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Application of Graphene as Carbon Nanotube For Future CNTFET Devices

Sanjeet K. Sinha, Sweta Chander, Govind S. Patel, Suman L. Tripathi and Sobhit Saxena

School of Electronics and Electrical Engineering
Lovely Professional University, Phagwara, Punjab, India

E-mail: sanjeet.22690@lpu.co.in

Abstract— **Due to rapid scaling of semiconductor devices, threshold voltage is also scaled down to some extend which further increases the leakage current of devices. In this paper, Impact of chiral vector on threshold voltage of carbon nanotube is observed for CNTFET device. We have simulated the CNTFET with a number of different combinations of chiral vector pairs using HSPICE tool and considered the Stanford model of CNTFET devices for simulation. It is much clear from the simulated result that in order to have high threshold voltages in CNTFET which is emerging device in nanometer regime, the chiral vectors (m,n) will be relatively smaller.**

Keywords:- MOSFET, CNT, CNTFET, chiral vector, threshold voltage.

I. INTRODUCTION

In earth crust graphite is a widely found mineral which have so many inside layers of graphene. Graphite is a carbon allotropes which is available inside metamorphic rocks in different continent of the earth. The available chemical bond in graphite is similar to diamond in term of strength of material. Whereas, lattice structures of carbon atoms gives the difference in hardness of diamond and graphite [1]. As far as lattice bonds are concerned graphite is having two dimensional lattice bond whereas the diamond have three dimensional Because of two dimensional lattice bond intermolecular bond inside graphite is weaker compare to diamond.

These characteristics permits the layers of the graphite to slide across other existing layers, which makes graphite become softer as well as malleable-material compared to diamond.

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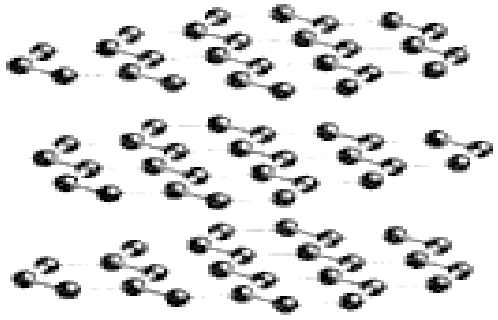

Fig. 1. Structure of Graphite

Graphene is having great potential for future nano-electronics device application because some favorable properties e.g mechanical-strength and high electronic-conductivity. Graphene exhibits the same properties of graphite [2]. Although because of sheer planes existing in graphite it is not be used as structural material in semiconductor devices [3]. Compare to other materials graphene is the strongest material available in the earth crust. Grapheme is much stronger than diamond and it is 40 times stronger compare to diamond and around 300 times stronger compare to the available steel [4]. However, electron motilities are concerned, graphene is having very high electron mobility as well as it is very good electrical conductor because of a free electron in each available carbon atom. Regarding heat conductivity grapheme conducts heats better than other available materials [5]. Actually grapheme consists a single-layer of existing graphite as shown in Fig.1. It is obtained from a graphite piece using some adhesive-tape technique to lift the existing top layer and finally it is transfer to available silicon wafer as shown in Fig.2.

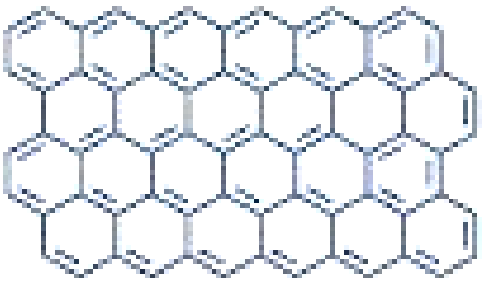

Fig. 2. Structure of Graphene

II. APPLICATION OF GRAPHENE AS CNTFET

As shown in Fig. 3, Carbon nanotubes are around 1-atom thick-sheet of existing graphene which is further rolled-up into a cylindrical shape of diameter with range in nanometer. Rolling-up of graphene sheet is the principal concept to produce a carbon nanotube [6].

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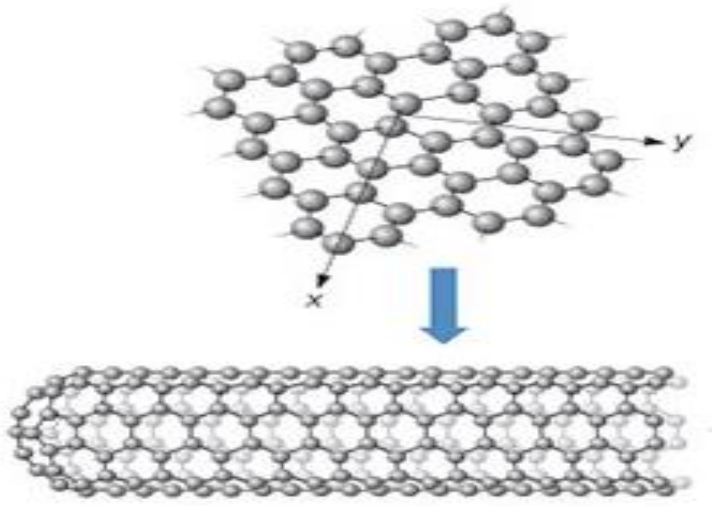

Fig. 3. Formation of CNT

A CNTFET (carbon-nanotube-field-effect-transistor) uses carbon-nanotube (CNT) as channel between source and drain material instead of existing n-type or p-type semiconductor material in available MOSFET device [7]. As far as research related to CNTFET is concerned, globally research are going on to have technology setup for mass production. In existing MOSFET structure un-doped carbon nanotubes are places whereas the heavily doped carbon nanotubes are placed in between source/drain and gate of the device which is shown in the Fig.4.

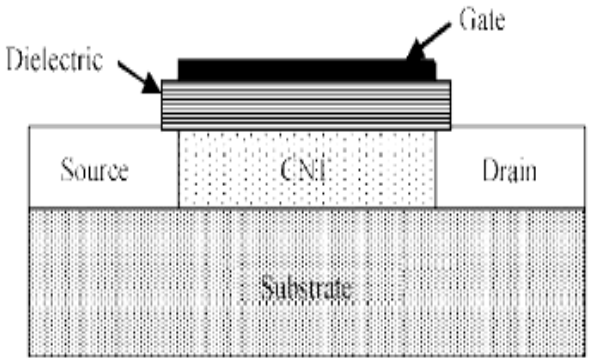

Fig. 4. Structure CNTFET

Because of high electron density as well as high current driving capabilities with existing band structure, CNTFET is expected to exhibits a high performance semiconductor device and optoelectronic devices.

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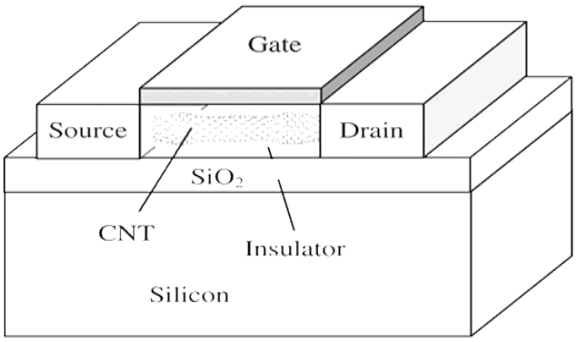

Fig. 5. Schematic of CNTFET

As shown in Fig. 5, a single wall CNT is acting as a semiconductor or conductor, with respect to the atomic arrangement angle arrangement inside the existing tube [8]. The chiral vector an important parameter in grapheme sheet, which is represented by an existing pair of m and n. To determine the conductivity of CNT, whether it is semiconducting material or metallic, the (m,n) pairs are considered. The CNT is said to be metallic if the existing m = n or sometimes m-n = 3i, where variable i, is considered as integer, otherwise the CNT is semiconductor.

S. Ijiima discovered CNTs in 1991 as a allotropes of carbon [9]. To determine the device parameters such as unit cells, diameter, brillouin zone's shape (Fig. 6), the grapheme lattice structure and the chiral vectors are responsible factor.

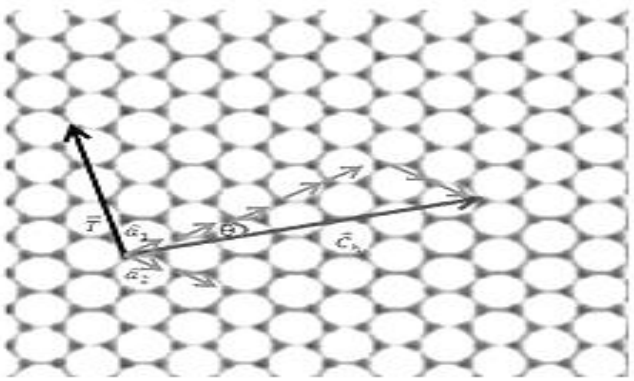

Fig. 6. Brillouin Zone of Grahene

The mathematical equation is illustrated in equation (1) to determine the diameter of CNT.

$$D_{CNT} = \frac{\sqrt{3}a_0}{\pi}\sqrt{n^2 + m^2 + mn} \qquad (1)$$

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Where inter atomic distance is represented by a_0, and is equals to 0.142 nm [10]. The chiral angle is responsible for the measurement of chiral-vector direction. Chiral angle (Θ) is calculated according to the equation given in the equation (2).

$$\text{COS}(\Theta) = \frac{(n+m)/_2}{\sqrt{n^2+m^2+\text{mn}}} \qquad (2)$$

The equation (3) illustrates the relation between the threshold voltages with diameter of the CNT.

$$V_{th} = a(V_{\Pi})/\sqrt{3}\, qD_{CNT} \qquad (3)$$

where q is electronic charge, a is defined as lattice constant which is equal to 2.49 Å and V_{Π} is defined as π to π bond energy of carbon equals to 3.033 eV.

Through the variation of chiral vector the threshold voltage as well as the diameter can be controlled [11-18]. To analyze the threshold voltage different chiral vector pairs are considered, as result a decreasing phenomenon of threshold, as shown in Fig. 7, is observed while increasing the chiral vectors. When the value of n is equal to zero comes with minimum value of m, the resultant threshold becomes highest value and vice-versa.

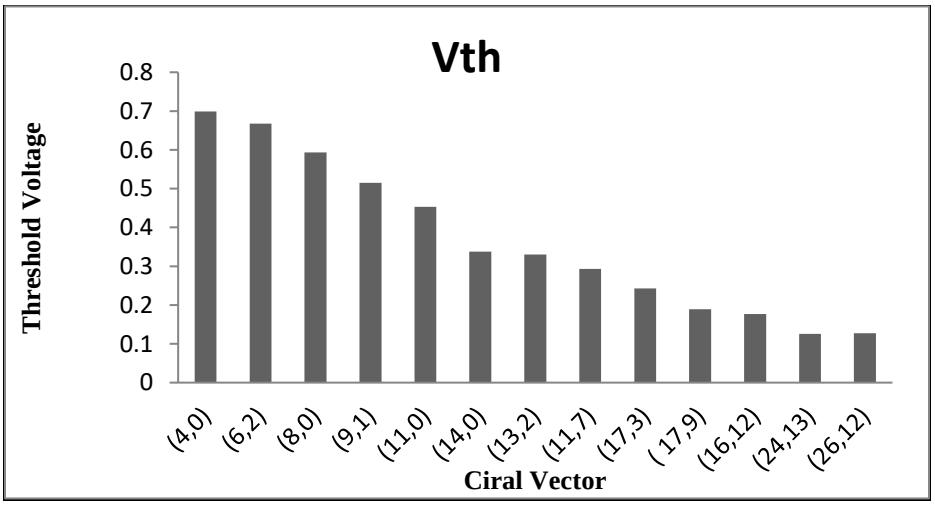

Fig. 7. Threshold w.r.t. chiral vectors

It is shown in Fig. 7, as the chiral vector are fixed at m = 4 and n = 0, the resultant threshold-voltage is around 0.69 V. In other hand when the chiral vector is considered as (16,14) the corresponding threshold voltage is around 0.17V.

III. CONCLUSION

In CNTFET devices threshold-voltage is dependent upon the chiral vectors and the diameter of the CNT. In other words the threshold-voltage of CNTFET devices are controlled by varying the chiral vectors of graphene material. In the paper the impact of Chiral vectors well as the diameters on the threshold-

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voltage of CNTFET is observed through HSPICE tool with Stanford model of CNTFET. It is justified through simulated results that to maintain high threshold voltage to avoid leakage current in the device, chiral vector pairs are to be considered relatively low value.

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