In the Name of God

The Wondrous World of Carbon Nanotubes

‘a review of current carbon nanotube technologies’

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Chemical vapour deposition

- Chemical vapour deposition (CVD) synthesis is achieved by putting a carbon source in the gas phase and using an energy source, such as a plasma or a resistively heated coil, to transfer energy to a gaseous carbon molecule.
- Commonly used gaseous carbon sources include methane, carbon monoxide and acetylene.
- The energy source is used to "crack" the molecule into reactive atomic carbon. Then, the carbon diffuses towards the substrate, which is heated and coated with a catalyst (usually a first row transition metal such as Ni, Fe or Co) where it will bind.
- Carbon nanotubes will be formed if the proper parameters are maintained. Excellent alignment, as well as positional control on nanometre scale, can be achieved by using CVD. Control over the diameter, as well as the growth rate of the nanotubes can also be maintained. The appropriate metal catalyst can preferentially grow single rather than multi-walled nanotubes

Chemical vapour deposition

- CVD carbon nanotube synthesis is essentially a two-step process consisting of a catalyst preparation step followed by the actual synthesis of the nanotube.
- The catalyst is generally prepared by sputtering a transition metal onto a substrate and then using either chemical etching or thermal annealing to induce catalyst particle nucleation. Thermal annealing results in cluster formation on the substrate, from which the nanotubes will grow.
- The temperatures for the synthesis of nanotubes by CVD are generally within the 650–900 ^{o}C range.
- Typical yields for CVD are approximately 30%.

Different techniques for the carbon nanotubes synthesis with CVD

- Plasma enhanced chemical vapour deposition
- Thermal chemical vapour deposition
- Alcohol catalytic chemical vapour deposition
- Vapour phase growth
- Aero gel-supported chemical vapour deposition
- Laser-assisted thermal chemical vapour deposition
- CoMoCat process
- High pressure CO disproportionation process

Plasma enhanced chemical vapour deposition

- The plasma enhanced CVD method generates a glow discharge in a chamber or a reaction furnace by a high frequency voltage applied to both electrodes.
- Figure 2-13 shows a schematic diagram of a typical plasma CVD apparatus with a parallel plate electrode structure.
- A substrate is placed on the grounded electrode. In order to form a uniform film, the reaction gas is supplied from the opposite plate.
- Catalytic metal, such as Fe, Ni and Co are used on for example a Si, SiO_2, or glass substrate using thermal CVD or sputtering.
- After nanoscopic fine metal particles are formed, carbon nanotubes will be grown on the metal particles on the substrate by glow discharge generated from high frequency power.
- A carbon containing reaction gas, such as C_2H_2, CH_4, C_2H_4, C_2H_6, CO is supplied to the chamber during the discharge.

Plasma enhanced chemical vapour deposition

- The catalyst has a strong effect on the nanotube diameter, growth rate, wall thickness, morphology and microstructure. Ni seems to be the most suitable pure-metal catalyst for the growth of aligned multi walled carbon nanotubes (MWNTs). The diameter of the MWNTs is approximately 15 nm.
- The highest yield of carbon nanotubes achieved was about 50% and was obtained at relatively low temperatures (below 330^{o} C).

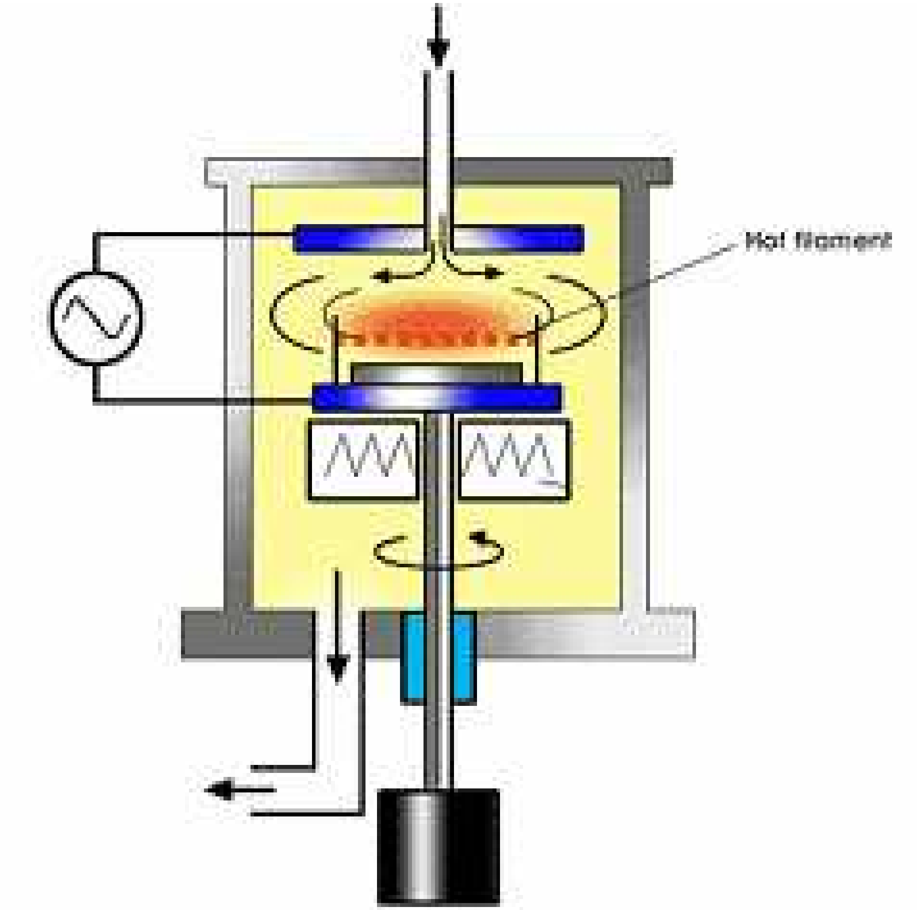

Figure 2-13: Schematic diagram of plasma CVD apparatus.