Low Temperature Growth of Single-Walled Carbon Nanotubes by High Vacuum ACCVD Method

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Single-walled carbon nanotubes (SWNTs) are one of the most promising materials for various novel applications. Currently, the alcohol catalytic chemical vapor deposition (ACCVD) method [1] is widely used to obtain high quality SWNTs such as vertically aligned SWNT films with small amounts of defects and impurities [2]. Recently, Shiokawa *et al.* [3] reported that SWNTs were grown at low temperature (~ 550 °C) and at low pressure of less than 0.1 Pa using the ACCVD method. Such CVD conditions are considered to be advantageous for growing small-diameter SWNTs with well controlled growth speed, which would give us valuable insights toward the control of SWNT chiralities. The purpose of present study is to clarify the growth mechanism of SWNTs through investigating SWNTs grown under well-defined high-vacuum environment.

Specifically, we have developed a high-vacuum CVD system that allows us to control the feedstock gas pressure as well as the reaction temperature accurately. We successfully synthesized SWNTs under various temperatures and pressures, and analyzed the obtained samples by resonant Raman spectroscopy (Fig. 1). From this, we found that the optimum synthesis temperature decreases as the ethanol vapor pressure decreases. We characterized thereby synthesized SWNTs by TEM (Fig. 2), SEM and AFM, showing that SWNTs with small diameter are preferably synthesized by the proposed approach that utilizes the low pressure and high vacuum conditions.

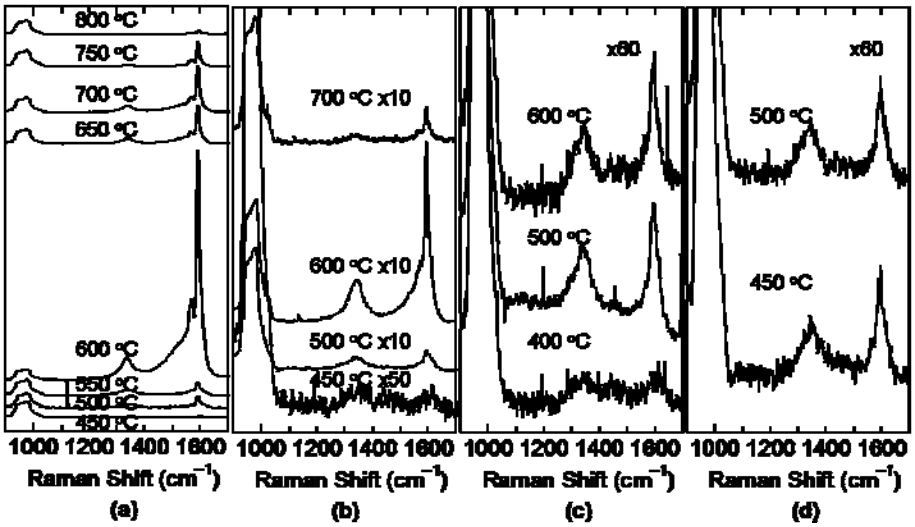

Fig.1 Raman spectra of SWNTs grown at different ethanol vapor pressures of (a) 10, (b) 1, (c) 1×10^{-2}, (d) 1×10^{-3} Pa. The CVD temperature is shown for each spectrum. The excitation wavelength was 488 nm.

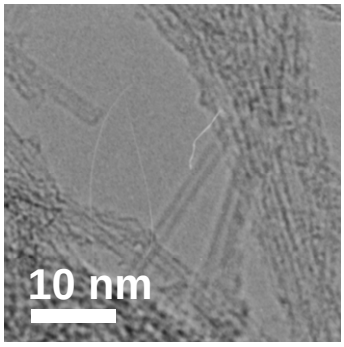

Fig.2 TEM image of SWNTs synthesized at 10 Pa and 600 °C for 30 min.

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