Growth process of multi wall carbon nanotubes on pre-patterned catalyst microstructures

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Carbon nanotubes (CNTs) are expected to be promising building blocks for future electronic circuits because of their unique electrical properties. Making electrical connections to an individual CNT, however, still remains a daunting task. Recently, selective area chemical vapor deposition (CVD) of carbon nanotubes (CNTs) has been demonstrated as an effective approach to directed assembly of CNT devices and circuits. The approach began by lithographically (photo- and electron-beam-) defining electrodes on a catalyst film (for example, Fe) deposited on an insulating substrate. This sample was then loaded into a CVD chamber where CNT growth occurred. Following growth, the CNTs were observed to grow selectively from the electrodes. In some circumstances, CNTs were observed to grow across some electrodes, forming an electrode/CNT/electrode circuit - a fundamental building block for CNT devices and circuits.

Like other self-assembly methods, this approach also requires accurate control of the growth conditions to increase the probability that electrodes will be linked by individual CNTs. In this contribution, we explore the effect of growth processes on multi wall CNTs growth on pre-deposited electrode microstructures.

Specifically, a series of SEM images were taken after 5, 10, 15, and 20 min of CNT growth from 100nm catalyst dots. To make comparison possible, images were taken from the same catalyst dots and at the same magnification. After 5 min growth of CNTs, the catalyst dots were completely covered by tangled multi wall CNTs. A small portion of the CNTs, however, grew in the substrate plane and radially away of the catalyst dots and these enabled us to calculate an average growth rate. After 10 min growth, more CNTs grew around the dots but the radial tubes were still visible. With further increases in growth time, no clear increase in CNTs was observed because the catalyst particles were completely surrounded by carbon sheets. The growth process of an individual CNT was easily observed and growth occurred at the top where catalyst particle was located. This suggests direct evidence of a diffusion model for multi wall CNT growth in CVD. The growth rate was found to be nonlinear and most growth process was finished in the first 5 minutes.

CNT regrowth on catalyst microstructures was explored by first introducing oxygen at a substrate temperature of 660^0C. After a 20 minute treatment, the number of previously deposited CNTs fell and the carbon sheets surrounding the catalyst particles were removed. Hydrogen was then introduced for 10 minutes to chemically reduce the oxidized catalyst particles and provide a starting point for CVD regrowth of CNTs. SEM observations confirmed that regrowth progressed in much the same manner as before and suggests an entirely reversible process. In the context of CNT-based nanocircuits, this method offers an avenue to “rewire” or “fix” unsatisfactory connections in much the same way that laser-trimming is used to tune parameters on current hybrid circuits.

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