In-situ Monitoring and Kinetic Analysis of Millimeter-Thick Single-Walled Carbon Nanotube Growth

Kei Hasegawa[1], Suguru Noda[1], Shigeo Maruyama[2] and Yukio Yamaguchi[1]

[1] *Dept. of Chemical System Engineering, The University of Tokyo, Tokyo 113-8656, Japan*
[2] *Dept. of Mechanical Engineering, The University of Tokyo, Tokyo 113-8656, Japan*

Rapid growth of single-walled carbon nanotubes (SWNTs) was realized by the water-assisted growth method [1], and its growth kinetics was supposed as the exponential decay of the initial growth rate [2]. We reproduced such rapid growth by our combinatorial catalyst preparation method and proposed a novel mechanism of the growth rate enhancement by the Al_2O_3 catalyst underlayer [3, 4]. In this study, we show the growth rate and the catalyst lifetime determined by the in-situ monitoring of growing SWNTs.

The growth condition was 8.0 kPa C_2H_4, 27 kPa H_2, 5.0 Pa H_2O, 67 kPa Ar at 1093 K. Figure 1a shows the nanotubes growing on the combinatorial catalyst library [5] of 0.2-3-nm Fe on $Al_2O_3/SiO_2/Si$, and Fig. 1b shows the time profile of the SWNT thickness with 0.5 nm Fe. The nanotube forest grew up at an initial growth rate of 4.5 μm/s, kept growing at that rate for 6 minutes, and then suddenly stopped growing. Kinetics can be more precisely determined by this in-situ monitoring method than the conventional batch experiments, because the catalytic growth of nanotubes is not so reproducible among different experimental runs.

Figure 2 show the effect of temperature (a) and C_2H_4 pressure (b) on the growth rate and the catalyst lifetime at the Fe thickness of 1.0 nm. Both the higher temperature and C_2H_4 pressure caused the higher growth rate. Higher temperature shortened the catalyst lifetime. On the other hand, the effect of C_2H_4 pressure for the lifetime was not significant. The underlying mechanism will be discussed considering the reaction both in the gas phase and on the Al_2O_3 substrate and the structural change of Fe nanoparticles.

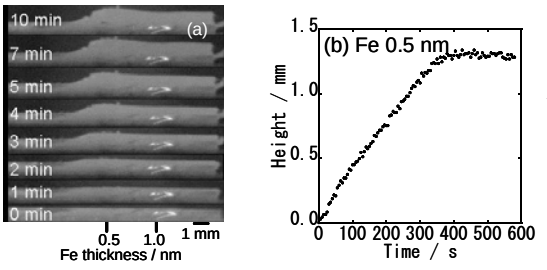

Fig. 1 (a) Photographs of growing CNTs. (b) Time profile of the growing CNTs

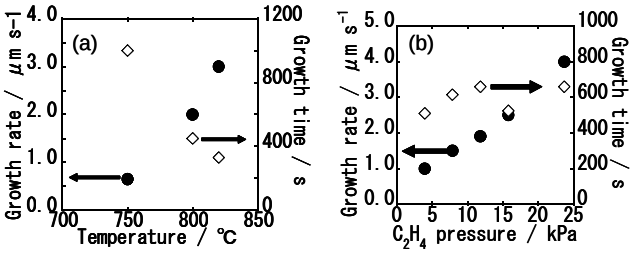

Fig. 2 Growth rate and lifetime at different temperatures (a) and C_2H_4 pressures (b).

[1] K. Hata, et al., *Science*, **306**, 1362 (2004). [2] D. N. Futaba, et al., *Phys. Rev. Lett,* **95**, 056104 (2005). [3] S. Noda, et al., *Jpn. J. Appl. Phys.*, **46**, L399 (2007). [4] K. Hasegawa et al., *J. Nanosci. Nanotech.* in press. [5] S. Noda et al., *Carbon*, **44**, 1414 (2006).

Corresponding Author: Suguru Noda
TEL: +81-3-5841-7330, FAX: +81-3-5841-7332, E-mail: noda@chemsys.t.u-tokyo.ac.jp