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RESEARCH ARTICLE

Fabrication of Si-CNT Junction by Plasma Sputtering of Graphite Rods on Silicon Wafers

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Abstract

In this work, fabrication of Si-C junction is done by plasma sputtering of the Carbon from graphite rods in Argon gas atmosphere without catalysts with thickness 25 – 82 nanometer . Study of images of the specimen by Scanning electron microscope shows that the carbon layer is in the form carbon nanotubes with diameters about 30 nanometer . More careful study of the carbon layer surface by high resolution optical microscope is done using both transmission and reflection methods , then the images are amplified more by computer software .The transmission images for carbon layer on the glass substrate shows two dimensional nanotubes structures . Images taken by reflection of white light from the carbon layer on Si-C junction, shows clearly zigzag nanotubes chairlity . The FTIR spectrum shows peaks characteristics of the carbon nanotubes , I-V measurements for gold electrodes shows semiconducting behavior as for thickness increasing.

Introduction

The fast growing technological importance of Carbon based nanostructures is well known . Carbon nanotubes (CNTs) have attracted much attention due to their unique properties [1].

In 1991 Iijima [2] observed for the first time tubular carbon structures. Two years later, Iijima and Ichihashi [3] and Bethune et al. [4] synthesized single-walled Carbon nanotubes (SWNTs) . Catalytic growth of nanotubes by the chemical vapor decomposition (CVD) method was first used by Yacaman et al. [5]

Nowadays several methods such as arc discharge , laser ablation , and different forms of chemical vapor deposition (CVD) have been used to synthesize the CNTs [6]. To prepare nanotubes , Si wafers are used as substrates for MWNTs or SWNTs carbon nanotubes [7] . Catalysts are used widely , but the fact that no catalyst was required was largely ignored or forgotten . More recently , a broad array of growth routes using pure carbon systems without any catalyst particle addition have emerged[8].

Electrical transport through Carbon nanotubes has attracted considerable interest due to the many possible applications of the nanotubes in nanoscale electronic devices [7] .

In this research we use a somewhat new way to prepare Carbon nanotubes CNTS on Silicon wafer by means of plasma sputtering of the carbon from graphite rods in the presence of a Argon gas without any catalysts ,and to study the structure of the carbon layer on the Si wafer in the Si-C junction by SCM and by FTIR .In the research also studied the I-V characteristics of the junction through the application of Gold electrodes on the rare and front sides of the junction.

Experimental method

Deposition of the Carbon layer is done using plasma coating automatic system (Q150R S/E/ES Sample Preparation System) where Argon is an ambient gas , the source of Carbon is graphite of purity(99.999), with pulse current 80 A and pulse duration of 5 seconds ,the desirable thickness can be obtained by repetition of pulses . As for the I –V characteristics Gold layer is deposited on the front and rare sides by the same plasma coating system . FTIR spectrum for the carbon layer on Si wafer is taken using FTIR spectrometer (model WQF-510).

The substrates for the samples are silicon wafers and slides of glass on which the Carbon layer is deposited .They are cleaned using a suitable solutions and acids then ultrasonically cleaned to remove any contamination or native oxide. Figure (1) shows cross sectional views of the samples .

Study structure of the carbon layer on the Si wafer in the Si-C junction by Scanning electron microscope (VEGA//TESCAN) for 20 , 10 ,5 and 2 micrometer scale is done, then the 2 micrometer scale image was amplified by computer software 500% the image clearly shows nanotubes .Additional study of our samples by high resolution optical microscope (optica B350) give fruitful results , the method used depend on taking images from the microscope by attached digital camera with amplification 1000 times then the pictures amplified using computer software. Two kinds of images were taken: transmission and reflection ones where carbon is deposited on both a silicon wafer and a microscope glass substrate at the same time. The transmission images for Carbon layer on the glass substrate shows two dimensional nanotubes structures. On the other hand the images taken by reflection from the Carbon layer on the Si wafer of light incident from intense white light source give very good images , amplification of the obtained images by computer software by 850% give very clear images of the nanotubes with zigzag arrangement.

Results and Discussion

we have found that it is possible to deposit layers of Carbon on Silicon wafer and glass substrates using plasma sputtering method from graphite rods in argon atmosphere .

Figure (2) shows the spectrum of the carbon layer with thickness of (27nm) deposited on glass ,the peaks spread over three regions, the first within the wavelength range (1500-1800 cm-1) and the second within the range (2848-2956 cm-1) and the third within the range of (3500-3900 cm-1) , the existence of these peaks is an evidence of the formation of Carbon nanotubes in Carbon layers.

Study of images of the specimen by high resolution optical microscope is done using both transmission and reflection methods . Figure(3) show the transmission images taken for carbon layers on glass substrate , in which a sufficient amount of carbon nanotubes that are oriented in the same direction are expected.

The study of the Carbon layer of the Si-C junction by Scanning electron microscope is shown in fig (4) for 20 , 10 ,5 and 2 micrometer scale. The figures shows clearly the grains (bundles of Carbon nanotubes) .The 2 micrometer scale clearly shows the minute points of the nanotubes , so we amplify the last figure 500% . The nanotubes are very clear as in figures (5) with tubes diameter of about 30 nanometer

Images taken by reflection from the carbon layer on Si - C junction , shows interesting properties which proves the existence of the carbon nanotubes . Figure (9) shows the images taken by optical microscope with (1000) magnification for carbon layers deposited on the SI wafer with thicknesses 27 nm the light is incident from the side so details of the nanotubes are shown in a form of aggregates of nanotubes of types SWNT or MWNT with good uniform. Also seen from figure (6) that the base color is a blue color of the Si wafer.

The density of the current is found by the following mathematical relationship

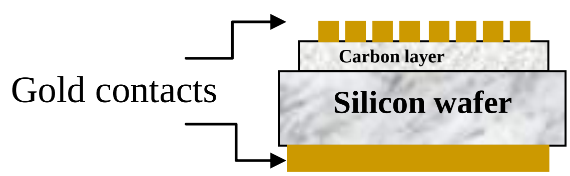
$$I \sim V^m$$

Figure(7) reveal reflection microgram of optical microscope image of the Carbon layer on Si wafer at amplification of figure (6) by 500 % and 850% using computer software which shows some of the CNT .

Where (m) is integer represent the degree of dependence of the current flowing in the diode on the applied voltages and have interpreted the three areas using the conducting mechanisms, which are subject to Ohmic contacts and space charge limited current.

Using the above-mentioned mechanism and to determind the value of (m) mentioned in the equation above , we have draw the relationship Log I as a function of Log V as shown Figure (9), and the three areas show that m = 1 in the first region , this means that the first area subject to ohm's law, the second zone has found the value of m = 2 this means that the current is directly proportional to the square of the applied voltage and the third area may be subjected to the law of force.

Figure(1) : cross sectional view of the samples



Figure(2) FTIR spectrum of the Carbon layer with thickness (27nm) .

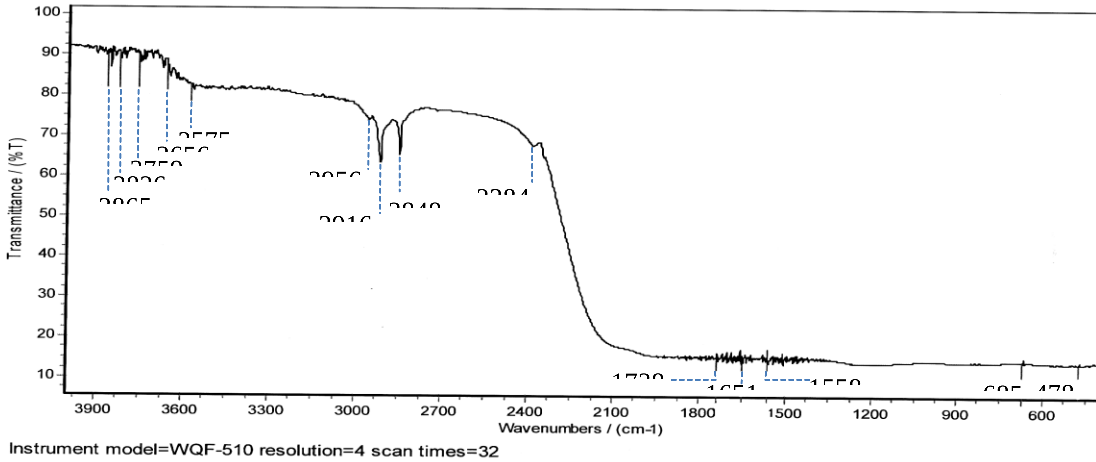


Figure 3: show the images taken by optical microscope with (1000)magnification for carbon layers deposited on glass with thicknesses 51 and 71 nm

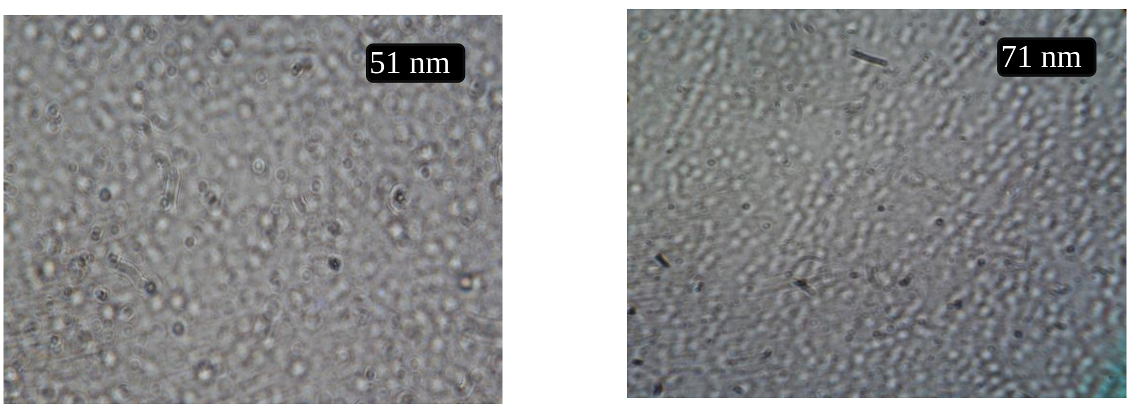


Figure (4) show Images of electron microscope with different scales .

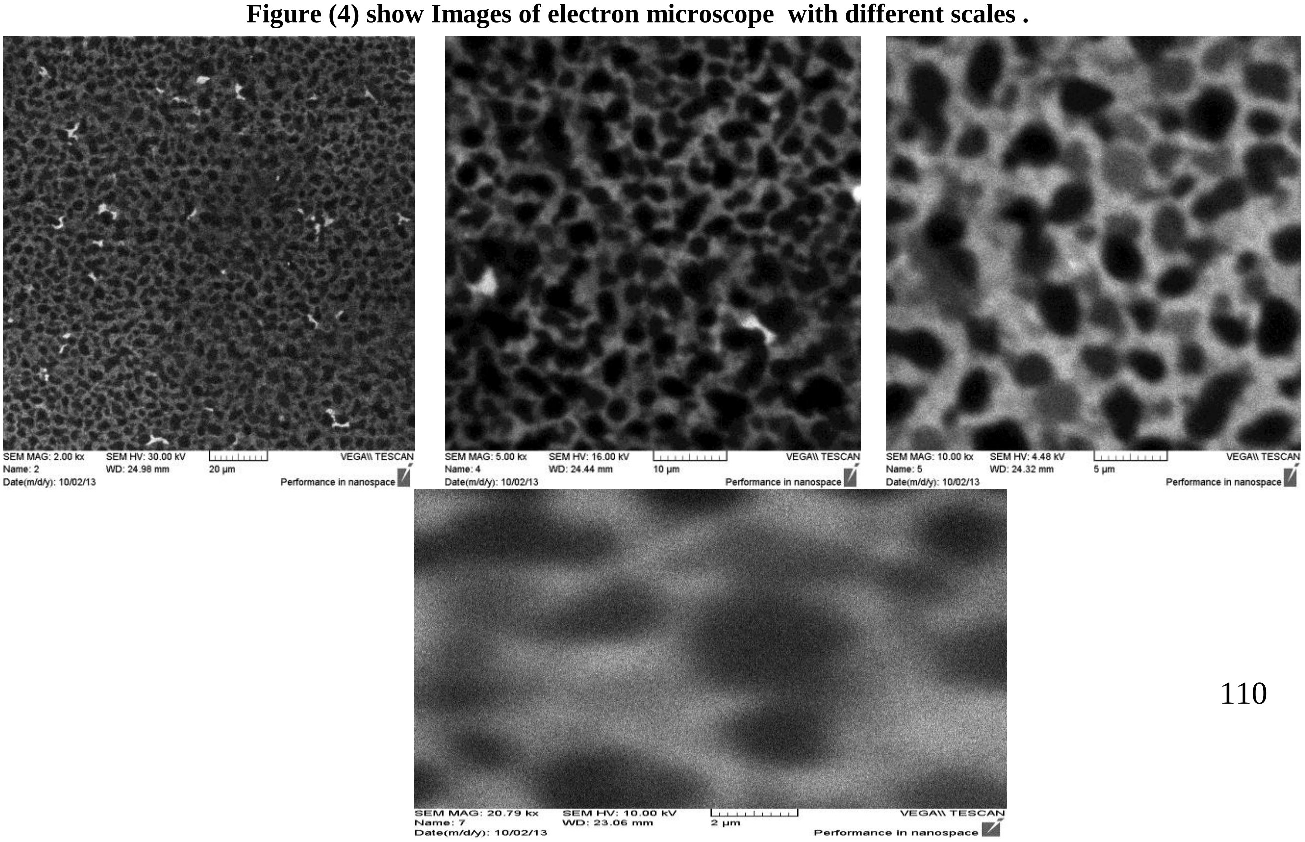
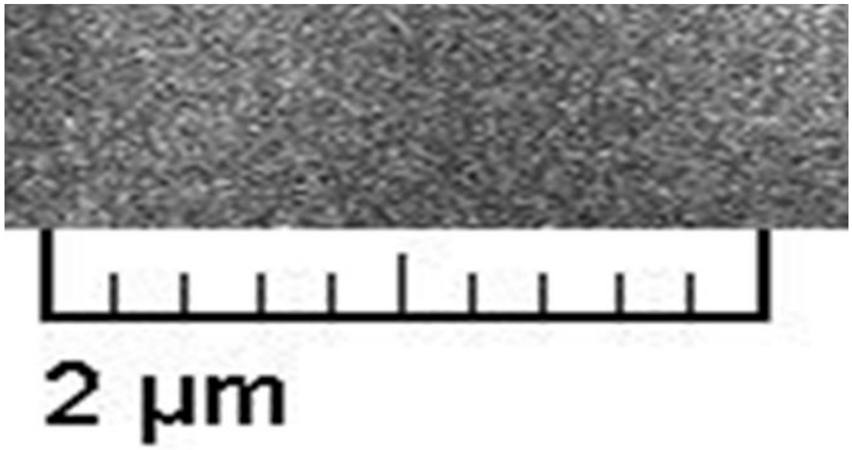
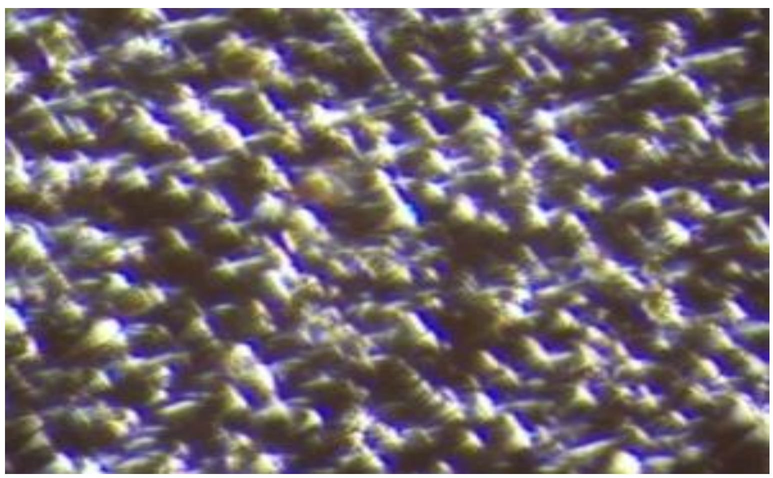


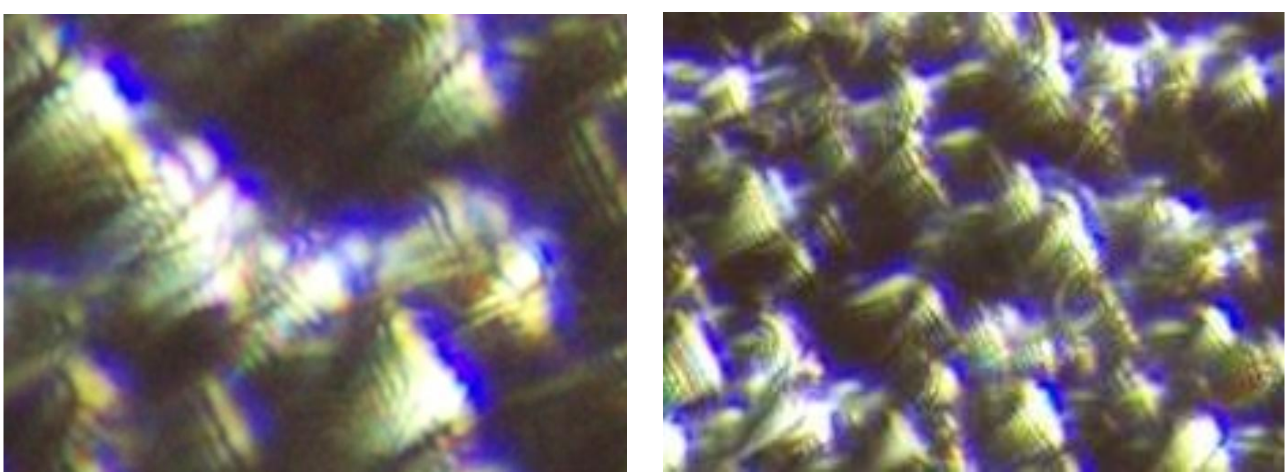
Figure (5) show Images of electron microscope for 2 micrometer scale after 500% amplification by computer software



Figure(6) show the images taken by optical microscope with (1000) magnification for carbon layers deposited on silicon wafer

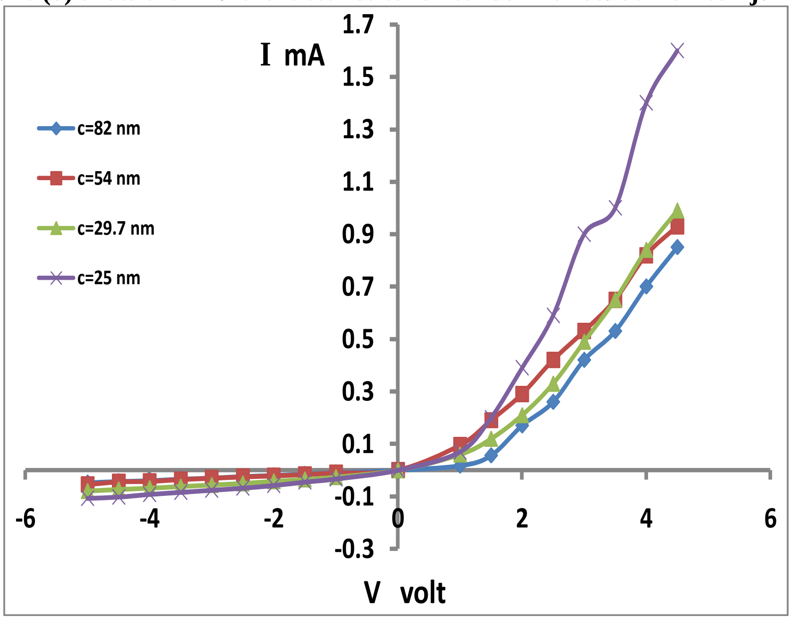


Figure(7) show the images for carbon layers deposited on silicon wafer after magnification by 500% and 850% .

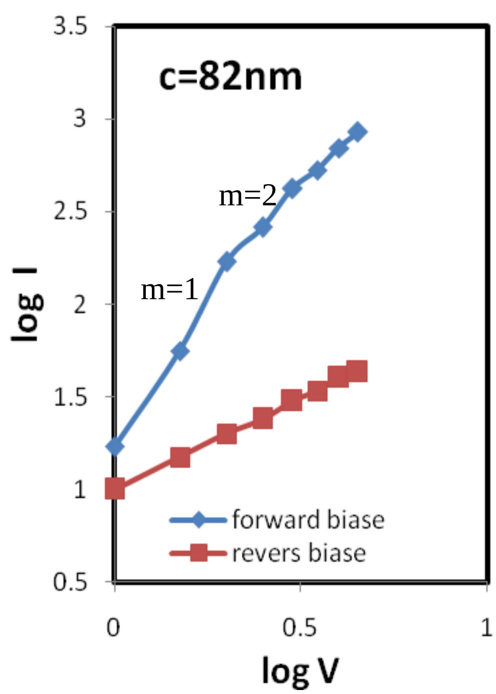


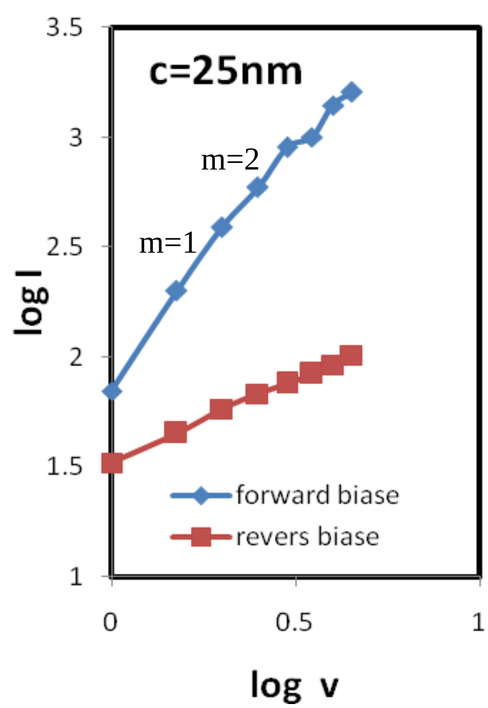
The I-V characteristics for Si – C junction with gold electrodes on the front and back sides of the junction is shown in figure(8) . It is very clear that the carbon has a semiconducting behavior in the junction which is a characteristic property of the zigzag nanotubes

Figure (8) show the I-V characteristics for carbon nanotube – silicon junction



Figure(9) show the relation between Log (I) and Log (V) for the forward and revers bias





Conclusion

1- Fabrication of Si – CNT junction by plasma sputtering of carbon from Graphite rods on Si wafer without catalyst is done in this research .

2- The formation of CNT in the Carbon layer on Si wafer is proved by FTIR spectroscopy ,by scan electron microscope and also by high resolution optical microscope .

3- Images of the Carbon layer taken by reflection of white light from the Carbon layer by 1000 thousands times amplifying high resolution optical microscope, shows zigzag chairlity for CNT which have semiconductor characteristics .This property is affirmed by I-V characteristics of the junction which semiconductor behavior .

Acknowledgments

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