Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.1024-1025

G-9-8L

One by One Control of Number of Carbon Nanotube Growth by Current Monitoring

M. Maeda[1,3], T. Kamimura[2,3], C. K. Hyon[3], K. Murata[3], K. Matsumoto[2,3]
University of Tsukuba[1]
1-1-1, Tenodai, Tsukuba, Ibaraki, 305 -8577, Japan
Osaka University[2], CREST/JST[3]

1. Introduction

CNT is the useful element for the future nanodevices. However the control of the position, the direction and the number of CNT is difficult. Therefore, it is indispensable to control them for the applications of electronic devices.

In the present study, we have established the new technology to control the number of the carbon nanotube (CNT) one by one between electrodes during the growth by monitoring the current.

2. Experiments

Figure 1 shows the schematic diagram for the growth control of CNT number with applied electric field. An n-type silicon wafer with a thermally grown oxide (400 nm) was used as the substrate. The layered electrodes of Ti/Pt (30/300 nm) and catalyst of Si/Mo/Fe (50/10/5 nm) were patterned on the substrate using the conventional photo-lithography process.

The sample was then, set in an electric furnace and electrodes are connected to the bias source. During the heat-up process, Ar gas of 1000 sccm was supplied. At a growth temperature of 900°C, ethanol vapor bubbled by Ar gas of 750 sccm was supplied with hydrogen gas of 500 sccm. During the growth of the CNT, DC bias was applied between two electrodes[1)] and the current was monitored. After the growth of CNT, the furnace was cooled down to room temperature with a 1000 sccm ?ow of Ar gas.

3. Results and Discussions

Figure 2 (a) shows the Scanning Electron Microscope (SEM) images of the CNT grown between electrodes without an applied electric ?eld. Three CNTs are observed which make bridge between the electrodes. After this observation, the dc bias was applied between electrodes and CNTs of this sample were cut using the electrical breakdown process[2)] and the current was monitored as shown in Figure 2 (b). When three CNTs were cut using the electrical breakdown process, three step-like decrease of the current was observed in the monitoring current. The number of CNTs observed by SEM coincided with the number of the step-like decrease of the current. Therefore, the number of CNTs between electrodes can be determined by counting the number of the step-like decrease of the monitoring current.

During the growth of CNT at 900°C, the current between electrodes was monitored and shown in Fig. 3. Two step-like increase of the current was observed. The first step-like increase of current is $\Delta I_1 \sim 1.2\times10^{-5}$ A and the second one is $\Delta I_2 \sim 2.8\times10^{-5}$ A. This step-like increase of current is attributed to the one by one increase of the number of CNTs which make bridge between the electrodes as will be confirmed later.

After the CNT growth, CNTs were cut using the electrical breakdown process and the current was monitored. In this process, two step-like decrease of the current was observed in the monitoring current as shown in Fig. 4, which means there had been two CNT's grown between electrodes. The number of steps of the current in the electrical breakdown process in Fig. 4 coincided with that of the monitoring current during the growth of CNT as shows in Figure 3. Therefore, each step of increase current in Fig. 3 corresponds to each bridging CNT between electrodes. These results mean that by monitoring the number of the step like increase of current, the number of CNT between electrodes can be controlled one by one.

4. Conclusions

We have first succeeded in one by one control of the number of CNT by monitoring the number of the step like current during the growth of CNT. The number of CNTs between two electrodes can be made an arbitrary number using this process. This technique is useful for the application of CNT devices.

Reference

[1] Masatoshi Maeda, Chan-Kyeong Hyon, Takafumi Kamimura, Atsuhiko Kojima, Kazue Sakamoto and Kazuhiko Matsumoto, Japanese Journal of Applied Physics **44**, 1585-1587 (2005)

[2] Philip G. Collins, Michael S. Arnold, Phaedon Avouris, SCIENCE **292**, 706-709 (2001)

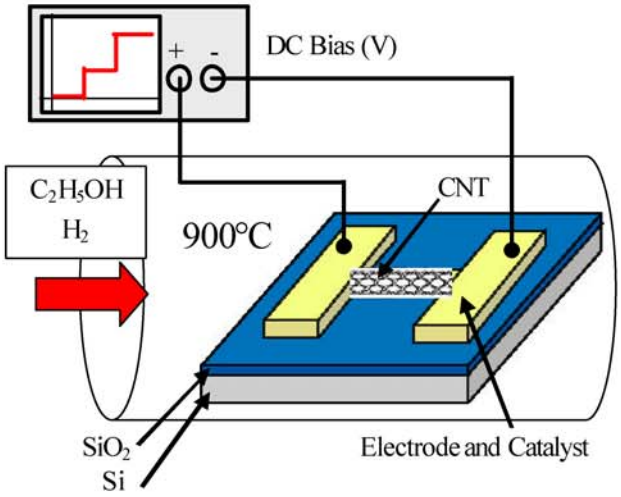
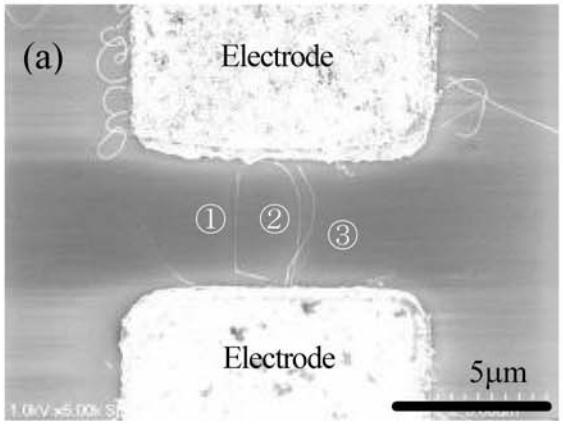


Fig. 1. Schematic diagram for the growth control of CNT with applied electric field and the current was monitored.



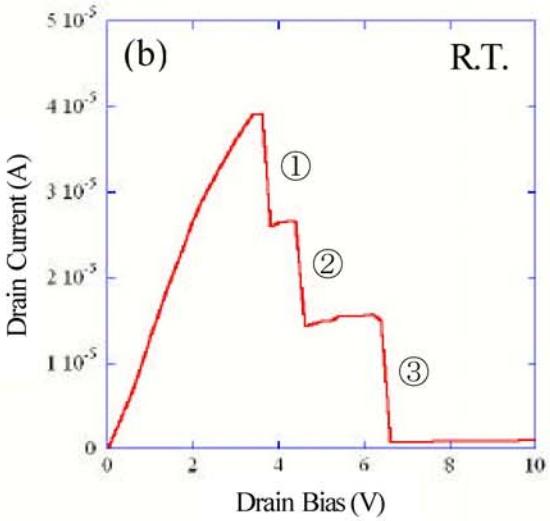


Fig. 2. (a) SEM image of three CNT grown between electrodes without applied electric ?eld. (b) Electrical breakdown process. Three step like decrease of the current was observed.

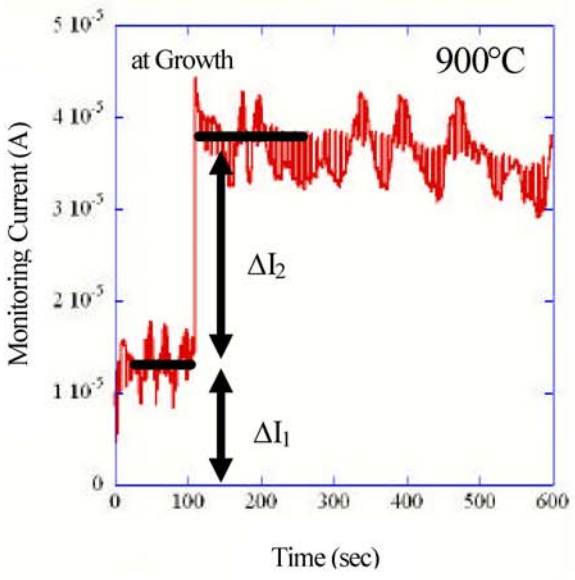


Fig. 3. Monitoring current during the growth of CNT at 900 °C Two step-like increase of the current was observed.

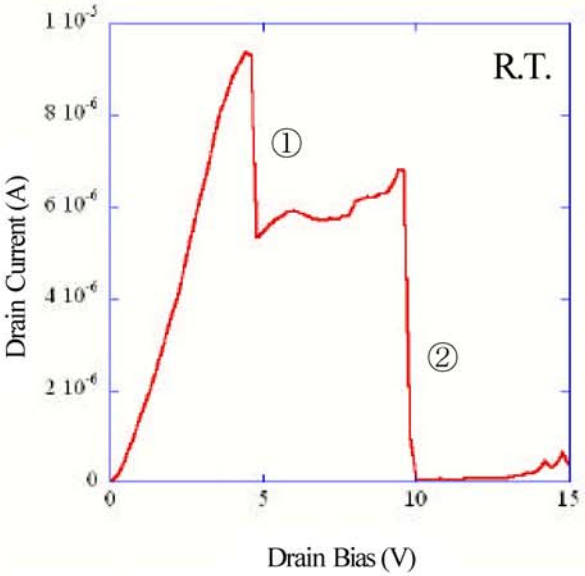


Fig. 4. Electrical breakdown process for the sample in Fig. 3. Two step like decrease of the current was observed which coincide with the two step like increace during the growth process.