



# IBS Center for Multidimensional Carbon Materials



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Chemical and Materials Engineering

### Synthesis and Characterization of Catalytically Grown Long Carbon Nanotube Arrays

10:30AM FRI | Bldg. 101

NOV 25 | Seminar room on the 1<sup>st</sup> floor

This study is focused on synthesis of centimeter long carbon nanotube (CNT) arrays by a water assisted catalytic chemical vapor deposition (CVD) process, and elucidating their growth mechanism. In order to surpass current limitations and achieve centimeter long CNT arrays, the growth kinetics and related mechanism were systematically examined to understand the relationship among growth variables, catalyst nanoparticles, and CNT structures. Knowledge about the growth rate, activation energy, and growth mechanism/model is generated through kinetics study and characterization of CNT growth. First, a real time photography method was developed to study growth kinetics. Using this method, we found that the growth of centimeter long CNT arrays revealed root growth mode. The length of the CNT arrays increased linearly with growth time for all the tested temperatures followed by an abrupt growth termination. It was demonstrated that Fe-lanthanide catalysts prolonged the catalyst lifetime and enhanced catalyst activity, which led to growing of centimeter long CNT arrays. Particularly, Fe-Gd catalyst yielded the longest catalyst lifetime and CNT growth length. Growth termination is caused by many complex reasons such as surface migration and loss of catalysts, formation of cementite and deposition of amorphous carbon on catalysts. In order to grow centimeter long CNTs, it is important to maintain balanced conditions, especially water and hydrogen concentration and a moderate growth rate and clean catalyst surface. The catalyst lifetime is prolonged by increasing the hydrogen partial pressure up to 0.1 volume concentration. Moreover, adding small amounts of water (180 ppm) increases the catalyst lifetime dramatically. We obtained the following optimized recipe: 560 mmHg of argon, 60 mmHg of hydrogen, 140 mmHg of ethylene, and 900 ppm of water. Based on the findings in this work, we were able to grow the longest vertically aligned CNT arrays reported so far, with length of 21.7 mm, growth rate of 27.47  $\mu\text{m}/\text{min}$  and activation energy of 212.2 kJ/mol.

Special Guest Speaker

You are cordially invited to attend!