

Growth Control of Vertically Aligned Single-Walled Carbon Nanotubes

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The vertically aligned single-walled carbon nanotubes (SWNTs) with film thickness up to 30 microns is grown on quartz or silicon substrates by alcohol catalytic CVD method [1,2]. The growth condition and growth mechanism of VA-SWNTs has been explored based on the *in-situ* growth monitoring by laser absorption [3,4] during CVD. Recently, the no-flow CVD [5] turned out to be very efficient, resulting a thicker film up to 100 μm . This result suggests the importance of gas-phase decomposition of ethanol. Actually, effect of ethanol flow rate on the growth dynamics of VA-SWNTs is significant. Based on the chemical kinetics model, the predicted thermal decomposition of ethanol is significant for low-flow rate condition at moderate temperature as 800 $^{\circ}\text{C}$. Because the reactivity of smaller hydrocarbon molecules can be very high, effect of small amount of decomposed molecule could be very important. Effect of each decomposed molecules on CVD process is examined by mixing a fixed amount of hydrocarbon in the *in-situ* monitoring system. Only about 1 percent of acetylene mixing to ethanol flow results 10 time fast growth rate. However, the growth decay time becomes much smaller with acetylene addition. The detailed chemical reaction process in gas-phase and on metal catalysts will be discussed based on CVD results using isotope labeled ethanol and acetylene as carbon source.

In addition to the chemical reaction control, efficient diameter control of SWNTs can be possible by touching the catalysts recipe. VA-SWNT with an average diameter as small as 1.2 nm was obtained by changing the metal alloy ratio. The careful measurement of optical absorption is the key to study this. Here, the slight increase of average diameter of SWNTs during growth is also observed. Because our growth is completely root-growth [6], average diameter of bottom of the film is slightly larger. This diameter change indicates catalyst aggregation/ripening may be occurring during synthesis. Finally, a versatile wet chemistry method using self-assembled monolayer (SAM) surface modification to localize the growth of SWNTs is demonstrated. By functionalizing the silicon oxide surface by classic SAM, the catalyst can be selectively dip-coated onto the hydrophilic area. This technique allows us to pattern VA-SWNTs for future device applications.

References:

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