Discontinuous Change in Carbon Nanotubes Caused by Continuous Change in Catalyst Nominal Thickness

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Controlled growth of single-walled carbon nanotubes (SWNTs) on substrates is crucial for many of their device applications. SWNT growth is largely dependent on both catalyst conditions (element of catalyst, diameter, etc.) and reaction conditions (source of carbon, temperature, pressure, etc.). Effects of these conditions interact with each other complicatedly.

Previously, we prepared a thickness profile of Co on a SiO_2/Si substrate [1] and that of Ni on quartz glass substrate [2] by our 'combinatorial masked deposition (CMD)' method [3], carried out alcohol catalytic CVD (ACCVD) [4], and grew SWNTs by metal nanoparticle catalysts spontaneously forming from nominal monolayers of metal. The thickness profiles formed by this method enable preparation of a series of nanoparticles with various sizes and areal densities on one substrate. Thus we can investigate influence of reaction and catalyst conditions systematically.

In this work, we studied the relationship between the structure of catalyst and that of growing nanotubes by preparing a gradient thickness profile (about 0.06-3.5 nm) of Co by using CMD method and by growing carbon nanotubes (CNTs) by ACCVD at 873-1123K. At 973K, two active regions appeared with an inactive region in between. SWNTs mainly grew at a thin Co region (~ 0.1 nm, Fig. (a)), small amount of short CNTs grew at a medium region (~ 0.4 nm, Fig. (b)), and multi-walled carbon nanotubes grew at a thick region (~ 1.5 nm, Fig. (c)). In the medium region, the dissolution of carbon into catalysts and the precipitation of carbon as CNTs from them may be unbalanced and the growth may not be sustainable.

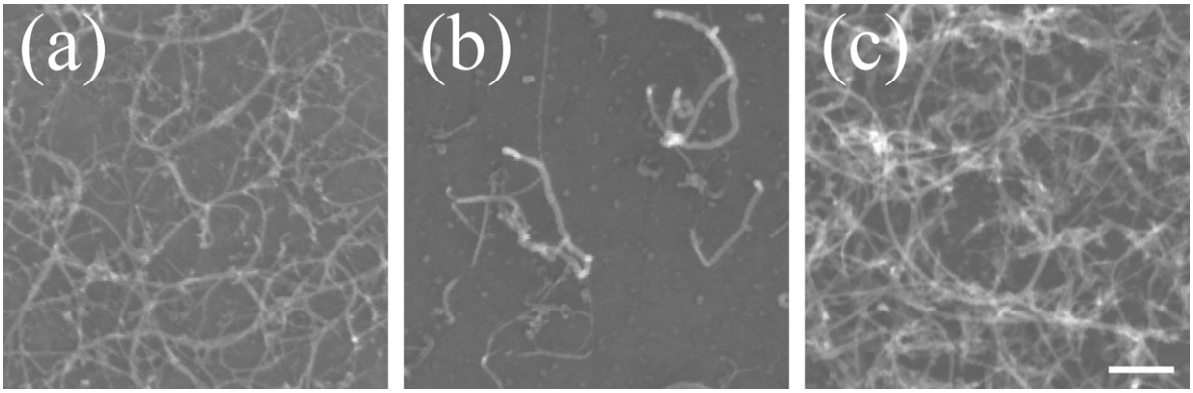

Fig. Plan-view FE-SEM images of CNTs at the nominal Co thickness of (a) 0.13, (b) 0.29 and (c) 0.92 nm. All images are in the same scale and the scale bar is 100 nm.

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