Growth Control of Single-walled Carbon Nanotubes

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1. Introduction

Single-walled carbon nanotube (SWNT) is a rolled up graphene sheet. The diameter range is from 0.4 to a few nm, and the length achieve millimeter. Controlling the detailed structures of SWNTs is imperative for realizing many SWNT applications, and understanding the SWNT growth mechanism is important to improve the growth techniques. In the present study, we synthesized SWNTs by a catalytic chemical vapor deposition (CVD) method and controlled the diameter by using nano-diamond particles and the orientation control on crystal quartz substrates, respectively.

2. Experiments

SWNTs were synthesized by catalytic CVD method and ethanol was used as the carbon source (Maruyama et al. (2002)). For diameter control, nano-diamond particles were used as the catalyst (Takagi at al. (2009)). The nano-diamond particles were dispersed on silicon substrate and oxidized in air. The oxidization process decreased the diameter of nano-diamond. In the case of the orientation control, crystal quartz was often used as a substrate (Kocabas et al. (2005)). Here, R-cut crystal quartz was used. Fe/Co nano-particles supported on zeolite particles were deposited on R-cut quartz substrates.

Scanning electron microscope (SEM), Raman scattering spectroscopy and atomic force microscope (AFM) were used for characterization.

3. Results and Discussions

Figure 1 show (A) SEM image and (B) Raman scattering spectra from SWNTs grown by using nano-diamond. SWNTs were synthesized uniformly on silicon substrates and the sharp and intensive G-band clearly appeared around 1590 cm^{-1}, which indicated that they were high-quality SWNTs. Because diamond is stable even at high temperature, the diameter of diamond nano-particles did not change in the CVD process. The oxidization pre-treatment of higher temperature decreased SWNT diameter. It suggested that SWNT diameter could be controlled by precisely-control of the diameter of nano-diamond particles in advance.

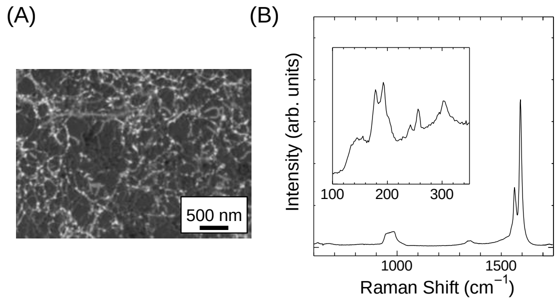

Fig. 1 (A) SEM image and (B) Raman scattering spectra of SWNTs grown from nano-diamond. The oxidized temperature of diamond particles was 700 °C, and CVD temperature was 800 °C.

The orientation control of SWNTs was performed on crystal quartz. The surface structure of R-cut surface was shown in Fig. 2(A). The surface of R-cut was not flat and the dimple structure was observed. However, SWNTs were aligned along to the direction of the x-axis, as shown in Fig. 2(B). The atomic structure of R-cut surface was similar to that of crystallographic face (0-11). It indicated that R-cut surface was a collective of small domain of (0-11) face, which aligned growing SWNTs.

References

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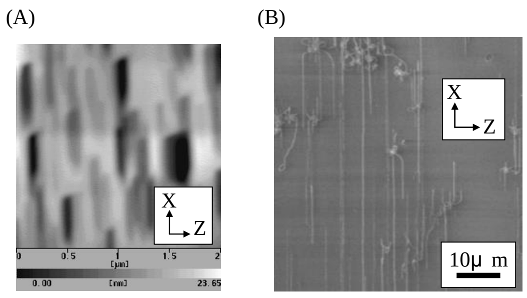

Fig. 2 (A) AFM image of the surface structure of R-cut crystal quartz substrate. (B) Horizontally-aligned SWNTs on R-cut quartz substrates.