Carbon Nanotube Growth Using Plasma Enhanced Chemical Vapor Deposition

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Carbon Nanotubes (CNT's) are nanoscale-diameter, cylindrical structures composed of carbon atoms in a hexagonal arrangement. They were discovered in 1991 by Japanese scientist Sumio Iijima. The unique properties of CNT's, such as tremendous strength and excellent thermal and electrical conductivity, have caused this material to become the focus of intense research by many groups.

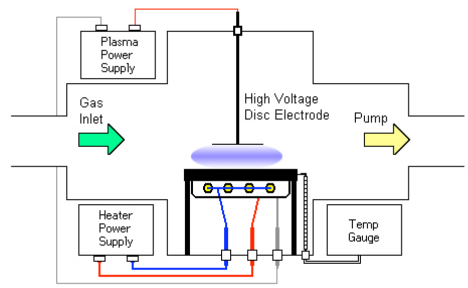

Fig.1: Schematic of PECVD reactor

Multiple techniques can be used for growing carbon nanotubes. Plasma-Enhanced Chemical Vapor Deposition (PECVD) is utilized since it allows the growth of oriented multi-wall CNT.

A cleaned substrate (primarily silicon) is coated with a metal that has been shown to act as a catalyst for CNT growth, such as Ni, Fe, Co, using various deposition methods (evaporation, sputtering, etc.). The coated samples are placed onto a heating plate in the center of the PECVD reactor (figure 1), which is then pumped down to a low base pressure (~1mTorr) to evacuate atmospheric gasses. Then the substrate is heated to a temperature shown to produce carbon nanotubes (450 to 700°C depending on process and chemistry).

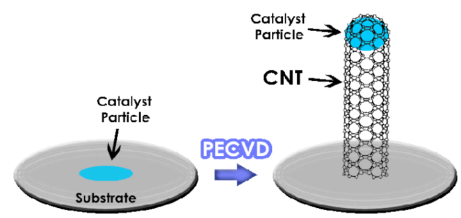

Fig. 2: Direct CNT growth from catalyst particle

The carbon-containing and reacting gases are introduced into the chamber through a network of mass flow controllers allowing to regulate the flow rate and gas composition of the mixture. A high voltage applied to the electrode above the sample causes an ionization of the gases, resulting in plasma formation. The energy from heating the substrate and from the high-voltage plasma causes decomposition of the gas into its components. The exact growth mechanism of CNT formation is not precisely known, however it is likley that carbon from the precursor gas dissolves in the catalyst until it is supersaturated, at which point the carbon is precipitated out of the catalyst in the form of a carbon nanotube (figure 2).

The PECVD method allows for independent control of growth parameters to influence growth rate and diameter. The two most important features of this technique are catalyst dependency and applied electric field. Patterning the catalyst using standard techniques permits control of growth location. The electric field orientation affects carbon nanotube growth alignment and produces CNT's that are straight and perpendicular to the surface.