IV.C.1c Controlling the Diameter of Single Walled Carbon Nanotubes for Hydrogen Storage

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Partner Approach

Duke is developing novel methods to prepare small diameter and uniform SWNTs by precisely controlling catalyst diameter and carbon feeding rate. Control of nanomaterial dimensions is critical to developing high capacity hydrogen storage materials. Both diameters of SWNTs and pore sizes of carbon materials have been shown to affect hydrogen uptake. It is important to development to precisely control these parameters.

Duke is also developing methods to prepare mesoporous carbon using inorganic/organic templates and advanced chemical vapor deposition techniques. This enables us to prepare mesoporous carbon materials with controlled pore sizes and in large quantity. Such materials will be studied for their hydrogen uptake and be compared to other carbon materials like nanotubes. Both bare carbon materials and metal nanoparticle-decorated materials will be studied within the center. Duke is developing unique metal loading processes that enable integration of angstrom-size metal particles with SWNTs and mesoporous carbon materials.

Partner FY 2006 Results

1. We discovered that the diameters of SWNTs grown can be controlled by controlling the carbon feeding rate even when highly polydispersed nanoparticles are used as catalysts (Figure 1). Additionally, understanding of the important role of the carbon feeding rate can help explain the cause of the low growth efficiency in most chemical vapor deposition (CVD) processes. It would also help us to design methods to improve the growth efficiency of the CVD growth of small diameter carbon nanotubes.
2. A novel method to load nanosized nanoparticles on purified carbon nanotubes was developed. The method used nanotubes as the nucleation sites for the in situ formation of metal nanoparticles (Figure 2). By controlling the concentration of metal slat in the suspension of nanotubes, the size of the metal nanoparticles can be controlled. Several samples of purified carbon nanotubes (CNTs) and CNTs decorated with Pt nanoparticles at different concentrations were shipped to NREL for hydrogen uptake measurement. The measurements showed similar H_2 uptake at both liquid nitrogen temperature and room temperature on the Pt/CNT samples. If the hydrogen uptake were due to pure physisorption, then we would expect a significant decrease from 77 K to room temperature. Thus, the measurement results may be explained by a "spillover" effect occurring where dihydrogen is dissociated by the Pt catalyst and atomic hydrogen is migrating onto the SWNT receptor material.
3. Several methods were developed to prepare mesoporous carbon with high surface areas.

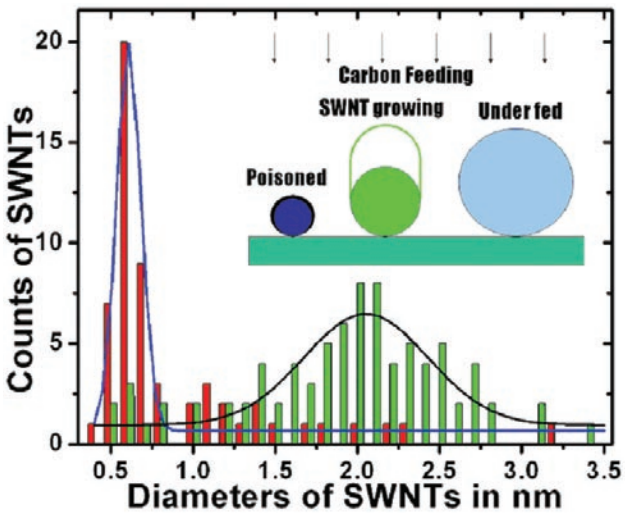

FIGURE 1. Diameter Distribution of SWNTs Grown Under Low (red) and High (green) Carbon Feeding Rate

The methods use both inorganic and organic templates to control the porosity and the pore size.

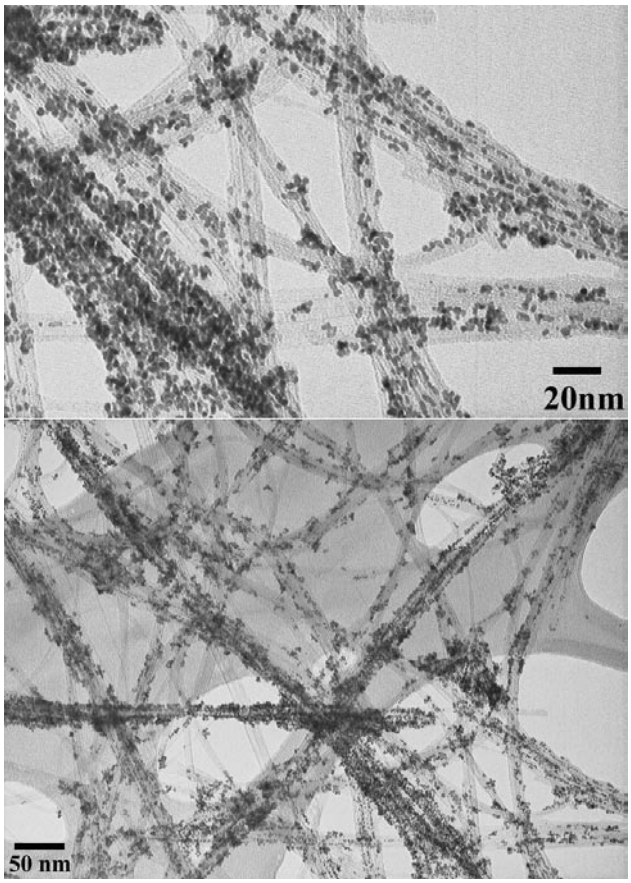

FIGURE 2. TEM Image of Nanotubes Decorated with Pt Nanoparticles

Partner FY 2007 Plans

1. Bulk synthesis of small diameter SWNTs. We plan to extend our understanding of the diameter control of nanotubes to bulk synthesis and make gram quantity small diameter nanotubes to study their hydrogen uptake. We are planning to demonstrate that small diameter CNTs can satisfy the DOE 2010 goal for hydrogen storage.
2. Diameter control in mesoporous carbon materials. Prepare mesoporous carbon materials with controlled pore size and volume. Perform detailed analysis and measurements on the hydrogen storage properties. Demonstrate that the material's storage capacity exceeds the DOE goal of 6 wt%.
3. Study the effect of metal loading on hydrogen storage capacity. Study the effect of metal decoration of carbon materials on hydrogen storage capacity. Provide more samples with different metals (Pt and Pd) and different loading percentage (1% to 10%) for measurement of storage capacity. Demonstrate the metal decorated carbon materials can be used to meet DOE 2010 requirements.

Duke FY 2006 Publications/Presentations

1. "Controlling the Diameter of Carbon Nanotubes in Chemical Vapor Deposition Method by Carbon Feeding", Chenguang Lu, Jie Liu. Submitted to Journal of Physical Chemistry B.

2. "Single Walled Carbon Nanotubes: from Synthesis to Devices" Jie Liu, Nanocience Workshop at University of Arkansas-Little Rock, May 1-2, 2006, Little Rock, AR.

3. "Understanding the Relationship between the Growth Conditions and the Diameter of Single Walled Carbon Nanotubes", J. Liu and C. Lu , 209th ECS Meeting, May 7–May 12, 2006, Denver, Colorado.