Applications of Carbon Nanotubes / Nanofibres in Photovoltaic Solar cells

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Abstract

Carbon Nanotubes/Nanofibres grown by electrode position on a n-type silicon substrate show considerable photovoltaic action when exposed to light. The formation of CNT/CNF type structures have been confirmed by the SEM images. The Raman spectra have indicated the formation of a considerable amount of SWNT. The Raman shift peak at 1597cm^{-1} is indicative of the 'G' band of MWNT, while the peak at 1357cm^{-1} gives an indication of the 'D' band. The dark I-V characteristics show the formation of a good p-n junction, while the illuminated I-V curves show the flat-top curve structure as is shown by solar cells. The efficiency of the solar cell has been calculated at 0.036% for the best cell with a Fill Factor of 0.4 or 40% at 100mW/cm^2. The peak power output from is of a few tens of nanoWatts with the junction capacitance being of the order of pico Farads.

Keywords: - Carbon Nanotubes (CNT), Carbon Nanofibres(CNF), Solar Cells.
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1. Introduction

Advances in traditional silicon materials and in thin-film materials have led to continuing progress in the efficiencies and a steady reduction of cost of solar cells and modules over the past 20 years [1-3]. The resulting increase in production of solar panels has been led by the traditional crystalline and multicrystalline silicon, which today account for fully 90% of the sales of PV panels. Currently, bulk hetero-junction structures based on carbon materials have attracted a great deal of interest for both scientific fundamentals and potential applications as photovoltaic cells (PVCs) because it is expected to have similar properties as silicon and would be highly stable[4]. Though Silicon and compound semiconductor-based devices are dominated in the solar cell technology, the cost of these solar cells is much high to reach for daily life and Silicon has also drawback of using under illumination due to the degradation, which limits its lifetime and stability. Besides, Carbon is a remarkable element existing in a variety of stable forms and can be used for making a new kind of cheap and clean energy resource which shows many interesting optoelectronic, physical and chemical properties with unique structure, properties and potential applications in energy storage and conversion.

In this communication, we present our studies on the synthesis of Carbon Nanotubes/Nanofibres grown by electrode

position on a n-type silicon substrate. The Sample were characterized by studying their microstructures, photoluminescence, Fourier transformed infrared (FTIR) spectra and photovoltaic performance.

2. Experimental details

CNTs and CNFs were synthesized by electrolysis [5] using acetonitrile (1 % v/v) and deionized water as electrolyte. Electrolysis was carried out at atmospheric pressure and the bath temperature was kept at ~300K. Carbon nanotubes were deposited onto Si (001) wafers attached to a copper cathode. Graphite was used as the counter electrode (anode). Before mounting the substrates on the cathode, they were thoroughly cleaned and rinsed with deionized water and ethanol solution respectively. The electrodes were separated by a distance of ~ 8 mm. The applied d.c. voltage between the electrodes was kept ~ 20 V by using a d.c. power supply capable of generating stabilized voltage (30 V, 2 A). The deposition was carried for ~ 4-6 hrs. The typical thickness of the films as measured by an interferometer was ~ 30 nm.After the synthesis of films of CNF on Si wafer by electrodeposition technique, the films were dried in the oven and then used for the characterization. For this purpose gold contacts were made on the CNF in the shape of grids using an aluminum grid by vacuum evaporation method. The back contact from Si wafer was made by silver-glue. The films were then ready for I-V or CV measurements.

3. Results and Discussion:

3.1. Microstructural studies:

By suitably changing the deposition parameters, films containing carbon nanotubes or nanofibers could be deposited onto silicon substrates. SEM pictures of as-deposited CNT and carbon nanofibres (CNF) films are shown in (Fig:-3.1a) and (Fig:-3.1b)respectively. Formation of carbon nanotube structures, presumably interconnected multi-walled nanotube in a web-like network is visible (Fig:-3.1b). Y-type interconnected nanotubes are also visible in the films. The typical diameters of CNT bundles were 15-25 nm for the films on Si. It may be seen that the growth of CNTs on Si surface was more uniform and regular and the CNT films consisted of long tubes of different dimensions while the CNFs indicated (Fig:-3.1b) short interconnected carbon nanotubes forming a maize like topography.

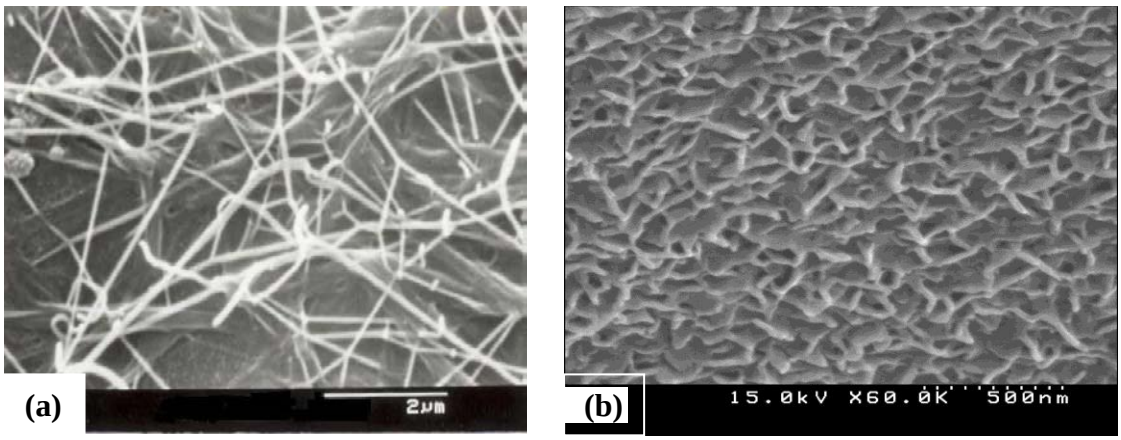


Fig 3.1:- SEM micrographs of three representative films: (a) as-deposited CNT film with 1% acetonitrile, (b) as-deposited CNF with 1% acetonitrile

3.2. Raman studies:

The Raman spectra (Fig:-3.2) are found to bear more confirmative signature of the presence of carbon nanotubes in the films deposited here. The films deposited here showed a sharp feature ~1351 cm^{-1} (D-band) and ~1597 cm^{-1} (G-band). This band centered around ~1351 cm^{-1} (D-band) is generally attributed to defects in the curved graphite sheet and tube ends. This band also corresponds to either disordered or small crystallites of sp^2 networks and could be attributed to finite size effects [6] **.** Basca et al [7] attributed some of the D-band scattering to curvature in the tube wall. This could be explained in terms of therelaxation of the wave vector selection rules arising out of the finite size effects allowing the M point phonon to contribute to the Raman scattering.

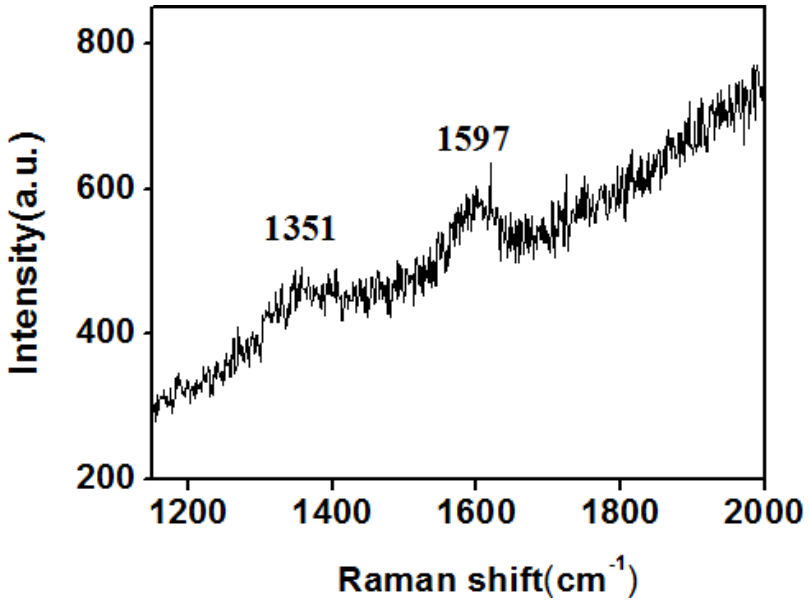


Fig 3.2:- Raman Spectrum of CNF film

3.3. Cell characteristics:

For the determination of the diode characteristics i.e. the p-n junction characteristics of the CNF films the dark I-V was drawn, which is given below (Fig:-3.3a). The plot shows that the CNF film shows ideal diode behavior.

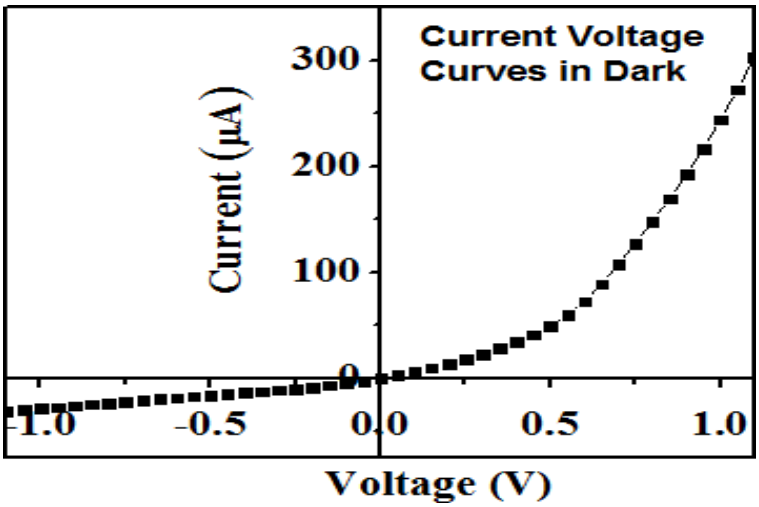


Fig 3.3a:- I-V Characteristics at Dark condition

The film was then illuminated with different Intensities of light and under every light Intensity the variation of the Open Circuit Voltage (V_{OC}) and the Short Circuit Current (I_{SC}) were studied. The variation of the Open Circuit Voltage with increasing illumination is shown in (Fig:-3.3b) and the variation of the Short Circuit Current with increasing Illumination is shown in (Fig:-3.3c).

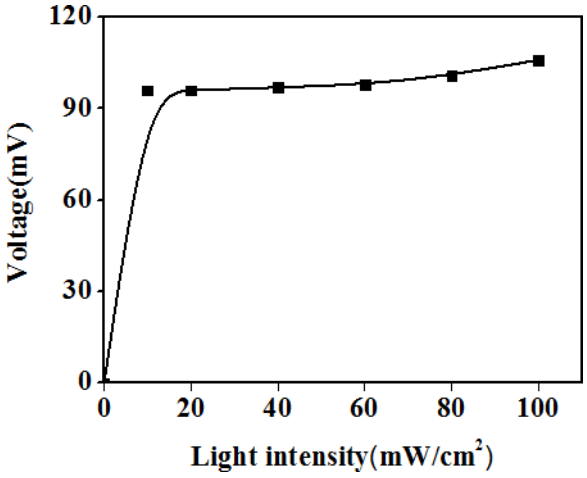


Fig. 3.3b:- Variation of the Open Circuit Voltage with illuminating intensity

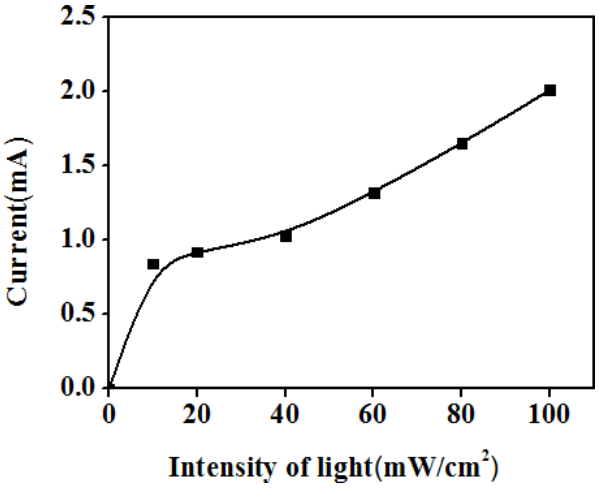


Fig. 3.3c:- Variation of the Short Circuit Current with illuminating intensity

The Open Circuit Voltage reaches saturation quickly while the short circuit current tends reaches saturation quickly but then again tends to increase slowly with increasing illumination. This can possibly be attributed to a heating effect from the source lamp. With increasing intensity, the heat from the lamp increase, and thus decreases the internal resistance. As the voltage remains nearly constant at saturation, the current increases according to Ohm's Law.

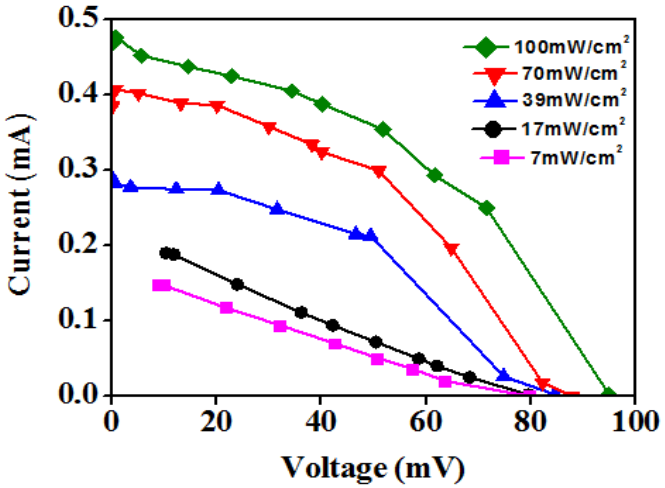


Fig 3.3d:- I-V Characteristics of a CNF/n-Si Solar Cell under different illuminated light

The representative solar cell characteristics revealed that the open circuit voltage(V_{oc}) and short circuit current (I_{sc}) were 95mV and 0.48 µA for highest intensity light illumination (100mW/cm^2) is shown in (Fig:-3.3d). These values of V_{oc} and I_{sc} reduced considerably with the light illumination of lower intensity. The fill factor (FF) of this solar cell was found to be around 40%. The best efficiency achieved by this type of solar cell was 0.036 % but the fill factor decreases considerably.

4. Conclusion:

The CNT/Si p-n junction based solar cell was successfully produced. The SEM micrographs show high quality CNT and CNF. The solar cell characteristics revealed that the open circuit voltage (V_{oc}) and short circuit current (I_{sc}) were 95mV and 0.48 µA for highest intensity light illumination (100W/cm^2). These values of V_{oc} and I_{sc} reduced considerably with the light illumination of lower intensity. The field factor (FF) of this solar cell was found to be around 40%. The efficiency was 0.036% for the best cell which should be increased after eliminating the different experimental problems.

References:

1. Ilie, O. Harel, N.M.J. Conway, T. Yagi, J. Robertson, W.I. Milne, J. Appl. Phys. 87 (2000) 789–794.
2. V.S. Veerasamy, G.A.J. Amaratunga, C.A. Davis, A.E. Timbs, W.I. Milne, D.R. Mackenzie, J. Phys.: Condens. Matter 5 (1993) L169–L174.
3. V.S. Veerasamy, G.A.J. Amaratunga, J.S. Park, H.S. Mackenzie, W.I. Milne, IEEE Trans. Electr. Dev. 42 (1995) 577–585.
4. V.S. Veerasamy, G.A.J. Amaratunga, J.S. Park, W.I. Milne, H.S. Mackenzie, Appl. Phys. Lett. 64 (1994) 2297–2299.
5. Thin Solid Films, Volume 476, Issue 2, 8 April 2005, Pages 288-294
6. R.J. Nemanich, S.A. Solin, Phys. Rev., B 20 (1979) 392.
7. W.S. Basca, D. Ugarte, A. Chatelain, WA. De Heer, Phys. Rev., B 50 (1994) 15473.