P: ISSN No. 2231-0045 RNI No. UPBIL/2012/55438 VOL.-9, ISSUE-2 November -2020

E: ISSN No. 2349-9435 Periodic Research

# Investigation of Resistance Variability of Zigzag Carbon Nanotubes Using Various Parameters

Paper Submission: 15/11/2020, Date of Acceptance: 26/11/2020, Date of Publication: 27/11/2020

**Abstract**

Authors succeeded in determining the resistance values of zigzag carbon nanotubes with respect to different radii of the tubes in the present work. The electron density in zigzag carbon nanotubes is calculated by using the Thomas-Fermi approximation method. This approach serves to estimate the charge density without invoking a solution of the Schroedinger equation for all energy levels. The carriers current approximated by Landaur-Buttiker formula. Finally resistance of zigzag carbon nanotubes is computed by integrating the mentioned formulations for different diameters of carbon nanotubes.

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**Keywords:** Thomas-Fermi approximation, CNT.

**Introduction**

Nanotubes were discovered quite accidently by SumioIijima [1] while studying the surfaces of graphite electrodes used in an electric arc discharge. Carbon nanotubes have good electrical properties because of these features, carbon nanotubes are used as emitter devices. When small electric field is applied along the axis of the nanotube, the electrons get emitted at very high rate from the ends of the tube. This phenomenon is called field emission. In other words we can say that emission of electron from parent atom in the presence of the high electric field is known as field emission. High thermal and electrical conductivity of carbon nanotubes make them important field emitters. One of the reasons for the high conductivity of the carbon tubes is that they have very few defects to scatter electrons thus leading to very low resistance. Magneto resistance is a phenomenon where the resistance of a material is changed by the application of a DC magnetic field. Carbon nanotubes display magneto resistive effects at low temperature. It is seen that, this is a negative magneto resistance effect because the resistance decreases with increasing DC magnetic field, so its reciprocal, the conductance G=1/R, increases. This occurs because when a DC magnetic field is applied to the nanotubes, the conduction electrons acquire new energy levels associated with their spiraling motion about the field. It turns out that for nanotubes these levels, called Landau levels, lie very close to the topmost filled energy levels (the Fermi level). Thus there are more available states for the electrons to increase their energy, and the material is more conducting. The electrically more conductive materials can be made with help of carbon nanotubes [2]. In this work we use the Thomas –Fermi approximation for computing the electron density. This facilitated to observe the current at different voltages using electron density and hence the determination of resistance has been possible.

**Objective of the Study**

When a large number of zigzag CNTs are+ placed perpendicular to the electrodes, electron emission can be observed. This technique is being used in flat panel displays. Television and computer monitors contain a controlled electron gun to impinge electrons on the phosphorus of the screen, which in turn emit light of the appropriate colors. Carbon nanotubes have been regarded as a promising field electron emission source for the field emission displays [FEDs] and vacuum electronic devices [3]. Field electron emission involves a quantum mechanical tunneling process under an applied electric field. Zigzag CNTs are used as field emitters having field emission parameters such as Turn-on-field, current density, mean field enhancement factor by Park [4], and others as conductance i.e. resistance.

**Review of Literature**

The role of resistance is most important in carbon nanotubes in measuring the conductivity i.e. resistivity. Many researchers worked on electrical conductivity of CNTs. Resistance plays an important role in measuring the thermal resistivity of CNT in different model. The general model for calculating the tube-tube contact conductance of a single thermal contact is given by [11]. A theoretical prediction model for the thermal conductivity of a random CNT network is given by various researchers, the model for a partially welded random network proposed by the Yang X.M.[10]. These models have been used in the thermal conductivity analysis by Zhang K.J.[9].

**Concepts**

In this work we have calculated the electron density of carbon nanotubes with respect to their diameter. For the calculation of electron density in carbon nanotubes we have used the Thomas-Fermi approximation method. It serves to estimate the charge density without invoking a solution of the Schroedinger equation for all energy levels. This approximation method takes the response of the electron gas to an externally applied potential. The electron density is computed by Thomas – Fermi approximation and given by [5]

$$n(x,T) = \int_0^\infty g(E)\left[1+\exp\left\{\frac{E-E_F-eV_{ext}}{k_BT}\right\}\right]dE \qquad (1)$$

Where, $g(E)$ is the density of states in the semiconducto. The preceding equation is then evaluated as

$$n(x,T) = N_e(x,T)F_{\frac{1}{2}}\{\frac{E_F+eV_{ext}}{k_BT}\} \qquad (2)$$

Where $N_e = 2[\frac{m_e k_B T}{2\pi\hbar^2}]^{\frac{3}{2}}$ and $m_e$ is the effective mass of electron and $F_{\frac{1}{2}}$ is the Fermi-Dirac integral conventionally defined by

$$F_\alpha(\eta) = \frac{1}{\Gamma(\alpha+1)}\int_0^\infty E^\alpha[1+\exp(E-\eta)]^{-1}dE \qquad (3)$$

After solving these equations the electron density per unit length of CNT is given by Thomas-Fermi approximation and calculated value for different diameter of CNT is given by equation

$$N_e = 15.065\times10^{24}(d_{CNT})^2 e^{\left(\frac{E_F+eV}{k_BT}\right)} \qquad (4)$$

We have calculated the conductance of carbon nanotube field effect transistors, which is denoted by G =dI/dV.

**Research Design**

Before the computing of conductance carriers current is calculated by Landaur-Buttiker formula [6].

$$I = \frac{4q}{h}\int f(E).TC(E).dE \qquad (5)$$

In equation (5), TC(E) is the transmission coefficient of electrons, its value is taken unity in this work and f(E) is the Fermi statistic. So equation (5) is rewritten in the form

$$I = \frac{4q}{h}\int \frac{1}{1+e^{\left(\frac{E-E_F}{k_BT}\right)}}dE \qquad (6)$$

In equation (6) *h* is the Planck constant and *q* is the total charge in the system. $N_e$ is the total number of electrons per unit length of zigzag CNT. Thus the total charge *q* in zigzagCNT will be

$$q = N_e \times e \qquad (7)$$

where e is the charge of electron. With the help of equations (5), (6) and (7) the carrier current is given by

$$I = -\frac{60.260\times10^{24}\times e}{h}(d_{CNT})^2 e^{\left(\frac{E_F+eV}{k_BT}\right)}\times k_BT\times\log[1+e^{-\left(\frac{E-E_F}{k_BT}\right)}] \qquad (8)$$

Thus the conductance is given by

$$G = \frac{dI}{dV} \qquad (9)$$

We have computed the conductance with the help of equation (8) and (9) which is given by

$$G = -23.374\times10^{20}(d_{CNT})^2 e^{\left(\frac{E_F+eV}{k_BT}\right)}\times\log[1+e^{-\left(\frac{E-E_F}{k_BT}\right)}] \qquad (10)$$

In equation (10), *E* is the angular energy level of zigzag CNT, in this work we have taken the value of *E* is$E_0$ with respect to different diameter of zigzag CNT, which is calculated by equation

$$E_m = \frac{|3m+1||V_{PP}|a_{cc}}{d_{CNT}}$$

Where $V_{pp}$ is the interaction potential and its value is -2.379 eV, $a_{cc}$ is carbon-carbon bond distance and its value is 1.42 Å. and given by Brenner-Tersoff [7,8].

$E_F$ is the Fermi energy level and its value is 0.625eV taken in this work. V is the applied external voltage and $k_B$ is the Boltzman constant and all calculations are made at room temperature i.e. T=300K, $d_{CNT}$ is the diameter of the carbon nanotubes.

From the equation (9) we can compute the resistances

R=1/G

With the help of equation (8) we have described the behavior of the I-V characteristic of carbon nanotubes, in this equation (8) negative sign gives the direction of current. The calculated values of current as a function of diameter for armchair carbon nanotubes are given in Table 1 .A graphical representation of current versus voltage is shown in Figure 1.

**Table 1; Current as a Function of Voltage for Different Diameter of Zigzag Carbon Nanotube**

| S.No. | Voltage in Volts | Current in k ampere for different diameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **1.018** | **1.096** | **1.175** | **1.253** | **1.331** | **1.409** | **1.488** | **1.566** |
| 1 | -0.5 | 86.486 | 108.458 | 132.530 | 158.756 | 187.205 | 217.714 | 251.010 | 285.698 |
| 2 | -0.6 | 1.848 | 2.317 | 2.831 | 3.392 | 3.999 | 4.651 | 5.363 | 6.078 |
| 3 | -0.7 | .040 | .050 | .061 | .073 | .085 | .099 | .115 | .130 |
| 4 | -0.8 | .001 | .001 | .001 | .002 | .002 | .002 | .003 | .003 |

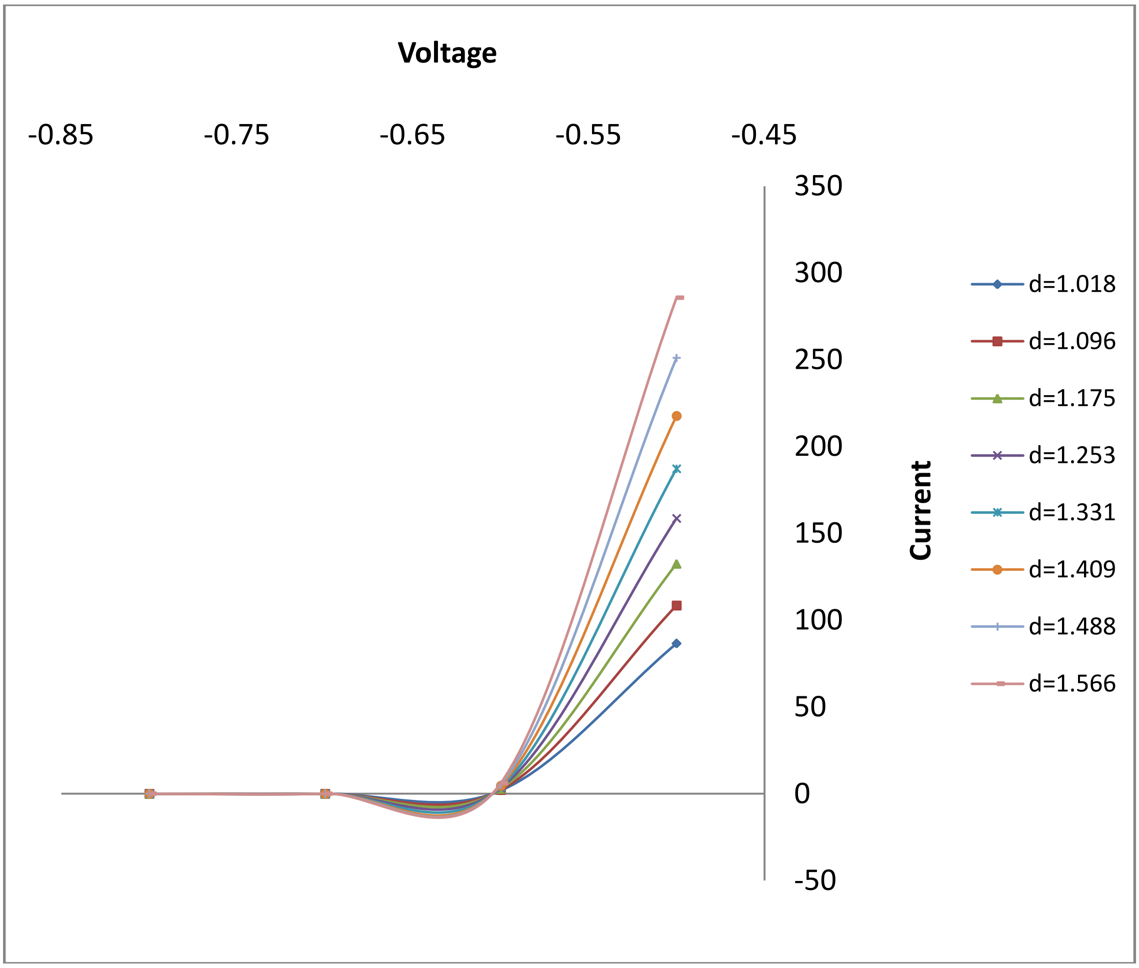


**Figure 1; Variation of Current as A Function of Voltage For Various Diameter of Zigzag Carbon Nanotube**

The calculated resistance R=1/G at different voltages for zigzag carbon nanotubes for different diameters is given in Table 2. A graphical representation of R=1/G as a function of voltage is shown in Figure 2.

**Table 2; Resistance as a Function of Voltage for Different Diameter of Zigzag Carbon Nanotube**

| S. No. | Voltage in volts | Resistance of carbon nanotubes in mΩ for different diameter in nm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1.018 | 1.096 | 1.175 | 1.253 | 1.331 | 1.409 | 1.488 | 1.566 |
| 1 | -0.5 | 2.991 | 2.385 | 1.952 | 1.629 | 1.382 | 1.188 | 1.030 | 0.906 |
| 2 | -0.6 | 140.038 | 111.669 | 91.386 | 76.289 | 64.696 | 55.630 | 48.250 | 42.392 |
| 3 | -0.7 | 6557.37 | 5227.39 | 4278.99 | 3571.42 | 3028.46 | 2604.16 | 2258.86 | 1984.520 |

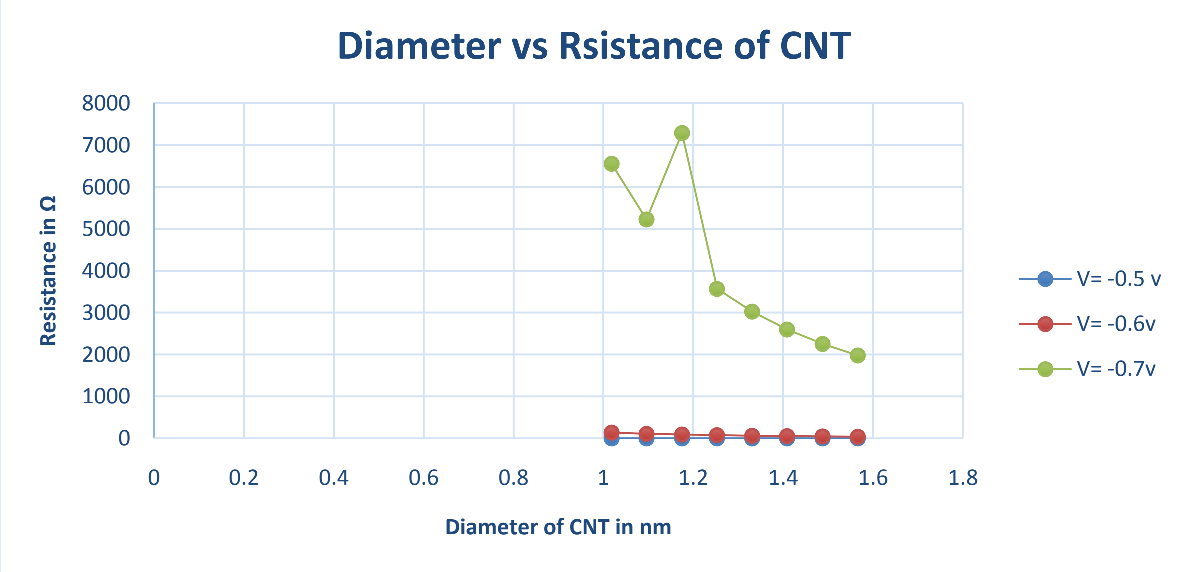


**Figure 2; Variation of Resistance as A Function of Diameterof Zigzag Carbon Nanotubes at Different -Ve Voltages**

**Conclusion**

The charge density computed by this method is more relevant because it serves to estimate the charge density per unit length without invoking a solution of the Schroedinger equation for all energy levels. The charge density per unit length is more useful to calculate the capacitance effect of carbon nanotubes and resistance of carbon nanotubes From Figure 1 it is clear that when negative voltage is increased there is no more current found upto -0.6V but when voltage reduces below -0.6V, current is increased exponentially. Thus we conclude that upto a certain voltage the I-V characteristics are non-Ohmic which would indicate that a barrier potential exists somewhere along this conduction path, possibly due to high contact resistance at electrodes of zigzag carbon nanotubes. Furthermore, for a certain applied voltage, current is exponentially increased. A graphical representation of current for different diameter of carbon nanotubes is also shown in Figure 1. It is clear from from figure 2 that when applied negative voltage varies, the resistance also varies. In other words we can say that when applied negative voltage increase the resistance R=1/G increase but due to negative sign, we conclude that the resistance is inversely proportional to the applied negative voltage. The resistance of zigzag carbon nanotubes varies from mΩ to KΩ in a manner that resistance increases with the increase of negative voltage but decreases with increase of diameter at a particular voltage..This range of resistance is more useful in designing the field emission devices.

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