observation, for different values of D we calculated different values of vth. The curve between I_{DS} and V_{DS} is shown below in figure 5:

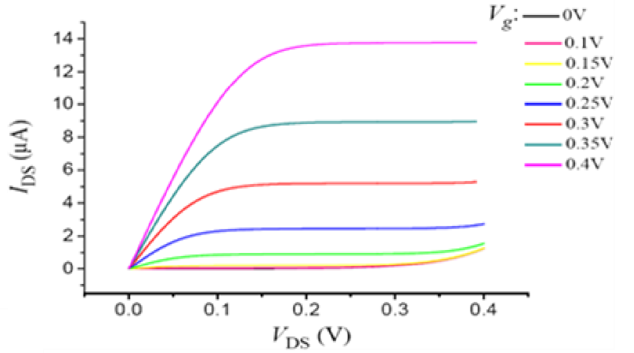

Figure 5: Plot b\w I-V [18]

The CNTFET has 2 types of parameters: fixed parameters and variable parameters. These are given below in tabular manner.

Table 1: Parameters specifications

Fixed Parameters		*Variable Parameters*	
Power supply	0.9 V	No. of CNTs per device	Nominal:8
Oxide thickness	4nm		
Gate\source\drain length	16nm	CNT diameter	1-6nm
Width of metal gate	36nm		
CNT pitch	4nm	Metallic CNT proportion	0-33%

3. CNTFET- Based Logic Circuits

Earlier CNTFET was only used for resistive load circuits. As the time passed, the advancements in CNTFET were also done. Later on it was used for logic gates like inverter, AND gate, NAND gate, NOR gate etc. It is also used in the designing of SRAM cells. A new logic called ternary logic is also developed. Ternary logic functions are used when a third significant value other than binary value is introduced. The ternary values to represent true, undefined and false states are 2, 1, and 0 respectively. The main advantage of it is that it reduces the number of computational steps required. It is also used for full adder and multipliers when the conventional binary logic gate design is combined with the ternary logic design.[19]. To evaluate the performance of a CNTFET, various simulation models have been proposed. The CNFET HSPICE model is widely used in circuit design and simulation. The window of HSPICE TOOL version B 2008.09 is shown below.

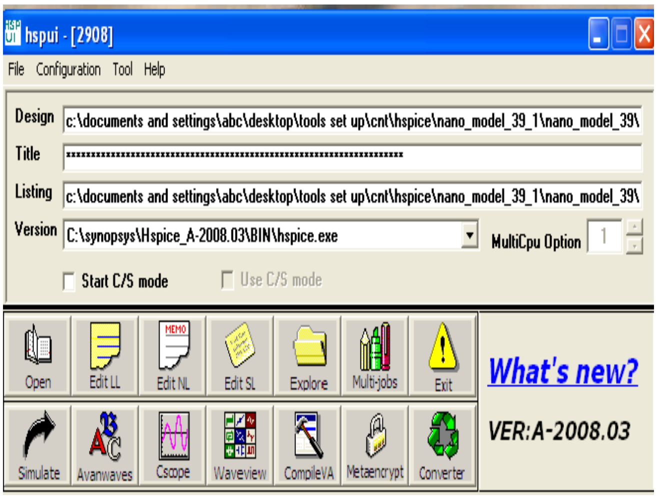

Figure 6: HSPICE tool window

4. Conclusion

This paper provides the summary of different types of CNTFETs and their structures. The spectacular conclusion is that the threshold voltage varies according to the diameter of CNT. 4-12 CNTs could be used according to the requirement. CNTFET proves to be an efficient device for nano electronics in future.

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