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FIELD-EMISSION STUDY OF MULTI-WALLED CARBON NANOTUBES GROWN ON SI SUBSTRATE BY LOW PRESSURE CHEMICAL VAPOR DEPOSITION

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CNTs are synthesized by Low Pressure Chemical Vapor Deposition (LPCVD) method at 600 *°C. The Si substrate is coated with Fe, used as a catalyst, by RF- sputtering. The thickness of the catalyst film is measured to be approximately* 15 *nm. Three precursor gases Acetylene (C_2H_2), Ammonia (NH_3) and Hydrogen (H_2) with flow rates* 15 *sccm,* 100 *sccm and* 100 *sccm respectively are allowed to flow through the tube reactor for* 20 *minutes. The as grown CNTs sample was characterized by Scanning Electron Microscope (SEM). SEM images show that the diameter of as grown CNTs is in the range of* 20-50 *nm. Field emission properties of as grown sample have also been studied. The CNTs film shows good field emission with turn on field $E_\alpha = 2.10$ V/μm at the current density of 4.59 mA/cm^2 with enhancement factor $\beta = 1.37 \times 10^2$.*

Keywords: *LPCVD, CNTs, FIELD-EMISSION PROPERTIES, SEM.*

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1. INTRODUCTION

The small dimensions, strength, and the remarkable physical properties [1-4] of carbon nanotubes make them a very unique material with a whole range of potential applications. CNTs can be synthesized with high purity, selective growth, high yield, and vertical alignment. In order to optimize carbon nanotubes yield and quality, three main synthesis processes have been used, namely, arc discharge, laser ablation [5], and chemical vapor deposition (CVD) [6-9]. Amongst the above three mentioned processes, CVD is the most promising route to bulk production of high purity nanotubes that can be carried to commercialization for economically producing quantities of carbon nanotubes. Synthesis of carbon nanotubes by chemical vapor deposition (CVD) including plasma-enhanced chemical vapor deposition (PECVD), microwave plasma chemical vapor deposition (MPCVD), low-pressure chemical vapor deposition (LPCVD) processes, produces high purity aligned carbon nanotubes in bulk and at low cost. This route also benefits from its ability for scale-up to commercialization and avoids the problems associated with alternative methods, which often give low yield, poor alignment, and lack the required purity. Field emission phenomenon has been studied for a long time and is widely applied in scientific instruments nowadays. Due to their distinguished electrical conducting capability, high aspect ratio, chemical inertness and structural stability, carbon nanotubes posses a great potential in field emission applications such as field emitters in flat panel displays and other vacuum electronic devices. Electron field emission based on carbon nanotubes are currently being investigated as a next generation cold cathode materials [10-15]. Many efforts have been made to develop various methods for fabricating CNT field emitters [16-24]. For the CNTs field emitters reported so far electrons are basically emitted from the tip of CNTs. The tip of CNTs are relatively unstable chemically compared to the sides because either dangling bonds of carbon exit at an open tip or angle strain exits at a closed tip. For this reason, electron emission from the tip of CNTs may be not desirable for the long term stability of CNTs field emitters. In the present work we synthesized the CNTs on Si substrate and their characterization has been done by Scanning Electron Microscope. Field emission properties have also been studied.

2. EXPERIMENTAL DETAILS

CNTs were grown using a LPCVD technique. The Fe-thin film catalyst was coated on the Si substrate using RF sputtering (MODEL: 12" MSPT) at a power of 50 W and an Ar pressure of 1×10^{-3} Torr. The thickness of Fe catalyst was 15 nm thick. The sputtered film was cleaned ultrasonically in acetone and dried at room temperature before loading into a quartz tube and was heated in a high temperature tube furnace to a desired temperature under a H_2 flow. A mixture of H_2:C_2H_2:NH_3 with flow rates of 100:15:100 sccm respectively, were introduced into the quartz tube. The reaction temperature was kept at 600°C and the growth time was 20 mins. The morphology of the as-grown CNT film was obtained using Scanning Electron Microscope (SEM).

We also studied the field emission properties of as grown CNTs film. First as grown CNTs sample was pasted on copper plate using silver epoxy and dried for 40 min. at 50 °C. The prepared sample was loaded in a chamber, when the vacuum of the order of 10^{-6} Torr was attained then sample was subjected to high voltage and reading for current were measured in mA in DC mode.

3. RESULT AND DISCUSSION

3.1 Scanning electron microscopy

Figure 1 represents the scanning electron microscope images of the carbon nanotubes that have been prepared by low pressure chemical vapor deposition system. The average diameter of the CNTs film is in the range 20-50 nm with length of several micrometers.

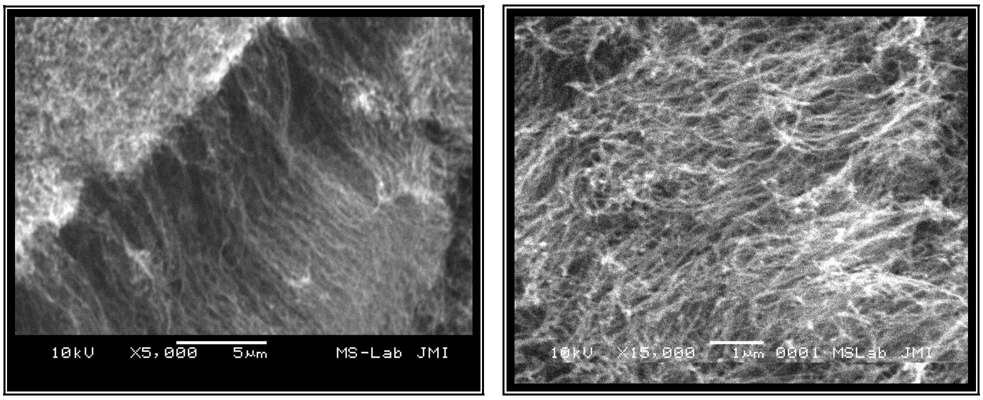

Fig. 1 – SEM micrograph of CNTs grown by LPCVD

3.2 Field emission properties

Figures 2 a, b represent the *j-E* curve and *F-N* plot of as grown CNTs. The obtained data was analyzed by the Fowler-Nordheim (FN) equation, the turn-on field (E_∞) at a current density of 4.59 (mA/cm^2) is shown in Figure 2a was 2.10 V/μm. A low E_∞ can be attributed to its geometry, i.e. to higher field enhancement at the smallest nanotube tip on the MWCNTs.

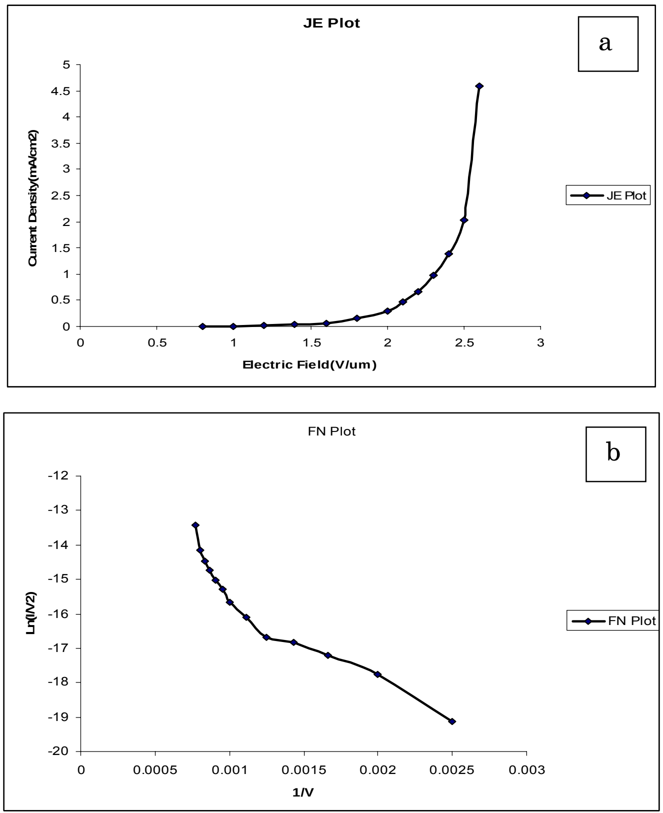

***Fig. 2** – JE plot of CNTs grown by LPCVD (a) FN plot of CNTs grown by LPCVD (b)*

The role of β is the enhancement of the applied macroscopic electric field such that under the action of the local electric field, tunneling of electrons from the Fermi level, into the vacuum, through the potential barrier becomes possible. The interpretation of β, which is a dimensionless quantity if electric field rather than voltage is used in the analysis, is therefore of great importance. The calculation of field enhancement factor (β) is done using the slope[$= - b\varphi^{3/2} D/\beta$] of the FN plot, where D is the working distance (500 μm). The calculated β value from the slope of the FN plot is 1.37×10^2 for the as-grown MWCNTs.

4. CONCULSION

Carbon nanotubes were synthesized by using a Low Pressure Chemical Vapor Deposition (LPCVD) Method at a temperature of 600°C. The film of Iron catalyst, have been grown by RF sputtering methods. The average diameter of the CNTs film characterized using Scanning Electron Microscope (SEM) is in the range 20-50 nm with length of several micrometers. The CNTs film shows good field emission with turn on field $E_\alpha = 2.10$ V/μm at the current density of 4.59 mA/cm^2 with enhancement factor $\beta = 1.37 \times 10^2$.

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