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Measurement of *V-I* Properties of Multi wall Carbon Nanotube Diodes by FIB Fabrications

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Abstract: We have fabricated carbon nanotube (CNT) diodes and measured *V-I* characteristic of Phosphate doped *n*-CNTs were grown by discharge pyrolysis at gas/solid interface with laser diode beam assist. Both ends of manipulated *n*-CNT and patterned Au electrodes were contacted with Pt and/ or-C electrodes and Ga ions were implanted to the *n*-CNT by focused ion beam technics deposition. SIM image of CNT grown with laser assist have linearity and highly orientation. The V-I characteristic of CNT diode Pt as electrodes showed rectification property.

1.Introduction

Carbon nanotubes (CNT) have attracted interest because of their novel electronics and mechanical properties. To develop CNT device, it is required to control their orientation. Recently, cone-shaped boron nitride are aligned toward the incident laser light irradiated during film growth by plasma assisted chemical vapor deposition. Therefore, we have attempted to grown the oriented CNTs by laser assisted discharge pyrolysis at gas/solid interface. In order to fabricate CNT diodes, we used focused ion beam (FIB) techniques. FIB has the following advantages. Ga ion FIB could implant Ga ions as acceptors impurity in carbon. Moreover, FIB could perform Pt and C deposition of arbitrary configurations. In this study, we carried out to the growth of n-type MWCNTs using gas/solid interfacial thermal chemical vapor deposition (CVD) method with LD laser beam assist. Additionally, we fabricated diodes utilizing n-CNTs by FIB technics.

2. Experimental Method

2.1 Growth of n-CNTs on silicon substrates

Fig. 1 shows growth system of n-CNTs. Iron particles were deposited on n-type silicon substrate (resistivity: 1-10 Ω cm, size: 10×40×0.63 mm) as a CNT of growth catalyst by magnetron sputtering. Electrodes were attached on the substrate which was set in the vacuum chamber, Ethanol (C_2H_6O) gas and donor source gas of trimethyl phosphite ($P(OCH_3)_3$) (mixed ratio: 1 wt%) were flowed (gas flow rate: 200 sccm) in to the chamber as a carbon source. When direct current (current value: 15 A, growth time: 10 min) applied the electrode, current pathway was observed on the substrate. CNTs were grown on the current pathway. A focused laser beam (wave length: 808 nm, power: 0.1W) was irradiated to the current pathway. Grown n-CNTs were observed by scanning ion microscope (SIM) images, using focused ion beam (FIB: Seiko, SMI2200) techniques, and scanning electron microscopy.

2.2 Fabrication of CNT diodes by Ga ion implantation

A n-CNT was manipulated on silicon oxide substrate which was patterned of Au electrodes. Pt and/ or C electrodes were deposited on both ends of the n-CNT by FIB deposition. Ga ions were implanted into the n-CNT as the accepter source.

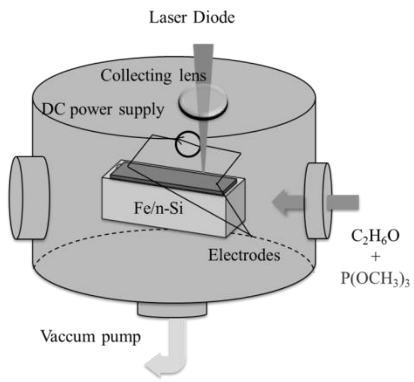

Fig. 1 Laser assist thermal CVD on Gas/Solid interface of grown *n*-CNTs

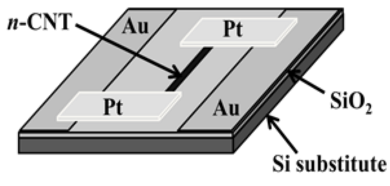

Fig. 2 Pt and/ or C electrodes were deposited on both ends of the n-CNT by FIB deposition.

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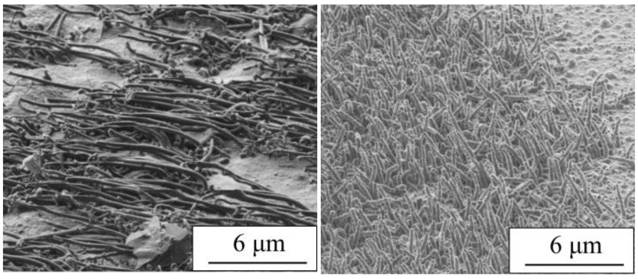


(a)Without laser assist **(b) Laser assist**

Figs. 3 SIM images of growth CNTs

Voltage-current (V-I) characteristics of the Ga ion implanted n-CNT were measured by two probe method.

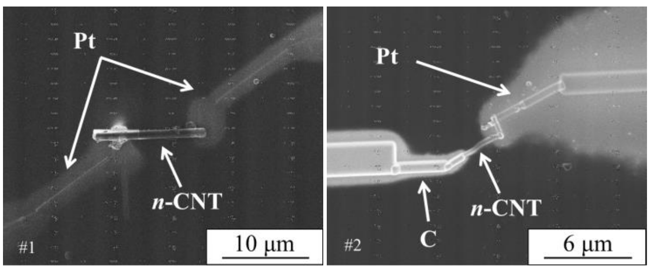
3. Experimental results and discussion

3.1 Growth of n-type CNTs

Figs. 3 show SIM images of CNTs. Non-oriented CNTs were observed without laser assisted sample (a). Linear and highly oriented CNTs were grown at sample (b). These results were revealed that CNT chirality and orientation were controlled by laser irradiation.

3.2 V-I characteristics of CNT

Figs. 4 show SIM images of an n-CNT with C and-or Pt electrodes. The n-CNT was manipulated between Au electrodes, and Pt electrodes were attached from Au electrode to the n-CNT as a sample by FIB Pt deposition. As well as, C and Pt electrode were contacted with the other n-CNT (sample (b)). Figs. 5 show V-I characteristics of n-CNT at sample (a) and (b) by two probe method. Sample (a) described rectification property and (b) showed combined diode and ohmic. The forward current I_F of sample (a) and (b) were 0.5 A, respectively. The forward voltages V_F were 0.68V and 2.4 V, respectively. Sample (b) showed avalanche breakdown voltage at -4.2 V. This indicates that diode characteristic was different and could control the electrical property by deposition the different electrodes.

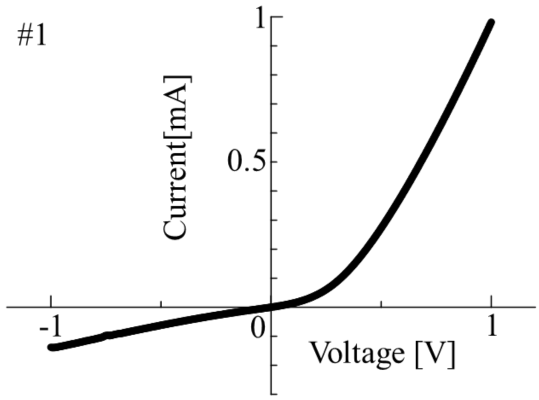


Figs. 4 SIM images of *n*-CNT

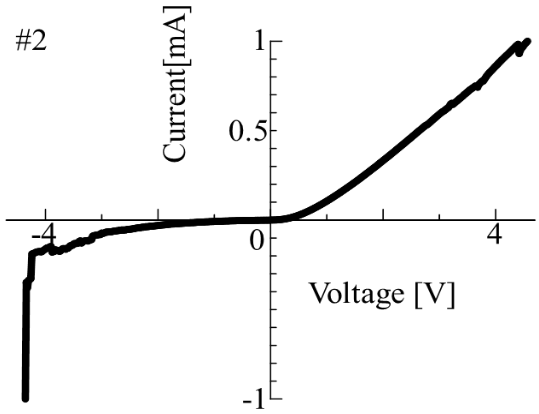
4. Conclusion

We have attempted to fabricate n-CNT diodes by FIB technics. The n-CNTs were growth by discharge pyrolysis at gas/solid interface with laser diode beam assist. Linear and highly oriented forest n-CNTs were grown by laser assist.

V-I characteristic of CNT diode showed rectification property. the forward voltages V_F were 0.68V and 2.4 V, respectively. Sample (b) showed avalanche breakdown voltage at -4.2 V.



(a) Pt as electrodes



(b) Pt as node electrode and C as cathode electrode

Figs. 5 *V-I* characteristics of a CNT diodes

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