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CARBON NANOTUBE-A NOVEL MATERIAL

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ABSTRACT

The materials having the dimensions of 1nm to 100 nm are termed as nanomaterials. Most of the nanomaterials are derived from carbon, diamond and graphite which are the allotropes of carbon. Naturally occurring diamond is the hardest carbon material and hence it is used to manufacture microchip and in industry for cutting, grinding, drilling and polishing.

Now a day, carbon nano tubes can be synthesised by Arc discharge, Laser ablation and Chemical vapour deposition. Because of their outstanding unique physical properties like electrical conductivity, thermal conductivity and expansion, mechanical properties etc. carbon nanotubes find wide application in the field of science, technology and life science. In pharmacy and medicine they are used for gene delivery to cells or organs, for selective cancer cell destruction and in the industry for increasing the strength of plastics and as catalysts for some chemical reactions. Also they are used to protect the objects from fire.

Keywords: Carbon Nanotube (CNT), Allotropes, Gene, Cancer Cells, Catalyst, Mechanical Properties.

I. INTRODUCTION

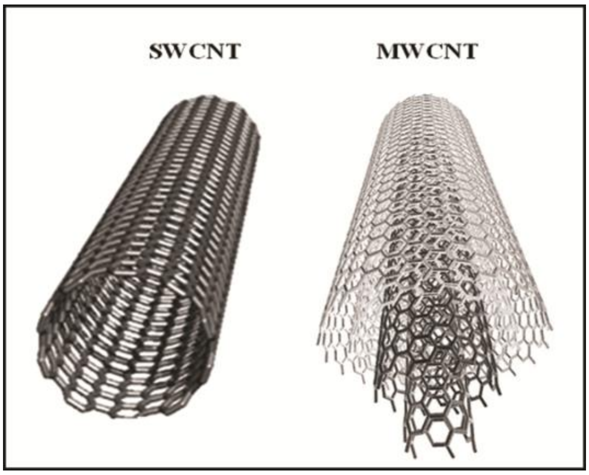
Most of the nanomaterials are derived from Carbon. The wordCarbon is taken from the Latinword 'carbo' which means coal. It is a chemical element with symbol 'C'. It has atomic number 6. Carbon is the 15^{th} largest element in the earth crust and 4^{th} largest element in the universe, after hydrogen, helium and oxygen. Carbon atoms are bounded in different ways known as allotropes of carbon such as graphite and diamond.

Allotropes of Carbon are the crystalline forms of a chemical element such as diamond and graphite. Due to its valancy, it forms many allotropes.Diamond is the allotrope of carbon. It is the hardest natural mineral. It is the semi-conductor which is used to manufacture microchip. It is used in the industry for cutting, grinding, drilling and polishing. Graphite is one of the most common allotropes of carbon. In 1789, Abraham Gottlob Werner coined the word graphite. Graphite conducts electricity due to delocalization of Π-bond electrons. It is used as dry lubricant. A single layer of graphite is known as graphene.

Fullereneis an allotrope of carbon whichis having hollow sphere ellipsoid tube structure. It is the hollow cage of sixty or more atoms. Spherical fullerenes are also called as buckminsterfullerene(buckyballs). Cylindrical shaped buckyballs are also known as CNT's or buckytubes.

CNT is a cylindrical shaped material made up of carbon having a diameter measuring on a nanometer scale. CNT are unique because, the bonding between the atoms is very strong and the tubes can have extreme ratio i.e., length to diameter upto132,000,000:1. Their name is derived from their long, hollow structure with the walls formed by one atom thick sheet of carbon called graphene.

CNT are categorized into SWNT andMWNT. Naturally they align themselves into ropes, held together by Van der Waals forces.



Schematic Diagram of Carbon Nanotubes

II. SYNTHESIS OF CARBON NANO TUBE (CNT)

2.1 Arc discharge method [1], [2]
2.2 Laser ablation process [3],[4]
2.3 Chemical Vapor Deposition [2]

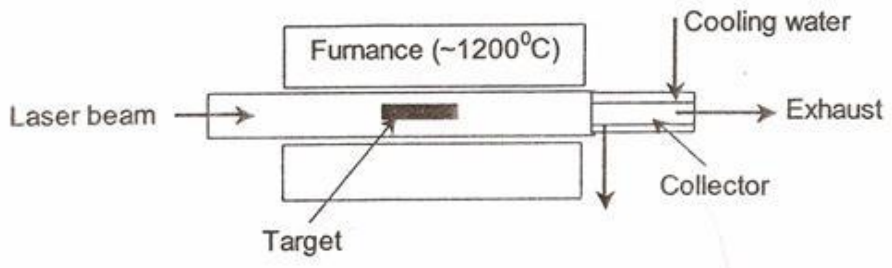
2.1 Arc Discharge Method

Arc discharge method was the first and most common method to produce CNT. This method is helpful in separating the CNT's from soot and catalytic metal. CNT's are produced by placing two carbon rods from end to end having the distance of 1mm. On applying direct current of 50-100A high temperature discharge between the electrodes takes place and finally forms a rod shaped electrode. Arc discharge method with liquid nitrogen produces CNT's.

MWNT synthesisby arc discharge method was first achieved by Ebbesen and Ajayan in 1992. SWNT synthesis by arc discharge method was achieved by Bethune and coworkers in 1993.

2.2 Laser Ablation Process

Laser ablation process was first discovered by Smally and his co-workers at Rice Universityin 1995. The experimental arrangement for synthesis of CNT is done by using quartz tube which contain argon gas and graphite target. A tube is placed in the centre of horizontal furnace and the temperature is maintained at 1200ºC .A water cooled copper collector is placed within the tube at one of its ends to collect the nano tube. The graphite target contain small amount of nickel and cobalt that act as catalyst in nucleation sites for the formation of nanotubes.



. Fig. . Schematic of laser ablation method

In the laser ablation process, a pulsed laser is made to strike at graphite target in a high temperature in presence of inert gas such as argon that sweeps the carbon atom to the colder copper collector on which they condense into nanotube. Tubes may be of 10-20nm in diameter and 100µm long can be made by this laser ablation method.

2.3Chemical Vapour Deposition(CVD)

CVD is the term used to describe heterogeneous reaction in which both solid and volatile products are formed. This method involves the decomposition of gaseous or volatile compound of carbon. This method is usually used in industries and it has become most important commercial method for SWNT production. Synthesis of both SWNT and MWNT has been well developed using CVD. They allow more control over morphology and structure of the produced nanotubes. One can produce well separated individual nanotubes either supported on flat substrate or suspended across trenches.This method involves decomposition of hydrocarbon gas such as Methane (CH_4) at 1100ºC. Methane CVD was first developed by Dai's group at Stanford.

III. PROPERTIES OF CARBON NANOTUBE(CNT)

3.1 Electrical conductivity[1],[4]
3.2 Thermal conductivity and expansion [1]
3.3 Mechanical properties[4]
3.4 Strength and elasticity[1]
3.5 Vibrational property of [4]

3.1 Electrical Conductivity of CNT

CNT are very good conductors of heat. The thermal conductivity is almost twice as large as that of diamond. It can be considered that CNT is either metallic or semiconducting in their electrical behaviour. Some types of armchair structured CNT's appear to conduct better than other metallic CNT. The electrical conductivity in MWNT is complex because of their inter-wall interactions and non-uniformly redistributed current over individual. Where as in SWNT they are uniformly distributed. But individual SWNT may contain defect i.e., SWNT behaves as transistors. The electronic structure of CNT is studied using scanning tunnelling microscopy (STM).

3.2 Thermal Conductivity and Expansion

CNT may be the best heat conducting material. Heat conducts in the host of the device and material. SWNT exhibit super conductivity below 20K. The strong in-plane carbon – carbon bond of graphene provides the exceptional strength and stiffness against axial strains and zero in-plane thermal expansion shows high flexibility against non-axial strains.

3.3 Mechanical Properties of CNT

CNT's are very strong. The Young's modulus of CNT is stronger than that of Young's modulus of steal. CNT have low density of defects in structure of their walls. So, even if they are bent they bend like straws but do not break. MWNT have improved mechanical properties but they are not as good as SWNT.

3.4 Strength and Elasticity of CNT

CNTs are high strength fibres. Especially single walled nanotube is stiffer than any other metal and has high resistance power. Each carbon atom of a single sheet of graphite forms a planar six member lattice which is connected through strong chemical bond to three neighbouring atoms. On applying the force to the tip of the nanotubes it will bend without causing any damage. When the force is removed, it returns to its original state. This property of nanotube is called as elastic property of CNT and this is useful in scanning probe microscopy (SPM).

3.5 Vibrational Property of CNT

The frequency of the two modes namely A_{1g} mode and E_{2g} mode are Raman-active and depend on the radius of the tubes.A_{1g} mode involves an 'in and out' oscillations of the radius of the tube. E_{2g} involves a squashing of the tube where it squeezes in one direction and expands in another direction oscillating between sphere and ellipse.

IV. PURIFICATION

Purification of CNT is a process that separates CNT from non-nano tube impurities in the raw products. Impurities generally include amorphous carbon, catalysts, catalyst supports, carbon nanotubes and unwanted nanotubes. Smaller chemical substances can be purified by using 2-3 molecules of nitric acid. This was first done by Wilson et al. in 2002. Generally, the purification can be done in three ways. [1], [2]

4.1 Gas phase [1]
4.2 Liquid phase [1]
4.3 Intercalation [1]

4.1 Gas phase

In 1996, Thomas Ebbesen and his co-workers successfully worked on this technique. This purification method uses oxidation process. In 2002, NASA Glenn Research Centre introduced a new gas-phase method for purification of SWNT in gram scale quantities. This method of purification uses combination of high temperature oxidation and repeat extraction with nitric and hydrochloric acid.

4.2 Liquid phase

In this method it removes the amorphous carbon without damaging the tube walls. It involves Preliminary filtration which is used to remove large graphite particles, Dissolution which is used to remove fullerene and catalyst particles, Microfiltration, Centrifugation separation and Chromatography. Therefore, it becomes very easy to separate CNT in chromatography.

4.3 Intercalation

In 1999, a research group introduced this method to purify CNT. This technique expands the Vander Waals gap between adjacent layers, which require energy. This energy is usually supplied by the charge transfer between the dopant and solid. It is used to insert a molecule into compounds with layered structure. [1], [2].

V. APPLICATIONS

CNT's not only have unique atomic arrangements but also with unique properties. Specially, in the field of science, technology and life science.

1. **In Pharmacy and Medicine:**
   CNT in pharmacy and medicine include drug, bio-molecule, gene delivery to cells or organs, tissue regeneration and bio sensor diagnostic and analysis.
2. **In Selective Cancer Cells Destruction:**
   CNT can be used as multifunctional biological transporters and near-infrared agents for selective cancer cell destruction.
3. **Mechanical Reinforcement:**
   CNT's are used to increase the strength of plastic composite.
4. **Catalysis:**
   CNT serve as catalysts for some chemical reaction.
5. **Fire protection:**
   Thin layers of buckysheet protect the object from fire.

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