Horizontally-Alignment Growth of Single-Walled Carbon Nanotubes on Quartz Substrates

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Orientation control of single-walled carbon nanotubes (SWNTs) is important for the analysis of their growth mechanism and the fabrication of SWNT applications. One of the orientation control techniques was horizontally-alignment. It is well-known that SWNTs can grow on sapphire [1] and crystal quartz substrates [2] along specific directions.

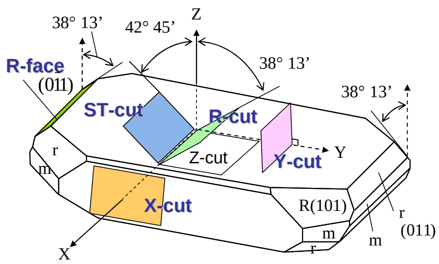

Fig. 1 Crystal quartz substrates of various cut-angle.

Crystal quartz substrates have various cut angles, as shown in Fig. 1. ST-cut substrates are most popularly used and SWNTs are grown along the direction of the x-axis on ST-cut surfaces. The orientation is improved after annealing the substrates at high temperature for an extended time. However, ST-cut is artificial surface and the atomic structure of ST-cut surface is not clear. In this study, R-face (101) crystal quartz substrates were used and we investigated SWNT growth on them. R-face (101) is one of the stable surfaces that appear on natural quartz crystal, and ST-cut surface is roughly parallel to R-face. Figure 2(A) shows an AFM image of R-face (101) surface. Because the step and terrace structure clearly appeared and the step height was approximately 0.3 nm, which agreed with the plane spacing of R-face (101), the terrace area was (101) atomic surface. On R-face substrates, SWNTs were synthesized by ACCVD method. Zeolite supported Fe/Co nano-particles were used as the catalyst. A typical AFM image of SWNTs grown on R-face is shown as Fig. 2(B). SWNTs were horizontally aligned along the direction of x-axis, which indicated that the atomic structure of (101) plane aligned SWNTs. SWNTs were aligned on ST, R, Y-cut and R-face substrates, while SWNTs were randomly grown on X-cut [3]. It indicated that the alignment of SWNTs on crystal quartz substrates came from the atomic structure along the direction of x-axis.

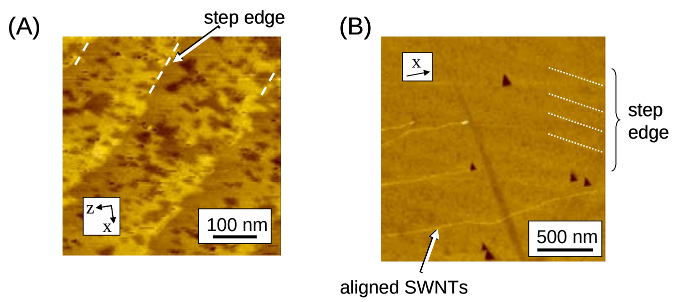

Fig. 2 AFM images of (A) the surface of R-face (101) crystal quartz substrate and (B) horizontally aligned SWNTs along to the direction of x-axis on R-face substrates.

[1] H. Ago et al., *Chem. Phys. Lett.*, **408** (2005) 433.
[2] J. Xiao, et al., *Nano Letters* **9** (2009) 4311.
[3] C. Kocabas, et al., *J. Phys. Chem. C*, **111** (2007) 17879.