# Diameter-Controlled Growth of Single-Walled Carbon Nanotubes by Using Nano-diamond Particles

Shohei Chiashi [1], Norihiro Hiramatsu [1], Kenta Nakamura [1], Takanori Umino [1], Yoshikazu Homma [2] and Shigeo Maruyama [1]

[1] *Department of Mechanical Engineering, The University of Tokyo*
*7-3-1 Hongo, Bunkyo, Tokyo 113-8656, Japan*
[2] *Department of Physics, Tokyo University of Science*
*1-3 Kagurazaka, Shinjuku, Tokyo 162-8601, Japan*

## §1 Introduction

Structure control is one of the important topics in the research filed of single-walled carbon nanotube (SWNT) growth and the chirality-controlled growth is still difficult and challenging object. Because the number of possible chirality is limited for the small diameter SWNTs, the SWNT growth with smaller diameter attract attention. Here, we perform CVD growth by using nano-diamond particles as the catalyst [1] and investigate the CVD condition dependence of SWNT tube diameter.

## §2 Experiment

As the catalyst particles, nano-diamond particles were used. The diamond particles were dispersed in ethanol and the solution was dropped onto silicon substrates. The substrates were heated in air and the nano-diamond particles were oxidized. The oxidization temperature ranges from 600 to 1000 °C. After the oxidization treatment, CVD was performed. The CVD temperature was 700, 800 and 900 °C and ethanol vapor was used as the carbon source. The CVD duration was 5 min. The nano-diamond particles were analyzed by atomic force microscope (AFM). Raman scattering spectroscopy and SEM observation were performed for the characterization of grown SWNTs.

## §3 Results and Discussion

Figure 1 shows SEM image of SWNTs grown from nano-diamond particles. In advance of the CVD, the oxidization treatment was performed at 700 °C for nano-diamond particles. Since the nano-diamond particles were uniformly dispersed, SWNTs were also uniformly covered on the surface of the silicon substrates. For the SWNT growth from nano-diamond, the oxidization treatment of nano-diamond particles is important. The diameter of as-received nano-diamond particles is approximately 4 nm and the oxidization in air decreases their diameter. The diameter distribution

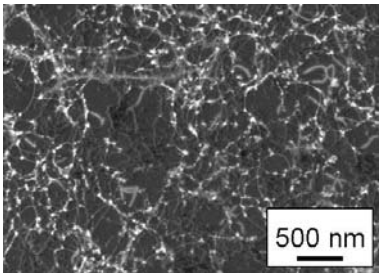


Fig. 1 SEM image of SWNTs grown form nano-diamond particles on silicon substrate. The oxidization treatment was performed at 700 °C, and the CVD temperature was 800 °C.

of nano-diamond after oxidization treatments is shown in Fig. 2(A). The oxidization temperature ranges from 600 to 1000 °C. The average diameter gradually decreases. After oxidization at 900 °C, the average diameter is 0.84 nm. Because the SWNT diameter is generally the almost the same as that of the catalyst particles, the narrow diameter distribution of nano-diamond particles limits SWNT diameter range. Figure 2(B) shows the RBM peaks from SWNTs grown at different CVD temperature (700, 800 and 900 °C). The diamond particles were oxidized at 900 °C. The tube diameter distribution was in range with the diameter distribution of nano-diamond particles and it depended on the CVD temperature. The nano-diamond particles hardly change their diameter during the CVD process, since diamond structure is quite stable. Therefore, it is suggested that the CVD temperature dependence of the tube diameter, as shown in Fig. 2(B), is not the origin of the aggregation or dispersion of the catalyst particles but is intrinsic to SWNT growth.

## §4 Conclusions

SWNTs were synthesized by using nano-diamond particles as the growth catalyst. The diameter-controlled nano-diamond particles effectively restricted the tube diameter distribution of SWNTs. Combining nano-diamond particles with smaller diameter and lower CVD temperature decrease SWNT diameter, precisely.


## Acknowledgement

This work was supported by Grants-in-Aid for Scientific Research (19054003) from the JSPS,


## References


1. D. Takagi, Y. Kobayashi and Y. Homma, *J. Am. Chem. Soc.*, **131** (2009) 6922.


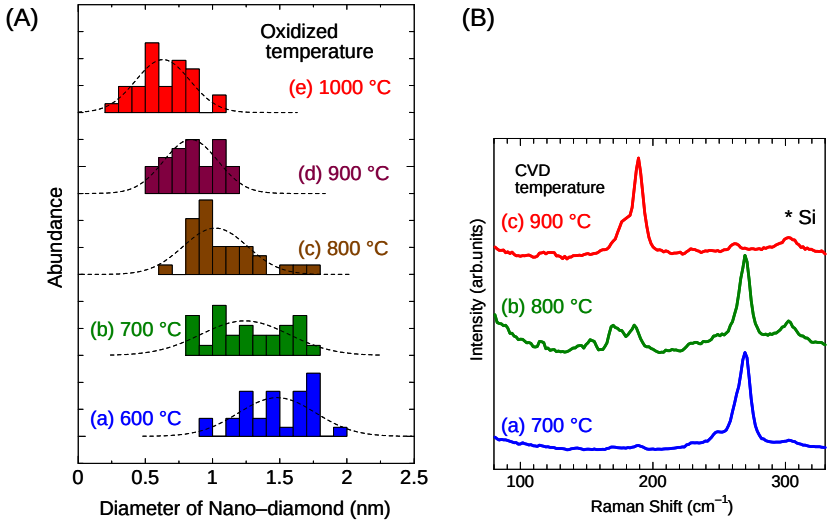


Fig. 2 (A) Oxidization temperature dependence of the nano-diamond diameter. (B) Raman scattering spectra (RBM peaks) from SWNTs grown from nano-diamond particles. The oxidization treatment was performed at 900 °C.


**Corresponding Author: S. Maruyama**

**Email: maruyama@photon.t.u-tokyo.ac.jp**