RESEARCH PAPER | Physics | Volume : 3 | Issue : 4 | April 2013 | ISSN - 2249-555X

Photovoltaic Properties for Carbon Nanotube Junction Prepared by Arc Discharge Technique in Argon Gas

KEYWORDS: Photovoltaic Properties ,Carbon Nanotube, arc Discharge

Ghazala. Y. Hermiz	Izzat. M. Al-Essa	Ghuson. H. Mohammad
University of Baghdad ,College of science, Dept.of Physics	University of Baghdad ,College of science, Dept.of Physics	University of Baghdad ,College of science, Dept.of Physics

ABSTRACT *The spectral response characteristics of carbon nanotubes (CNT) photovoltaic detector prepared by an arc-discharge technique under various pressure (10-3,10-4,10-5) mbar of argon gas on a p-Si and p-Si/SiO2 substrate were studied. The SiO2 layer prepared by thermal evaporation technique from high purity of nano particle of SiO2 material. The structure of CNTs thin films has been characterized by X-ray diffraction and the morphology of carbon nanotube was examined by scanning electron microscopy (SEM). The detection properties includes [responsivity (Rλ) , quantum efficiency(η) , noise equivalent power (NEP) and specific detectivity (D*)] have been measured for all pressure of argon gas. The maximum spectral responsivity and maximum quantum efficiency were obtained at 400 nm and the maximum detectivity was about 4.75x1011 cm.Hz1/2.W-1. for CNT/Si detector and this value increased to 9.25x1011 cm.Hz1/2.W-1 for CNT/SiO2/Si junction.*

Introduction

The discovery of carbon nanotubes by Iijima in 1991[1] pioneered a new direction in carbon research that complemented the activities on the fullerene research front Carbon nanotubes (CNT) rank among the most exciting new developments in modern science and engineering , they have attracted particular interest because they are predicted, and indeed observed, such as extremely high strength, lightweight, elasticity, high thermal[2,3] and air stability, high electric and thermal conductivity, and high aspect ratio offer crucial advantages over other nano-fillers[4]. The potential utility of carbon nanotubes in a variety of technologically important applications such as molecular wires and electronics, sensors, high strength materials, and field emission has been well established [5].

The formation of CNT heterostructures is the fundamental and technological interest because of their unique mechanical and physical properties made them have enormous potential for use in a wide variety of applications. Despite this potential CNT/Si offer some advantages over carbon nanotubes. These advantages include chemical inertness, high thermal conductivity, improved stability at high temperatures, and high mechanical strength, high-mobility channels in FET_s .Due to its high mechanical strength, leads to high efficiency CNT/Si photovoltaic devices. This technique has led to the demonstration of a series of nanotube devices and integrated systems such as field-effect transistors [6].

Experimental

Carbon nanotubs (CNT) thin films were synthesized on Si and Si/SiO_2 substrates by the DC arc discharge method in Argon gas as the atmosphere under the various pressure (10^{-3},10^{-4},10^{-5}) mbar. After the silicon samples were cleaned and etched by immersing and stirring them in diluted hydroflurlied acid [7] (1:10 concentration for 15min), thermal evaporation technique (Balzers coating unit model B510) was used to deposit SiO_2 material with nano particle size (270) nm on the silicon substrate.Two graphite rods with purity 99.999% and diameters of 3cm and 7cm as an anode and cathode electrodes, respectively. DC current of approximately 50 ampere with voltage of 25 volt was applied between two electrodes.

The morphology of the films was examined using Scanning transmission electron microscopy (SEM).The X-Ray Diffraction (XRD) patterns of the thin films was studied using Cu Kα radiation source with wavelength 1.54056Å in the scanning 0-50 (2θ).

The detection characteristics of carbon nanotubes (CNT) photovoltaic detector which includes ([responsivity (R_λ), quantum efficiency(η), noise equivalent power (NEP) and specific detectivity (D*)] have been measured for all pressure of argon gas in the range of (200-110)nm.

Result and discussion

The Morphology Structure

In order to confirm the exact structure of the film, the structural analysis of film was detected with Scanning Electron Microscopy (SEM). The SEM images of carbon nanotubes grown directly on Si substrates in Ar atmosphere is shown in the Fig.(1). SEM images revealed the continuous, homogeneous, layer with nanocrystallites size. CNT thin films grown in the Ar atmosphere has crystalline structure and clear grain boundaries became apparent and shows a very thin and adherent layer formed by very small (nanometric size) crystallites.

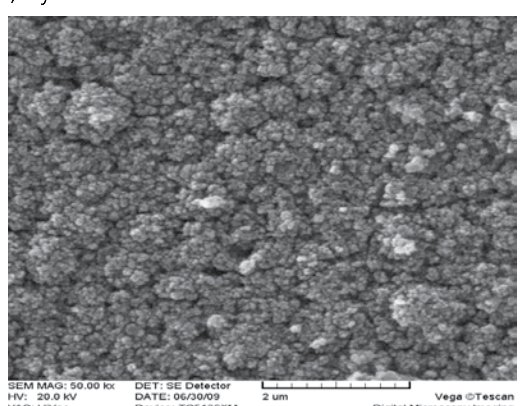

Fig.(1)The SEM image for CNTs thin films grown in Ar with magnification X5000

Transmission Electron Microscopy (TEM) Analysis

Fig.(2) shows the TEM image of the as-synthesized CNTs as a powder grown by arc-discharge technique at various pressure of Ar atmosphere and purified CNTs. TEM images show the greatest soot is exist in the samples beside of that it contains amorphous carbon, particles, where this is an indication that no tubes are observed in this image but a number of nanotubes were covered by the soot and this is characteristic of arc-discharge technique as referred by Huang [8].

Volume : 3 | Issue : 4 | April 2013 | ISSN - 2249-555X

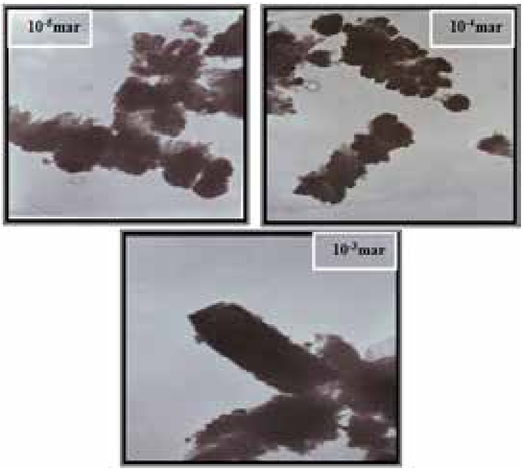

Fig.(2)The SEM image for CNTs thin films grown in Ar with magnificationX3400

X– Ray Diffraction Analysis

Fig. (3) shows the effect of Ar pressure on the structure of CNT thin films at room temperature. It is found from this figure that no significant sign of structural transformation was observed in the X-ray diffraction patterns until 10^{-5} mbar and the graphite (100) exhibits large shifts toward higher angles with decreasing gas pressure. The intensity of these peaks also changed during the increase of the pressure. This behavior can be explained by the film growth at low deposition pressure is slower than that at high pressure. At lower gas pressure and due to the thin plasma density, the ion bombardment of growing film leads to increase the compressive stresses in the deposited films, making the films compact and denser with the increasing deposition gas pressure and then highly energetic ion bombardment changes.

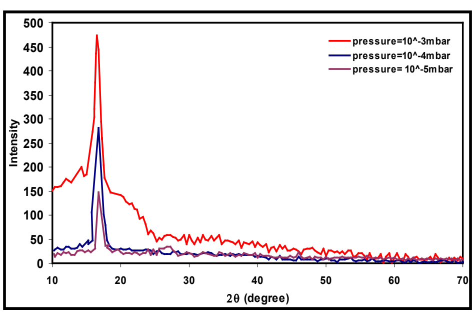

Fig. (3): X-ray diffraction patterns of CNT thin films at different pressure of Argon atmosphere

Spectral Measurements for CNT junction

a-Spectral Responsivity (R_λ)

Fig. (4 a and b) shows the wavelength- dependent spectral responsivity (R_λ) for CNT/Si and CNT/Si/SiO_2 junctions , respectively , at room temperature under various pressure (10^{-3} ,10^{-4} and 10^{-5} mbar) for Ar gas, respectively. It is clear that a maximum responsivity appears at the visible region and its peak is at about 400nm .Another peak was observed at about 900 nm but it is lower of intensity than that at 400nm. With a fact that the first peak can be considered as a genuine result, such results may stimulate the manufacture of dual-peaks detectors and sensors. Also, it can be noticed from this figure that the increase of the gas pressure causes an increase in the value of spectral responsivity. The effect of adding SiO_2 layer is clear. The characteristics of the obtained structure lead to two effective regions. The first region is formed between the substrate (silicon) and the CNT thin films while the second one is formed between the SiO_2 layer and the deposited thin films which in turn include an increase in the value of spectral responsivity in all pressure of gas.

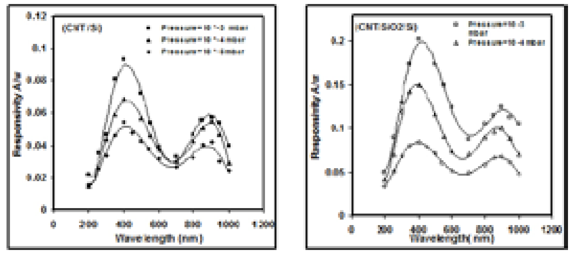

Fig.(4) The variation of spectral responsivity as a function of wavelength for CNT junctions prepared at different Ar pressure of gas a- for CNT/Si, b-for CNT /SiO2/Si junctions

Quantum Efficiency

The quantum efficiency was determined as a function of wavelength for CNT/Si and CNT /SiO_2/Si junctions, as shown in Fig. (5 a and b), respectively under various pressure (10^{-3} 10^{-4} and 10^{-5}) mbar of Ar gas at room temperature. The maximum quantum efficiency was achieved at 400nm which a value of 63% for CNT /SiO_2/Si and 28.5% for CNT/Si in Ar gas at pressure 10^{-3} mbar. In general, these figures show that the quantum efficiency increases with the increasing of gas pressure. The value of quantum efficiency is larger for CNT /SiO_2/ Si junctions than CNT/Si junctions due to SiO_2 layer between Si and CNT thin films which leads to increase the quantum efficiency. The reasons are mentioned earlier in the discussion of the spectral responsivity.

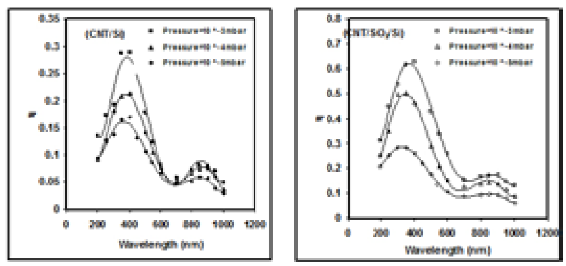

Fig.(5)The variation of the quantum efficiency as a function of wavelength for CNT junctions prepared at different Ar pressure of gas a- for CNT/Si, b-for CNT /SiO2/ Si junctions

Noise Equivalent Power

The variation of NEP as a function of wavelength for CNT/Si and CNT /SiO_2/Si junctions under various pressure (10^{-3} 10^{-4} and 10^{-5}) mbar of Ar gas at room temperature is shown in Fig. (6a and b), respectively . In general, the minimum NEP occurs when Rλ has the maximum value. From these figures we can notice that NEP decreases with increasing of pressure. It increases from 0.0214 $x10^{-11}$(Watt) to 0.0915 $x10^{-11}$(Watt) when pressure varies from 10-3 mbar to 10^{-5} mbar in Ar atmosphere, and we relate this to the defects which increase noise current. Also, we can observed from these figures that NEP decreases from $0.0214*10^{-11}$ Watt to $0.00986*10^{-11}$ Watt when adding the active layer of SiO_2 between Si and CNT thin films at λ=400nm and pressure of 10^{-3} mbar of Ar atmosphere.

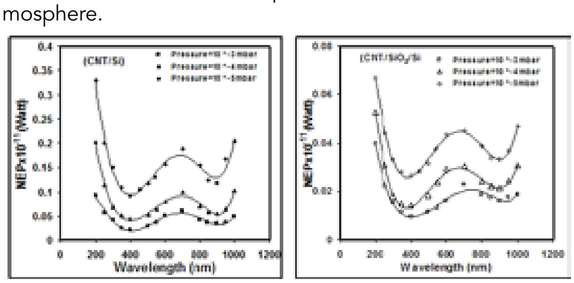

Fig.(6)The variation of the quantum efficiency as a function of wavelength for CNT junctions prepared at differ-

Volume : 3 | Issue : 4 | April 2013 | ISSN - 2249-555X

ent Ar pressure of gas a- for CNT/Si, b-for CNT /SiO_2/Si junctions

Specific Detectivity

The specific detectivity (D*) of the CNT/Si and CNT/SiO_2/Si junctions was measured at room temperature as a function of incident light wavelength. Results of D* under various pressure (10^{-3} 10^{-4} and 10^{-5}) mbar of Ar gas is illustrated in Fig. (7 a and b). The maximum value occurs at pressure 10^{-3} mbar which is equal to about $4.67x10^{11}$ m. $Hz^{1/2}.W^{-1}$ and $10.15x10^{11}m.Hz^{1/2}.W^{-1}$ for CNT/Si and CNT/SiO_2/Si junctions grown in Ar atmosphere, respectively. It is obvious that the D^* value decreases with decreasing the pressure from 10^{-3} mbar to 10^{-5} mbar of gas. due to the decrease of NEP. Also, we can see from these figures that the detectivity is affected by the SiO_2 layer; it is increased by the SiO_2 layer.

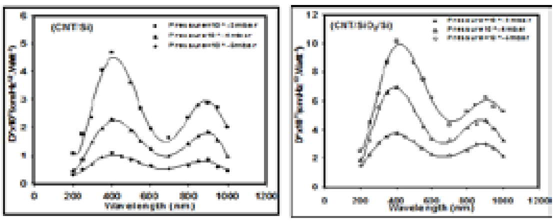

Fig.(7)The variation of the quantum efficiency as a function of wavelength for CNT junctions prepared at different Ar pressure of gas a- for CNT/Si, b-for CNT /SiO_2/Si junction

Conclusion

The arc-discharge technique was identified to offer a more promising route to develop scalable carbon nanotube production technique under various pressure of Ar gas. The pressure dependence of XRD pattern for CNT thin films shows the preferred orientation (100) which exhibits large shifts toward higher angles with increasing gas pressure i.e improved in crystalline in Ar gas. There is an improvement in the responsivity when adding SiO_2 layer for CNT/SiO_2/Si junctions in comparison with CNT/Si junctions. Also, the responsivity, specific detectivity and quantum efficiency increase with increasing of deposition gas pressure, while noise equivalent power decreases with increasing of deposition gas pressure.

REFERENCE 1. S. Iijima, "Helical Microtubules of Graphitic Carbon", Nature Vol.354, pp56–58 (1991). | 2. J.Hone, M.Whitney, C. Piskoti, A. Zettl, "Thermal conductivity of single-walled carbon nanotubes", Physical Review, B 59 (4), R2514-R2516, (1999). | 3. Yi, W. Lu, L. Zhang, D. L. Pan, Z. W. Xie, S. S. "Linear specific heat of carbon nanotubes", Physical Review, B 59 (14), R9015-R9018, (1999). | 4. Daniel Minoli "Nanotechnology Application to telecommunications and Networking", John Wiley & Sons, Inc., Hoboken, New Jersey,(2006). | 5. Erlangung des Doktorgrades"Carbon Nanotube Composites-Mechanical Electrical and Optical Properties", Ph.D. Thesis, Rheinischen Friedrich, Wilhelms –University Bonn (2006). | 6. David Beach, "Synthesis of Carbon Nanotubes Using Nanotechnology" Indianan State University, Terre Haute, Indiana(2005). | 7. I. P. Mangalhara, R. Thangaraj and O. P. Agnihotri, "Bull. Mater. Sci.", Vol.10, p.333 (1988). | 8. Huang Zeng , Ling Zhum , Guangming Haoand ,Rongsheng Sheng "Synthesis of Various Forms of Carbon Nanoyubes by AC Arc Discharge", Carbon,Vol.36 ,No.3.pp 259-261(1998).