From clusters to nanotubes

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The growth mechanism of single-walled carbon nanotubes (SWNTs) from a metal cluster is studied through molecular dynamics simulations [1] and various experimental techniques such as chemical reaction of metal clusters by Fourier-transform ion cyclotron resonance (FT-ICR) mass-spectrometer; direct TEM and XPS observation of supported catalyst particles [2]; in-situ Raman and AFM measurements during laser CVD [3]; in-situ monitoring of SWNT film thickness [4]; combinatory method of binary metal particle preparation [5, 6]. Catalytic growth of SWNTs from a metal cluster with about 1 - 2 nm diameter as shown in the molecular dynamics simulation in Fig. 1 is a well accepted concept. However, the experimental CVD condition has been developed largely by try and error because the growth mechanism is not well understood. The carbon source molecule, metal species, supporting material, and metal-cluster preparation technique have been usually arbitrarily chosen. We have found that high-purity SWNTs can be generated at relatively low CVD temperatures by using alcohol as carbon source [7]. Based on this finding, we have proposed alcohol catalytic CVD (ACCVD) technique for narrow chirality growth of SWNTs as demonstrated in the near IR fluorescence spectroscopy in Fig. 2 [8], and vertically aligned SWNT from on quartz or silicon substrate in Fig. 3 [9, 10]. The complete understanding of the growth mechanism is desired for the further development of CVD technique with chirality controlled and/or orientation and position controlled growth.

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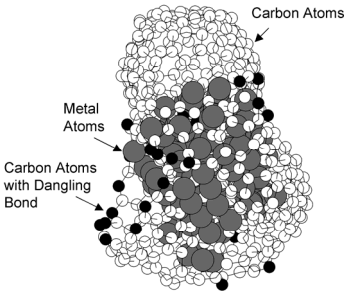

Fig. 1 MD simulation of nanotube nucleation

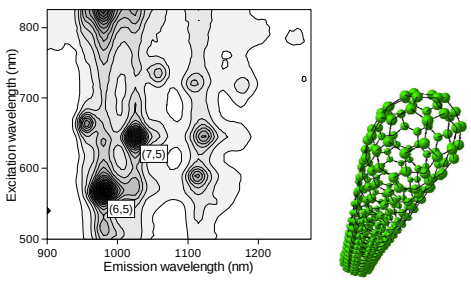

Fig. 2 Near infrared fluorescence of SWNTs and structure of (6,5) nanotube

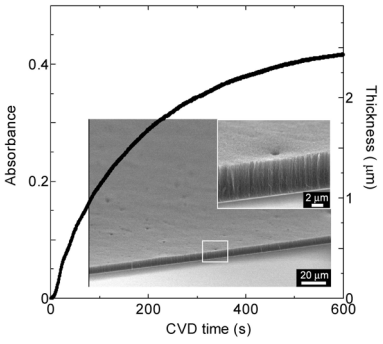

Fig. 3 Growth of vertically aligned SWNTs