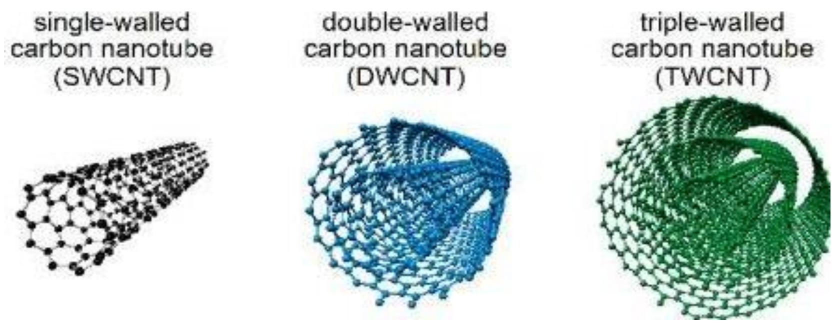
19CH201 – ENGINEERING CHEMISTRY FOR CIRCUIT BRANCHES

Unit-3 NANO CHEMISTRY

NANOTUBE (CNT)



Carbon nanotubes are allotropes of carbon with a nanostructure having a length- do-diameter ratio greater than 1,000,000. When graphite sheets are rolled into a cylinder, their edges joined and form carbon nanotubes i.e. carbon nanotubes are extended tubes of rolled graphite sheets.

Nanotubes naturally align themselves into 'ropes' held together by Vander waals forces. Each carbon atoms in the carbon nanotubes are linked by the covalent bond (sp^2 bond)

Structure (or) Types of carbon nanotubes

Carbon nanotubes are lattice of carbon atoms, in which each carbon is covalently bonded to three other carbon atoms.

Depending upon the way in which graphite sheets are rolled, two types of CNTs are formed.

(i) Single-walled nanotubes (SWNTs)
(ii) Multi-walled nanotubes (MWNTs)

(i) Single-walled nanotubes (SWNTs)

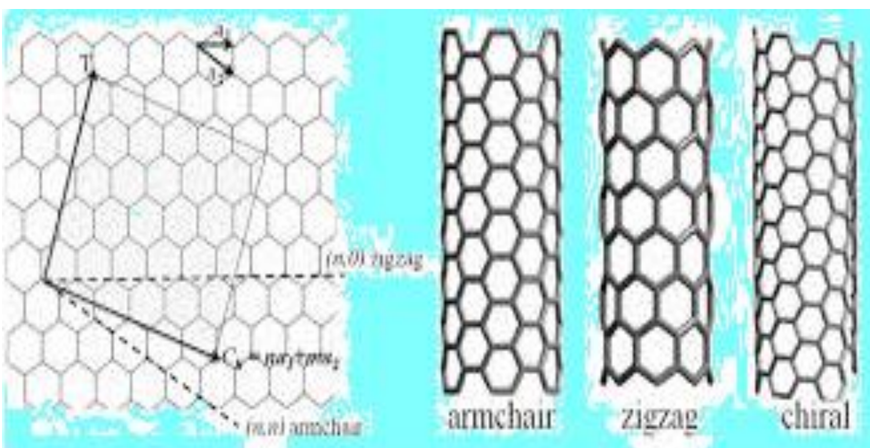
SWNTs consist of one tube of graphite. It is one atom hick having a diameter of 2 nm and a length of 100µm. SWNTs are very important, because they exhibit important electrical properties. It is an excellent conductor.

Three kinds of nanotubes are resulted, based on the orientation of the hexagon lattice.

(a) Armchair structures : The lines of hexagons are parallel to the axis of the nanotube.

(b) Zig-zag structures : The lines of carbon bonds are down the centre.

(c) Chiral nanotubes : It exhibits twist or spiral around the nanotubes.

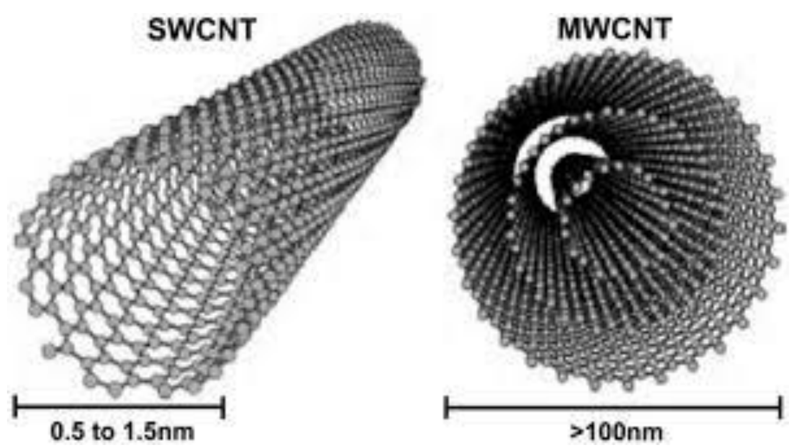


Structure of single walled carbon nanotubes

It has been confirmed that armchair carbon nanotubes are metallic while zig-zag and chiral nanotubes are semiconducting.

(ii) Multi-walled nanotubes (MWNTs)

Multi-walled nanotubes (MWNT) consist of multiple layers of graphite rolled in on themselves to form a tube shape. In the Russian Doll Model, sheets of graphite are arranged in concentric cylinders, example a(0,8) single-walled nanotube. In the parchment model, a single sheet of graphite is rolled in around itself, resembling a rolled up newspaper. DWNT are resistance to chemicals and synthesis on the gram-scale by reduction of oxides solid solutions in methane and hydrogen.



Single walled and Multiwalled carbon nanotubes

Synthesis of carbon nanotubes

Carbon nanotubes can be synthesized by any one of the following methods. (i) Pyrolysis of hydrocarbons
(ii) Laser evaporation
(iii) Carbon arc method

(iii) Chemical vapour deposition

(i) Pyrolysis

Carbon nanotubes are synthesized by the pyrolysis of hydrocarbons such as acetylene at about 700^{O}C in the presence of Fe-Silica or Fe-graphite catalyst under inert conditions.

(ii) Laser evaporation

It involves vapourization of graphite target, containing, small amount of cobalt and nickel, by exposing it to an intense pulsed laser beam at higher temperature (1200^{O}C) in a quartz tube reactor. An inert gas such as argon is simultaneously
allowed to pass into the reactor to sweep the evaporated carbon atoms from the furnace to the colder copper collector, on which they condense as carbon nanotube.

(iii) Carbon arc method

It is carried out by applying direct current (60 – 100 A and 20 – 25 V) arc between graphite electrodes of 10 – 20 m diameter.

(iv) Chemical vapour deposition

It involves decomposition of vapour of hydrocarbons such as methane, acetylene, ethylenes, etc. at high temperatures (1100^{O}C) in presence of metal nanoparticle catalyst like nickel, cobalt, iron supported on MgO or Al_2O_3.
Carbon atoms produced by the decomposition condense on a cooler surface of the
catalyst.

Properties of carbon nanotubes

(i) Kinetic properties

Multi-walled nanotubes, exhibit a striking telescoping property whereby an inner nanotube core may slide, almost without friction, within its outer nanotube shell thus creating an atomically perfect linear or rotational bearing.

(ii) Electrical properties

The electrical properties of CNTs vary between metallic to semiconducting materials. It depends on the diameter and chirality of the nanotubes. The very high electrical conductivity of CNT is due to the minimum defects in the structure.

(iii) Thermal conductivity

The thermal conductivity of CNT is very high, this is due to the vibration of covalent bonds. Its thermal conductivity is 10 times greater than the metal. The high thermal conductivity is also due to minimum defects in the structure.

Applications of carbon nanotubes

Due to the unusual and unique properties of CNTs, they find potential in the following field.

1. CNTs in storage devices

Carbon nanotubes play an important role in the battery technology, because some charge carriers can be successfully stored inside the nanotubes.

Example :

(i) CNT in fuel cells : Hydrogen can be stored in the CNT, which may be used for the development of fuel cells.

(ii) CNT in Lithium battery : Lithium atoms as a very good charge carrier, can be stored inside the carbon nanotubes. It has been estimated that one Lithium atom can be stored for every six carbon atoms of the CNT and hence can be used in Lithium batteries.

2. CNT in catalysis

Carbon nanotubes serve as efficient catalysts for some chemical reaction.

Examples :

(i) Hydrogenation reaction

Nested carbon nanotubes with ruthenium (Ru) metal bonded to the outside have been proved to have a strong catalytic effect in the hydrogenation reaction of cinnamaldehyde when compared with the effect of the same metal Ru attached to other carbon substrates.

(b) Other chemical reactions

(i) Reduction of nickel oxide (NiO) to the base metal Ni.

(i) Reduction of $AlCl_3$ to its base metal.

(ii)

(iii) Cadmium sulfide crystals have been formed inside the carbon nanotubes by reacting cadmium oxide crystals with hydrogen sulfide gas at $400^{o}c$

(iv) A stream of H_2 gas at 475°C partially reduces MoO_3 to MoO_2 with the formation of steam (H_2O) inside the multiwalled nanotubes

3. Drug delivery vessels

CNTs can be effectively used inside the body for drug delivery by placing the drug with in the tubes.

4. Quantum wires

The quantum wires, made of metallic carbon nanotubes are found to have high electrical conductivity.

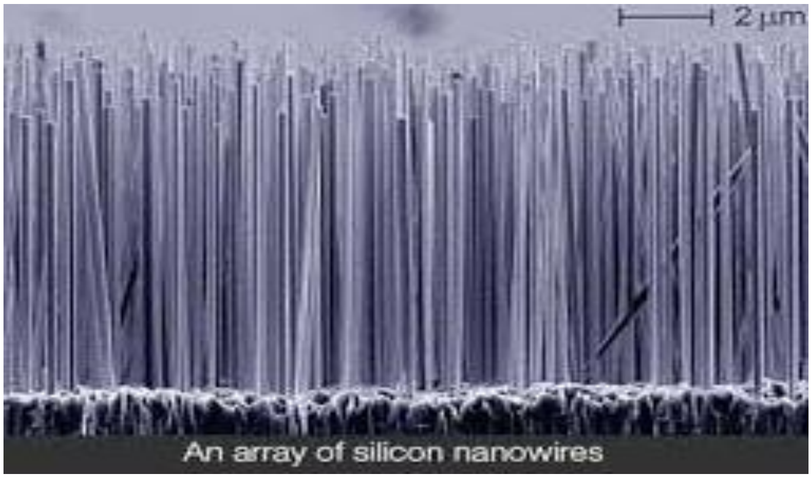
5. Cathode ray tubes

Carbon nanotubes, used as fine electron guns in cathode ray tubes in thin high-brightness – low-energy, low-weight displays are known as field emission displays (FEDs)

NANOWIRE

A nanowire is a nanostructure, with the diameter of the order of a nanometer (10^{-9} meters). Alternatively, it can be defined as structures that have a thickness or diameter constrained to tens of nanometers or less and an unconstrained length.

At these scales, quantum mechanical effects are important — which coined the term "quantum wires". Many different types of nanowires exist, including metallic (*e.g.*, Ni, Pt, Au), semiconducting (*e.g.*, Si, InP, GaN, etc.), and insulating (*e.g.*, SiO_2, TiO_2).



Nanowire

Molecular nanowires are composed of repeating molecular units either organic (*e.g.* DNA) or inorganic (*e.g.* $Mo_6S_{9-x}I_x$).

Characteristics of Nanowires

- Silicon nanowires exhibit strong photoluminescence characteristics.
- Nanowires are dimensional material.
- It shows distinct optical, chemical, thermal and electrical properties due to this large surface area.