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Growth Control of Carbon Nanotube for Electron Device Applications

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1. Introduction

We have investigated the effects of the electric field for the control of the growth of the carbon nanotube (CNT) between electrodes. CNT is the useful element for the nanodevices. However the control of the position and the direction is difficult. Therefore, it is indispensable to control the growth of CNT.

An n-type silicon wafer with a thermally grown oxide (200 nm) was used as the substrate. The layered electrodes of Mo/Si (30/150 nm) and catalyst of Fe (5 nm) were patterned on the substrate using the conventional photo-lithography process. The CNTs were grown between two electrodes by the thermal chemical vapor deposition using bubbeled ethanol and hydrogen. During the growth of CNT, the DC bias was applied between two electrodes.

2. Experiments

Figure 1 shows the schematic cross section of the sample for the growth of CNT with applied electric field. The catalyst used is iron and electrodes used are molybdenum.

First the effect of the shape of the electrode was examined. Two types of shape were adopted. One is the sharp triangular structure in order to concentrate the electric field between the sharp tips of the electrodes. The other is the conventional rectangular structure. The electric field between them is expected to be perpendicular to the electrode and to be parallel each other. Second, the effect of the applied bias with two types was examined, as shown in Figure 2. One is the constant applied voltage during the growth period.[1)] The other is the ramp DC voltage, which decreases, e. q., from 10 V to 0 V at constant rate for 20 minutes, during the growth period.

3. Results and Discussions

The sample was observed using Scanning Electron Microscope (SEM). The difference of the shape of CNTs by the difference of the electrode structure, and of the type of the applied bias, was examined.

Figure 3 shows SEM results for the sharp triangular structure and the rectangular electrode. In the cases of the sharp triangular structure, only few CNT grew straightforward to the opposite electrode only near the sharp tip of the electrode, and almost CNT shows the curved structure and starts to grow from the side of the triangular electrode follow in the curved electric field. In the case of the rectangular electrode structure, all CNT grew straightforward to the opposite electrode. From these results, CNT was found to grow along the electric field between two electrodes.

The effect of the applied bias with two types was examined using the rectangular electrode. Figure 4 shows SEM results for the constant DC voltage and the ramp DC voltage between two electrodes. In the cases of the constant DC voltage between two electrodes, CNT starts to grow from positive biased electrode, and it is hard to reach the negative biased electrode. Just before the negative biased electrode CNT stop to grow. The reason was explained by the etching effect of the positive ionized hydrogen which attacks the carbon atom near negative biased electrode and stop to grow the CNT. In the cases of the ramp DC voltage which decrease from 10 V to 0 V for 20 minutes, length of CNT increased and CNT can bridge between two electrodes. This is because the etching effect of carbon by the positive ionized hydrogen may be decreased by the decreased applied bias. In order to increase the number of the bridging CNT, the effects of van der Waals interactions from the substrate was removed by putting the spacer layer made by SiO_2 between the catalyst and substrate shown in Fig. 5. These results are summarized in Fig. 6. In Fig. 6, (1) In the cases of the constant DC voltage between two electrodes, the bridging ratio was 28%. (2) In the cases of the ramp DC voltage which decrease from 10 V to 0 V for 20 minutes, the bridging ratio increased up to was 78%. Furthermore, in the cases of the ramp DC voltage and with the spacer layer, the bridging ratio was 90%.

4. Conclusions

The effects of the applied bias for the control of the growth of the carbon nanotube was examined. Using the combination of the rectangular electrode and the ramp DC bias, we have succeeded in bridging the strait CNT between electrodes.

Reference

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[2] Y. -T. Jang, J. -H. Ahn, B. -K. Ju, Y. -H. Lee, Solid State Communications **126**, 305-308 (2003)

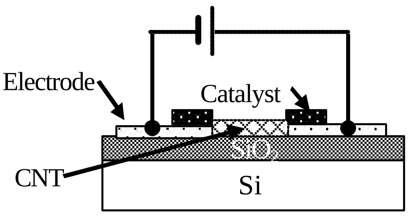
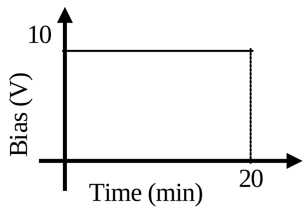
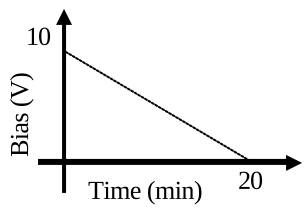


Fig. 1. Schematic cross section of the sample for the growth of CNT with applied electric field.



(a)



(b)

Fig. 2. Bias structure. (a) the constant applied voltage during the growth period. (b) the ramp DC voltage, which decreases, from 10 V to 0 V at constant rate for 20 minutes.

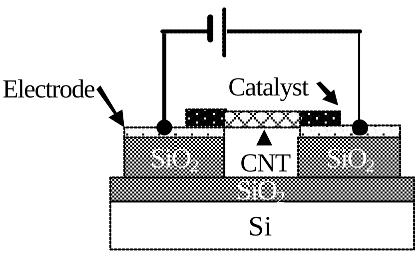


Fig. 5. Schematic cross section of the sample with the spacer layer by suputtered SiO_2 between catalyst / electrode and the substrate.

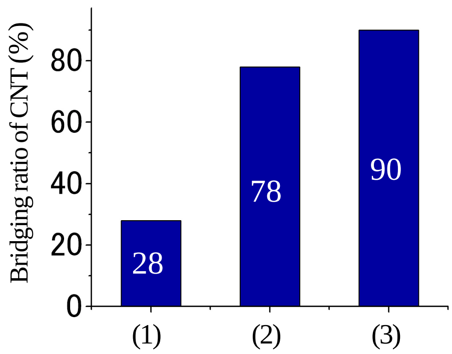
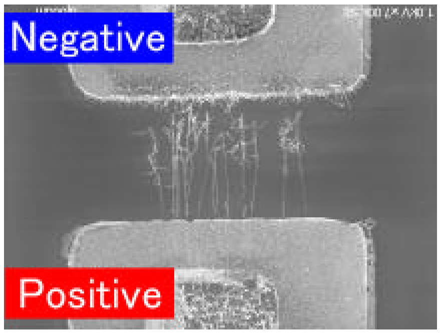


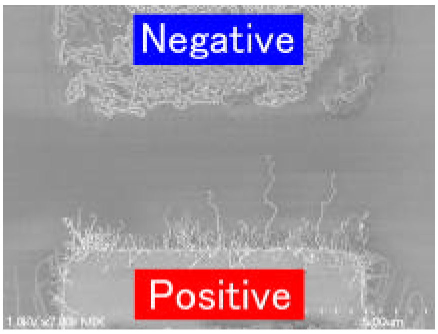
Fig. 6. Bridging ratio of CNT. (1) constant DC voltage, (2) the ramp DC voltage and (3) the ramp DC voltage with spacer layer.

(a)

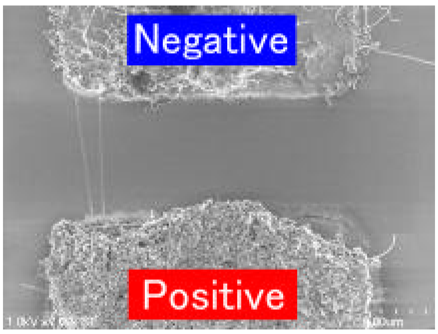


(b)

Fig. 3. Trace of grown CNT for (a) the sharp triangular electrode, and for (b) the rectangular electrode structure.



(a)



(b)

Fig. 4. SEM image of the CNT with (a) constant DC voltage between two electrodes, and with (b) the ramp DC voltage which decrease from 10 V to 0 V for 20 minutes.