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P8-1

Constraining the Direction of Carbon Nanotubes by Oxide Capping Layer

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***Abstract* --** Organized positions and orientations of carbon nanotubes (CNTs) attract scientific attentions. Sandwiched structures with the catalyst capped by oxide layers pave a practicable way for this destination. Experimental results showed that the thick oxide capping layer could successfully constrain the growth direction of CNTs with proper buffer or adhesive layer.

1. Introduction

Carbon nanotubes (CNTs) with unique electrical and mechanical properties are thought to be an ideal candidates for novel nanoelectronic devices.[1] CNT field-effect transistors (CNT-FET) have been fabricated successfully by Tans *et al*.[2] and Martel *et al*.[3] There have been various fabrication methods developed to address individual CNT in desired positions and orientations, such as liquid suspensions,[4] or AFM manipulations.[5] However, there was a lack of organized control for large array and high reliability. Patterned growth by chemical vapor deposition (CVD) with electrical fields seemed a promising technique.[6] Nevertheless, there existed uniformity issue with the complicated growth system for producing internal field. There were still no reliable, rapid and reproducible approaches to build up complex arrays of nanotube devices. In CVD, the location of nanotubes could be controlled by patterned catalyst, but the number of tubes and orientation were still not well defined. Sandwiched structures with capping materials on the catalyst layer easily defined the tube position and little effect on orientation. Combined with different pattern geometry, it would be another promising approach for large arrays of nanotube devices.

2. Experiment

We constructed a sandwiched structure, shown in Fig. 1, which had a catalyst layer consisting of 10nm Ti/ 3.5nm Fe/ 20nm Ti. An oxide layer of 15nm was capped onto the catalyst layer. All the sandwiched layers were deposited sequentially onto a silicon substrate by electron-gun evaporation and by lift-off process. The growth processes of CNTs were conducted by microwave plasma chemical vapour deposition (MPCVD). Briefly speaking, the reacting chamber was evacuated to 150mtorr, then hydrogen gas flowed in, meanwhile the stage was heated to 500℃. Samples loaded in the chamber were pretreated with hydrogen plasma for 10min at a pressure of 30torr. The microwave power was 1200W and the stage height reads 50. After pretreatment process, gas flow of methane was supplied as the carbon source in the growth process of CNTs for 10min. The features of CNTs grown by microwave plasma CVD were examined by scanning electron microscope (SEM).

3. Result and discussion

Fig. 2 shows the sandwiched structure with different two adhesive layers Ti and Cr, respectively. After synthesizing of CNTs, the SEM images are represented in Fig. 3. Clearly the structure with Cr layer showed no CNT grown all the structure while there are some CNTs protruding through the edges of the sandwiched structure with Ti layer.

In the higher magnification SEM images in Fig. 4, it could show that better adhesion between oxide layer and catalyst would prohibit the growth of CNTs. The mechanism is due to the growth model of CNTs. Growth of CNTs needs nanoparticles as catalytic media. The excellent adhesion between oxide layer and catalyst layer causes the difficulty in particle formation; therefore, CNTs could not grow from the edge of the structure. In other words, the Ti layer providing worse adhesion than Cr could supply gaps at the edge of structures where the catalyst exposed and formed nanoparticles for CNTs growth. Fig. 5 represents the mechanism mentioned above.

4. Conclusion

Combining with different adhesive or buffer layer, the sandwiched structures showed different results. The oxide capping layer with Ti layer successfully suppressed the up-growth of CNTs; however, there was no CNTs grown with the Cr layer. The oxide capping layer could function well to constrain the growth directions and positions of CNTs. In practice for device application, the capping layer should be further improved, and the number of CNTs per unit area also should be well-controlled.

Acknowledgement

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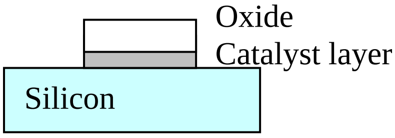
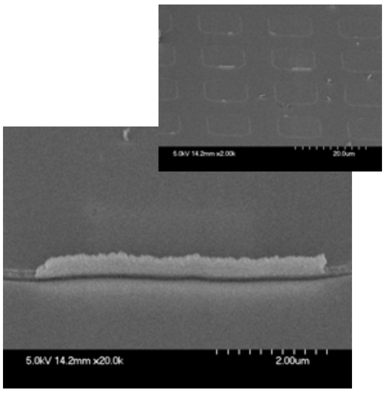
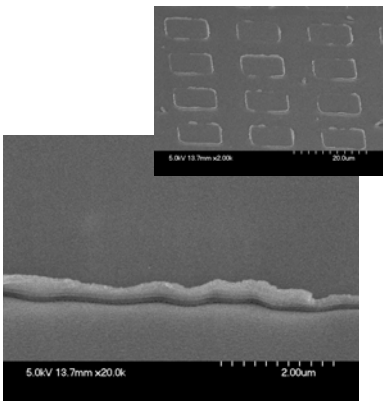


Fig. 1. Sandwiched structures with capping oxide layer.

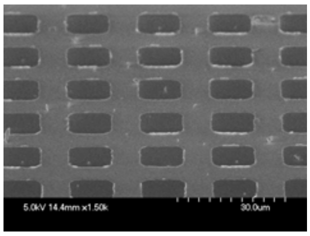


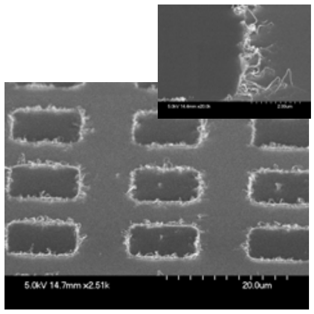
(a) Cr layer



(b) Ti layer

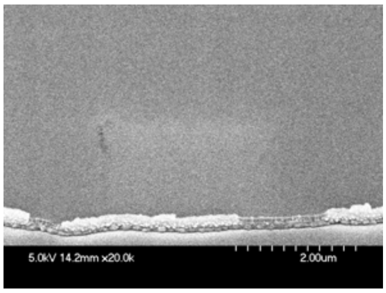
Fig. 2. Sandwiched structure with the capped oxide, (a) Cr adhesive layer and (b) Ti layer.



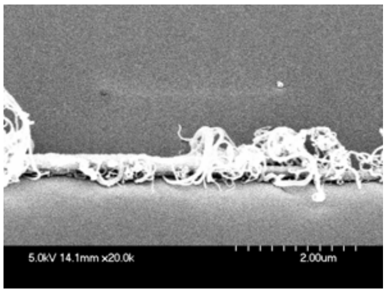


(a) Cr layer (b) Ti layer

Fig. 3. (a) No CNTgrowth with Cr layer, and (b) CNTs grew from the sandwiched structure with Ti layer.

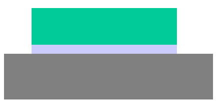


(a) Cr layer



(b) Ti layer

Fig. 4. (a) No CNTgrowth with Cr layer and excellent adhesion; (b) CNTs grew from the sandwiched structure with Ti layer with poor edge adhesion.



(a) Cr layer; good adhesion (b) Ti layer; poor adhision

Fig. 5. The mechanism of different adhesive layer, (a) Cr and (b) Ti.