EFFECT OF CHIRALITY VECTOR ON DRAIN CURRENT OF PLANAR CNTFETS

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Abstract: Practical Scaling of MOSFETs below 20nm has led to many limitations such as short channel effects, as a solution new geometry of FETS was designed. Research on present era of CNTFETS is carried on to design high speed, energy efficient digital circuits. This paper models the variation of drain current with the change in value of ‘n’ of the chiral vector with carbon Nano tube length of 5nm which acts as channel between source and drain.

Keywords: CNTFETS, tube diameter, drain current

1. Introduction

The rapid progress of silicon technology is continuing with present generation technologies of gate lengths less than 22 nm. Moore’s law states the scaling of ICs, which carried out a lot of research in Nano world. Early years of silicon era used MOSFETs for designing the circuits. Many research articles have been published that demonstrate the improved short-channel effects of conventional bulk MOSFETs [1-4,5-7]. Section II gives a brief report on CNTs and modelling of CNTFETs [8-9]. Results and discussions are carried out in section III. Conclusions are discussed in section IV.

2. CNTS and CNTFETS

Dennard’s scaling lead to many short channel effects, which can be reduced either by changing the material of the transistors or by changing the geometry. Research on solutions to breakdown of Dennard’s law has led to the evolution of FinFETs and CNTFETs. Carbon Nanotubes are rolled up single layered graphite sheets with diameters ranging roughly from 1nm to 100nm. Carbon nanotubes are formed by concentric layers of carbon atoms in a honey comb lattice. Carrier transport is of 1-D, which opens up the possibility of ballistic transport. Extraordinary strength of Carbon-carbon bond of graphitic configuration exhibits excellent electronic and mechanical characteristics. Low power dissipation is observed due to ballistic transport. Current density of CNTs is as high as 10^9A/cm^2 [10]. Diameter of CNTs is controlled by chemistry rather by conventional fabrication. Circumference of Nano tube is expressed by chirality vector, which are shown in figure 1 and 2.

\[ C = na_1 + ma_2, \]

where \((n, m)\) are integers which describe the honeycomb lattice of any nanotube.

Figure 1: Structure of CNTs in terms of Chirality vector.

Figure 2: structure of CNT.

Diameter of CNTs is given by the equation:

\[ d = \frac{a_0 \sqrt{n^2 + m^2}}{\pi} \]

--- [1]

Where \(a_0\) = chiral vector, \(n\) & \(m\) are integers, \(d\) is diameter. CNTs behave as semiconductors or metals depending on the values of \((n, m)\) of chiral vector. In particular, if \(n-m = 3i\), where \(i\) is integer, or \(n=m\) then it is metallic, otherwise semiconductor. As CNTs exhibit excellent Electronic
properties, they are used in FETs as channel between Source and drain. CNTFET is three terminal device consisting of Carbon nanotube between source and drain, which is turned ON and OFF via third terminal gate. Several types of CNTFETs are fabricated but majorly they are grouped into two geometries

1) Planar CNTFETs
2) Coaxial CNTFETs.

This work analyses the current variation of Planar CNTFETs with respect to change in value of ‘n’ an integer of chiral vector. Current variation is also observed by reducing carbon nanotube length. Planar CNTFETs are relatively simple and are moderate compatible with existing manufacturing technologies [11].

Considering equation 1, diameter of CNT depends on value of ‘n’, which is an integer of chiral vector. In the chiral index m=0, and n is any value of integer (n,0) which represents a semiconducting nano tube. Now Equation 1 is represented as

\[ d = a_0 n \]  \[ 2 \]

where \( d \) is diameter, \( a_0 \) is C-C bond length of 0.142nm

From equation -2, diameter is proportional to value of n. Therefore as n increases, diameter also increases. Simulations are carried out by increasing the value of n, and reducing the CNT length, i.e channel length. Simulations are carried out in the next section which concludes that Drain current increases with increase in ‘n’ and decrease in CNT length.

3. Results And Discussions

This research work provides the drain current variation with three different values of n, by maintaining C-C bond \( a_0 \) as constant with a value of 0.144nm. Figure 5 shows Planar CNTFET parameters. As mentioned in the below figure, value of \( n = 13 \) and \( m = 0 \) of chirality vector with reduced carbon nanotube length of 5nm.

Figure 5: Device settings of Planar CNTFET with \( n=13 \)

Figure 6 shows the variation of drain current with change in maximum applied voltage of 1v. \( n=13 \) with maximum voltage applied as 1v. Figure shows that drain current increases with increase in applied voltage, with maximum current of 2.91µA at 1v.
As mentioned in the below figure, value of $n = 13$ and $m = 0$ of chirality vector with reduced carbon nanotube length of 5nm.

Figure 8 shows the variation of drain current with change in maximum applied voltage of 1v. $n=14$ with maximum voltage applied as 1v. Figure shows that drain current increases with increase in applied voltage, with maximum current of 3.005µA at 1v.

As mentioned in the below figure, value of $n = 13$ and $m = 0$ of chirality vector with reduced carbon nanotube length of 5nm.

Figure 10 shows the variation of drain current with change in maximum applied voltage of 1v. $n=16$ with maximum voltage applied as 1v. Figure shows that drain current increases with increase in applied voltage, with maximum current of 3.005µA at 1v.
Increase in Drain current is observed in the above table, with change in value of ‘n’. It is also observed that the current increases with increase in diameter.

4. Conclusion

This paper summarizes about CNTs and two major geometries of CNTFETs. Paper consists of the simulations of drain current with different values of ‘n’. This paper concludes that semiconductor CNTs which are acting as channel between source and drain in Planar CNTFETs with n as any integer and m=0, diameter is proportional to n. As ‘n’ increases diameter increases, therefore obtained simulations concludes that the drain current increases with increase diameter and ‘n’.

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