Web Coating Catalysts for Carbon Nanotubes

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This study demonstrates vacuum web coating as a viable process to make catalysts for large-scale production of CNTs. This presentation also provides an overview of current nanotube technology, with a special focus on synthesis.

CNTs have remarkable physical and chemical properties that render them appealing for use in many applications ranging from energy storage, nanoscale electronics, nanomechanical devices, and high-strength, light-weight composite materials.[1] CNTs comprise one or more graphene sheets rolled into cylinders with nanometer diameters and micrometer lengths. The number of cylinders varies from one CNT (single-walled) to more than fifty cylinders nested within one another (multi-walled). CNTs are unique structures that provide very large surface areas, high mechanical strength, and novel electrical properties. Depending only on their diameter and chirality, CNTs are either electrically semiconducting or metallic.[2] Their large aspect ratios make CNTs behave as nearly ideal 1D quantum wires. Moreover, CNTs have very large Young modulus in their axial direction.

The three most common methods to produce CNTs are arc discharge, laser ablation and chemical vapor deposition (CVD).[3] In arc discharge, a vapor is created by an arc discharge between two carbon electrodes. In the laser ablation technique, a high-power laser beam impinges on a volume of carbon feedstock gas. CVD synthesis involves carbon vapor phase and an energy source to "crack" the molecule into reactive carbon atoms. Several CVD techniques exist including thermal CVD, plasma enhanced CVD, laser assisted CVD, High pressure CO (carbon monoxide) disproportionation process (HiPco), and CoMoCAT processes. One common denominator between all of these methods is metal catalyst particles on which the precursor to CNT are formed. While the exact growth mechanism of CNTs is still under debate, it is widely recognized that metal catalyst particles play a vital role.

A major challenge facing carbon nanotube technologies and industries is the ability to produce large amounts of CNTs. CNTs are presently produced on small scales at high costs. Economically feasible large-scale production techniques still have to be developed. In general, CVD methods are easiest to scale up and favor commercial production. For successful commercialization, the ability to produce catalysts necessary for CNT synthesis is critical. This presentation examines vacuum web coating as a viable process to make catalysts for large-scale production of CNTs. The production of catalytic platelets with micron lateral dimension and precisely controlled nanomeric thickness and the production of rolls of thin film catalysts for CNT synthesis will be discussed. More specifically, we utilize roll-to-roll vacuum coating technology to produce catalytic nanoplatelets substrates and hot filament CVD is utilized to grow CNTs from the nanoplatelets.[4] This novel method of producing CNTs has the following key advantages that are of scientific and commercial interest: 1) it is a robust and scalable method capable of producing large volume of CNTs, 2) it minimizes cost and amount of substrate materials used, 3) it has remarkably high CNT yields, 4) it produces high-aspect ratio (long) CNTs, and 5) the produced form of material limits post processing.

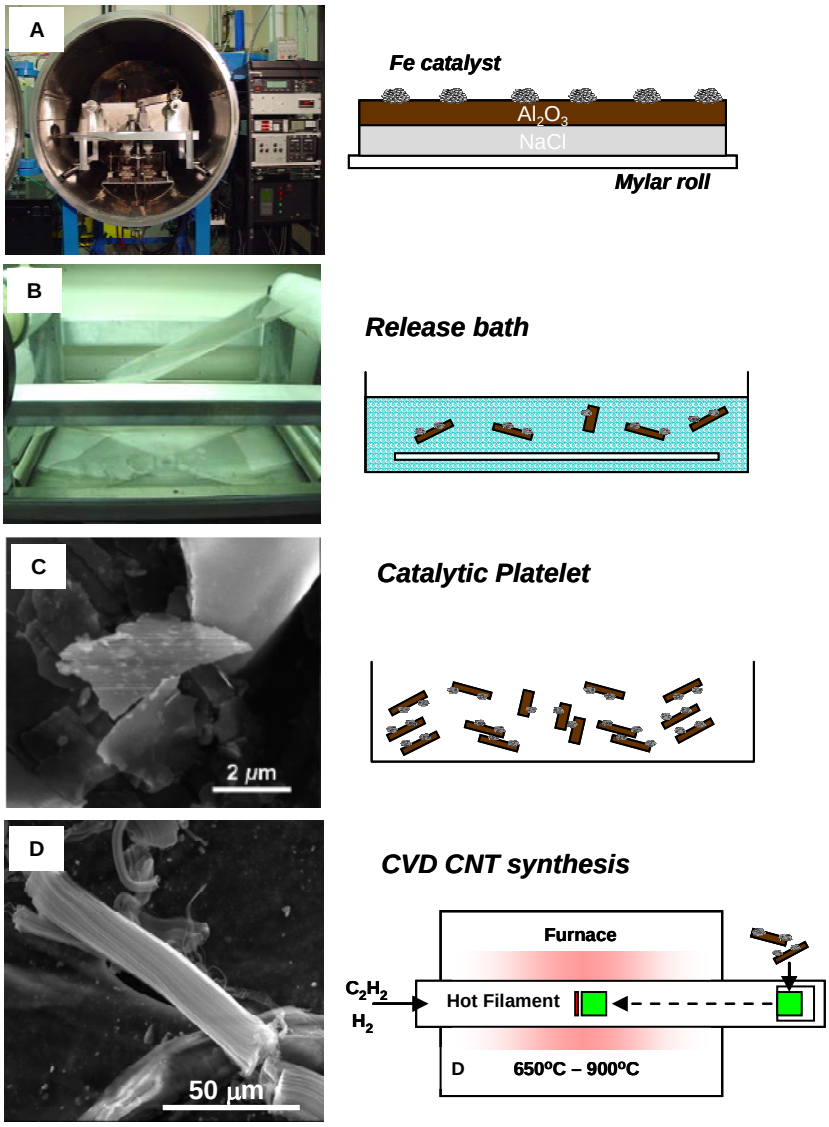

Figure 1. Process by which catalytic platelet substrates for CNT synthesis are produced. A) Photograph of vacuum roll coater and diagram of multilayer thin films deposited on moveable substrate, B) photograph and diagram of release process for comminuting catalytic nanoplatelets, C) scanning electron micrograph (SEM) and diagram of resulting catalytic nanoplatelets, and D) SEM of CNT grown on catalytic nanoplatelets and diagram of associated hot filament CVD process. The CVD synthesis of CNTs was performed at Rice University by the Robert Hague group.

1. Baughman, R. H. et al. *Science* **2002**, *297*, 787-792.
2. Odom, T. W. et al. *J. Phys. Chem. B* **2000**, *104*, 2794-2809.
3. Baddour, C. E. et al. *International Journal of Chemical Reactor Engineering* **2005,** *3*, R3.
4. Pint, C. L. et al. *Nano Letters* **2008**, *8*, p. 1879-1883.