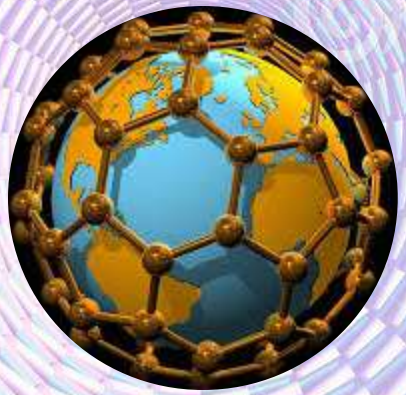
# CARBON NANO TUBES (CNT)



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# CARBON NANO TUBES (CNT)

❖The discovery of carbon nanotubes (CNT) in 1991 opened up a new era in materials science. These incredible structures have an array of fascinating electronic, magnetic and mechanical properties.

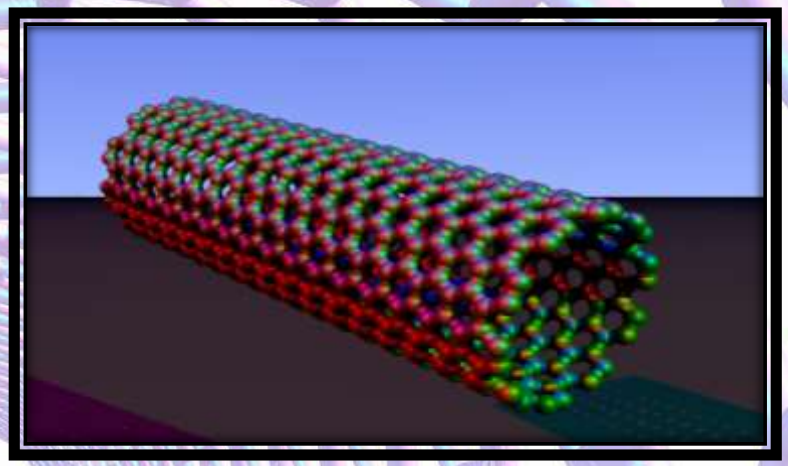
❖CNT are at least 100 times stronger than steel, but only one-sixth as heavy, so nanotube fibers could strengthen almost any material

❖A carbon nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale.

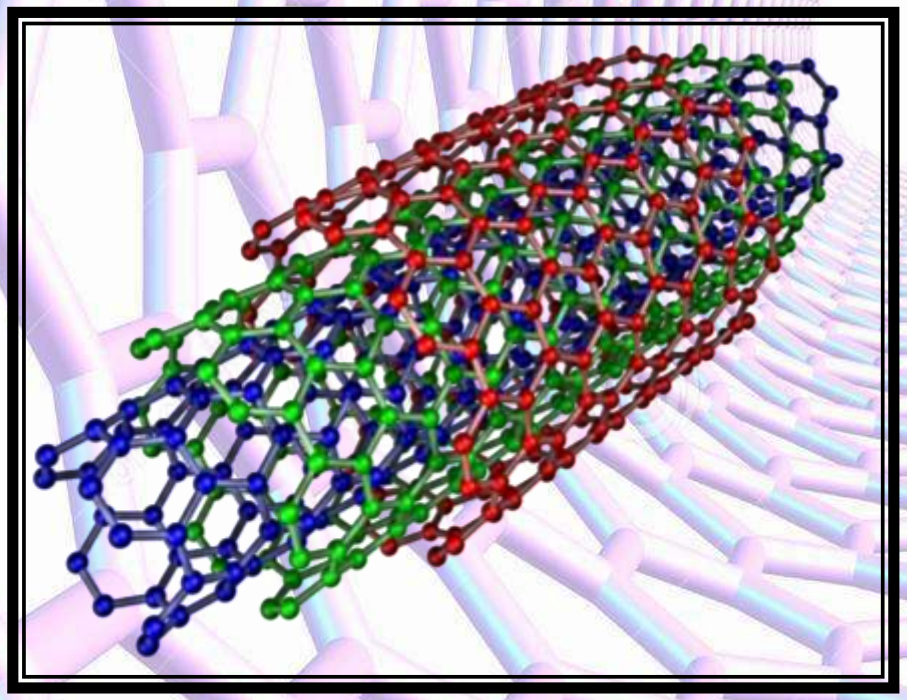
❖A carbon nanotube can be as thin as a few nanometers yet be as long as hundreds of microns. To put this into perspective, if your hair had the same aspect ratio, a single strand would be over 40 meters long

# TYPES OF CARBON NANO TUBES (CNT)

## Single-Walled Carbon Nano tubes



❖A single-walled carbon nanotube is just like a regular straw. It has only one layer, or wall



## Multi-walled carbon nanotubes

❖Multi-walled carbon nanotubes are a collection of nested tubes of continuously increasing diameters. They can range from one outer and one inner tube (a double-walled nanotube) to as many as 100 tubes (walls) or more. Each tube is held at a certain distance from either of its neighboring tubes by interatomic forces

# SYNTHESIS OF CARBON NANOTUBES

❖Various methods are available for the synthesis of carbon nanotubes as illustrated in Fig. Among these, the following three processes are widely used to synthesize CNTs:

- ❖Electric arc-discharge
- ❖Laser ablation
- ❖Chemical vapor deposition (CVD)

# PLASMA ARC-DISCHARGE METHOD (ELECTRIC- ARC DISCHARGE METHOD)

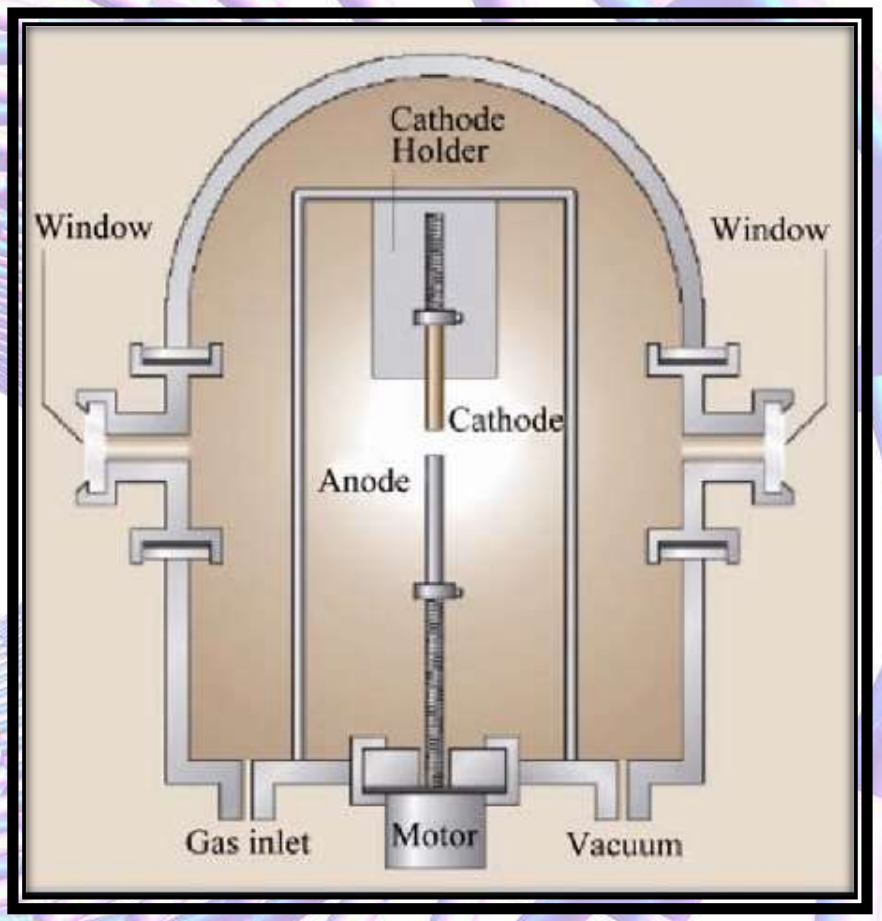
❖This is a simple method for the synthesis of both multi walled and single walled nanotubes.

❖The MWNTs were grown for the first time by Thomas Ebbesen and P. M. Ajayan at NEC Fundamental Research Laboratory, Tokyo, Japan in 1992 by employing the arc-discharge method.

❖Typical plasma arc-discharge (electric arc-discharge) equipment for the growth of CNTs consists of a vacuum chamber in which two graphite electrodes are mounted as shown in the Fig.

## Cont..,

- A high potential difference is applied between the two opposing graphite electrodes in aninert atmosphere such as helium.
- Due to the high conductivity of the plasma, an arc is generated between the closely spaced electrodes which produces heat inside the system.
- During the arc-discharge, the atoms evaporate from the anode and grow on the cathode in the form of nanotubes.



## *Cont..,*

❖For growing SWNTs, graphite electrodes are impregnated with metalcatalysts like Co, Cu, and Fe.

❖By suitably controlling the growth conditions like the arcing current and the pressure of inert gas inside the discharge chamber, MWNTs can be obtained.

❖The synthesized MWNTs have lengths of the order of ten microns and diameters in the range of 5-30 nm.

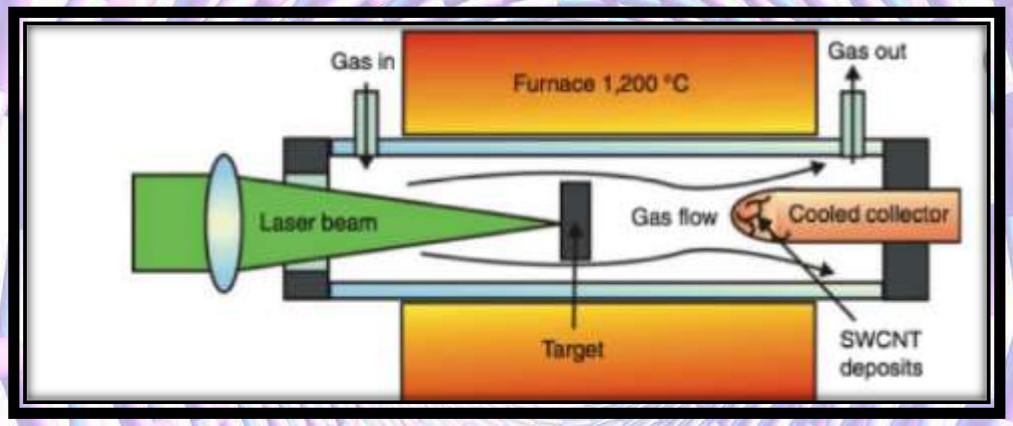
❖Boron and silicon nitride nanotubes can also be prepared by this method using elemental boron and silicon electrodes, respectiely.

# LASER-ABLATION TECHNIQUE

- In this technique, a graphite pellet is placed in the middle of a quartz tube filled with aninert gas (normally argon) and placed in an oven maintained at a temperature of 1200°C.
- The graphite pellet contains a small amount of catalytic materials like cobalt and nickel. They act as catalytic nucleation sites for the formation of the carbon nano tubes.
- A conical water-cooled copper collector is mounted at one end of the quartz tube. When an intense pulsed laser beam is allowed tobe incident uniformly on the surface of the pellet, the graphite is sublimated.

## Cont..,

❖ The argon gas inside the quartz tube then sweeps the sublimated carbon atoms from the high temperature region to the cold copper collector on which they condense in the form of nanotubes.




In this technique, the SWNTs are formed as ropelike crystallites, 5-20 nm in diameter and tens to hundreds of micrometers in length.

*Cont..,*

The major parameters that determine the amount of SWNTs produced are

- the amount and type of catalysts used
- power and wavelength of the laser employed
- process temperature
- type of inert gas present
- pressure inside the quartz tube and
- the fluid dynamics near the carbon target.

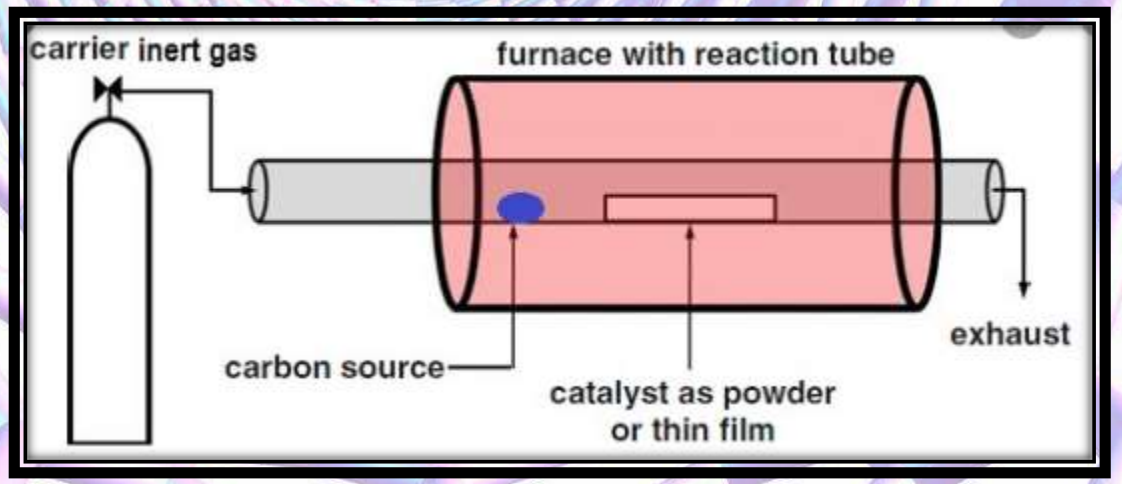
## LIMITATION

- When synthesizing SWNTs, fullerenes, graphitic polyhedrons, enclosed metal particlesand amorphous carbon are formed as byproducts.

# CHEMICAL VAPOUR DEPOSITION (CVD)

❖Chemical vapor deposition is a suitable method for large scale production of carbon nanotubes. A schematic diagram of chemical vapour deposition is shown in Fig.

❖In this method, a mixture of hydrocarbon gas (ethylene, methane or acetylene) and a process gas (ammonia, nitrogen, hydrogen) is made to react on the heated metal substrate kept at a temperature of around 700°C at atmospheric pressure in a reaction chamber.



## Cont..,

- Generally, silicon, glass and alumina are used as substrates. Porous silicon is an ideal substrate for growing self-oriented nanotubes on large surfaces.
- The substrate is covered by metal nanoparticles like Fe, Co and Ni which act as catalysts. During the decomposition of hydrocarbon gas, CNTs are formed and deposited on metal catalysts.
- The catalyst particles can stay at the bottom or top of growing carbon nanotubes. The catalyst used is one of the important factors that determine the type of carbon nanotubes formed.
- The diameter of the nanotubes depends on the particle size of the catalyst. This technique is capable of controlling growth directions on a substrate and synthesizing a large quantity of carbon nanotubes.

# CARBON NANOTUBE APPLICATIONS

- Micro- and nano-electronics
- Structural composite materials
- Flat-panel displays
- Conductive plastics
- Atomic Force Microscope (AFM) tips
- Ultra-capacitors
- Radar-absorbing coating
- Technical textiles
- Gas storage
- Power applications (e.g. batteries with improved lifetime, photovoltaic applications)
- Sensors and Biosensors
- Extra strong fibers

# SPECIFIC APPLICATIONS IN FUEL CELLS, CHEMICAL SENSORS AND CATALYSTS

## *Fuel cells*

- Because of their capillary effect, SWCNTs can be used to condense gases in high density inside them. Therefore, hydrogen ($H_2$) can be stored at high densities without being condensed into liquid. Potentially, this storage method could be used on vehicles in place of gas fuel tanks for hydrogen-powered cars.
- In this method, there is a loss of potential energy (25-45%) when compared to the energy associated with the gaseous state and hence storage efficiency is reduced. Storage of $H_2$ in gaseous state using SWCNTs increases the storage efficiency.

## Cont..,

## Chemical sensors

- Carboxyl-modified SWCNTs can act as sensors for detecting atoms and ions of alkali metals Na,Li and K.
- The CNTs integrated on silicon platform can be used as hydrogen sensors.
- The CNTs can also be used to sense carbon-di-oxide, nitrous oxide and glucose.

## Cont..,

## Catalysts

- The CNTs find potential applications in metal-free catalysis of organic and inorganic reactions.

- For example, oxygen groups attached to the surface of carbon nanotubes have the potential to catalyze oxidative dehydrogenations or selective oxidations.

- Nitrogen-doped nanotubes may replace platinum catalysts used to reduce oxygen in fuel cells. A forest of vertically aligned nanotubes can reduce oxygen in alkaline solution more effectively than platinum.

# LIMITATIONS OF CARBON NANOTUBES

- The CNTs exhibit lack of solubility in most solvents.
- The production of structurally and chemically reproducible batches of CNTs with identical characteristics is difficult.
- It is difficult to maintain high qualityand minimal impurity levels.


Thank you