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Subject : Physics

B.SC – Final Year Semester V
Paper – II :

UNIT - 3

Topic : Carbon Nanotubes.

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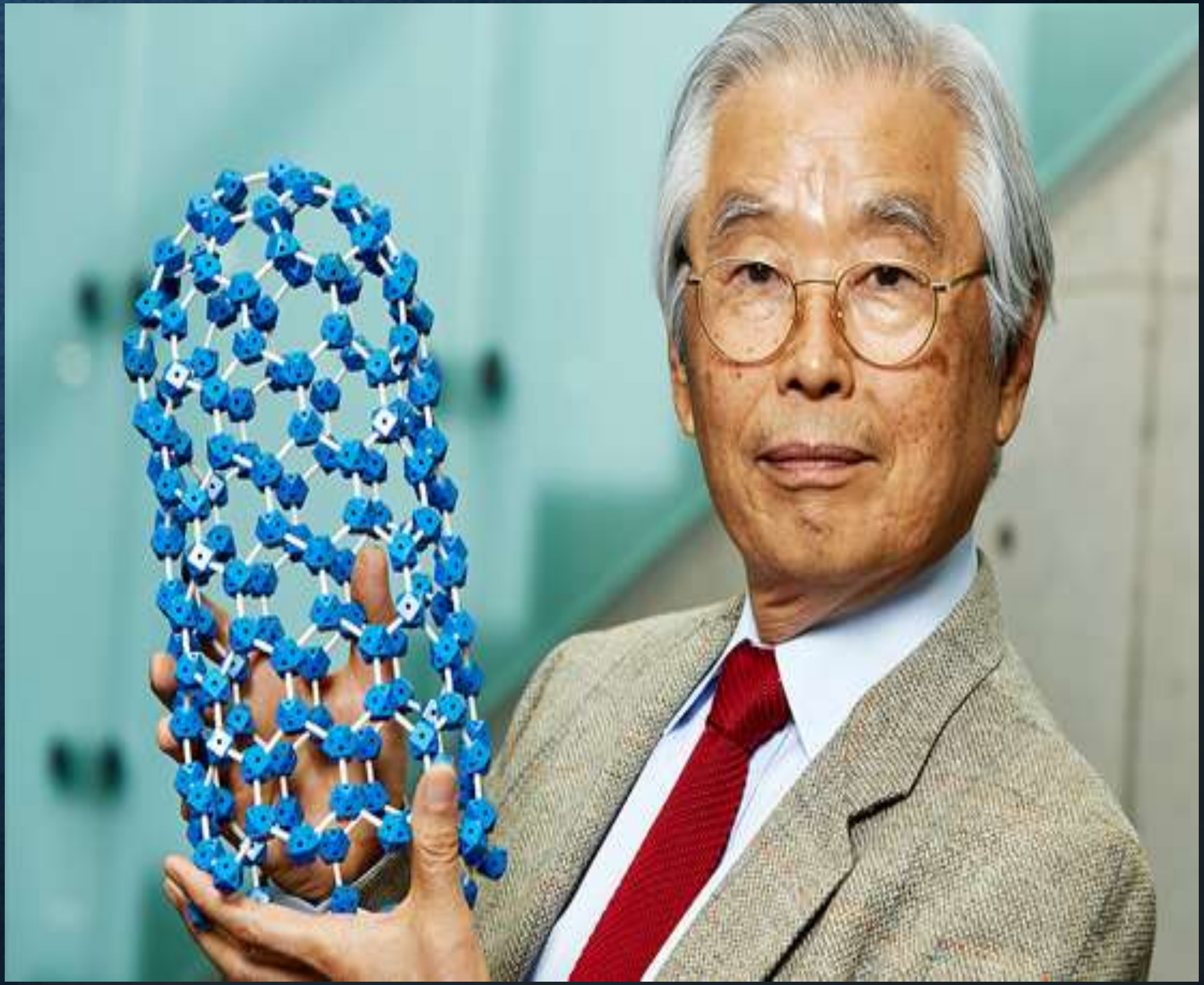
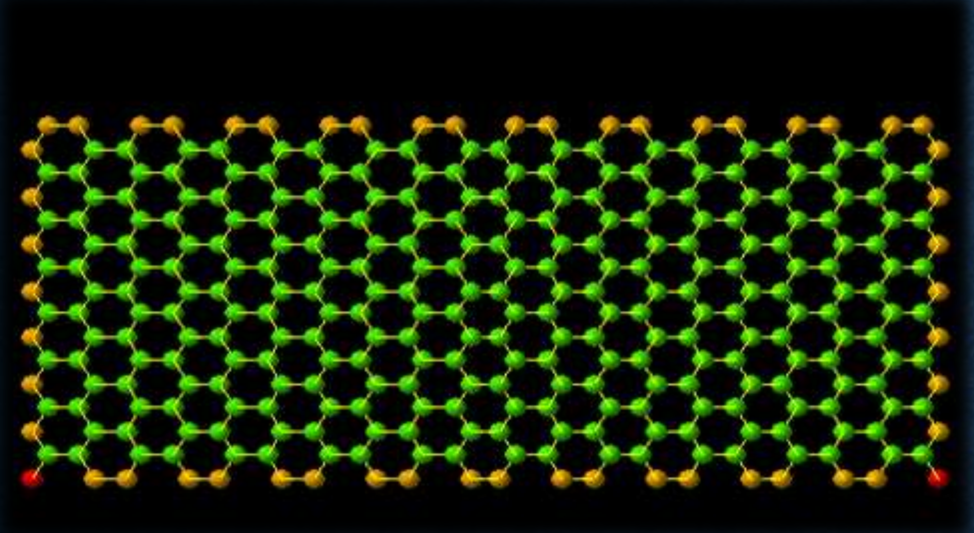
INTRODUCTION

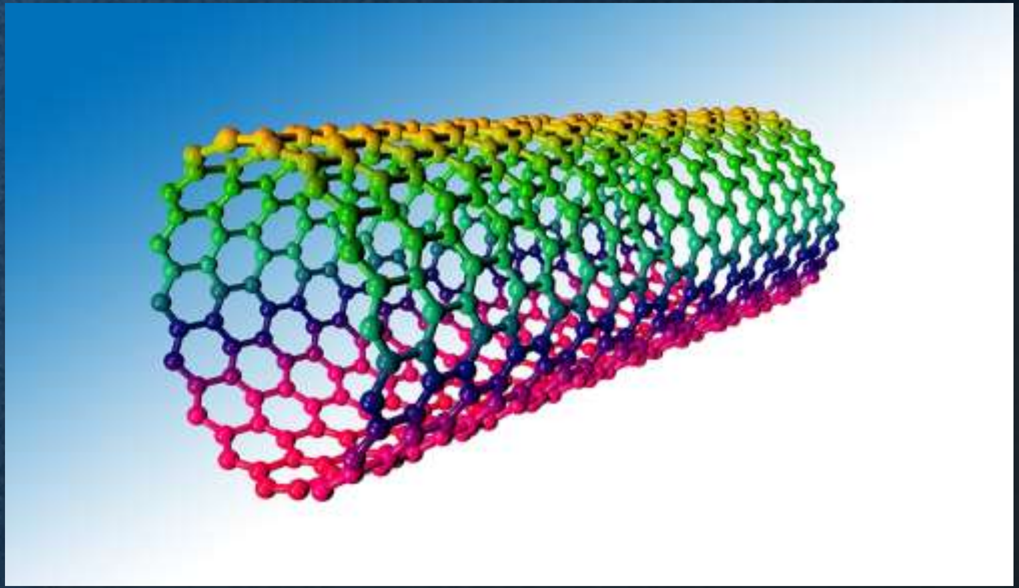
- In 1991 Sumio Lijima, a Japanese Physicist discovered one more allotrope of carbon named as Carbon Nanotube.

- Sumio Lijima is a Senior Research Fellow at NEC's Central Research Laboratories, who inspired the world with his discovery of new carbon nanotube materials.

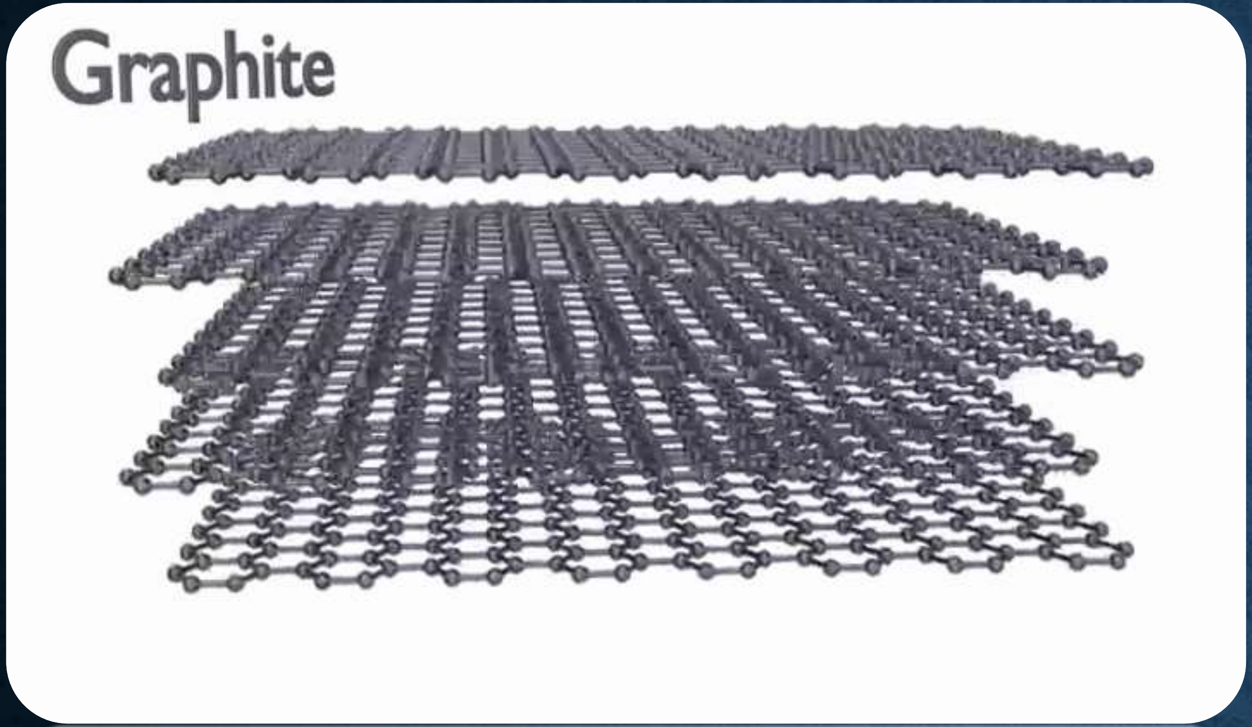


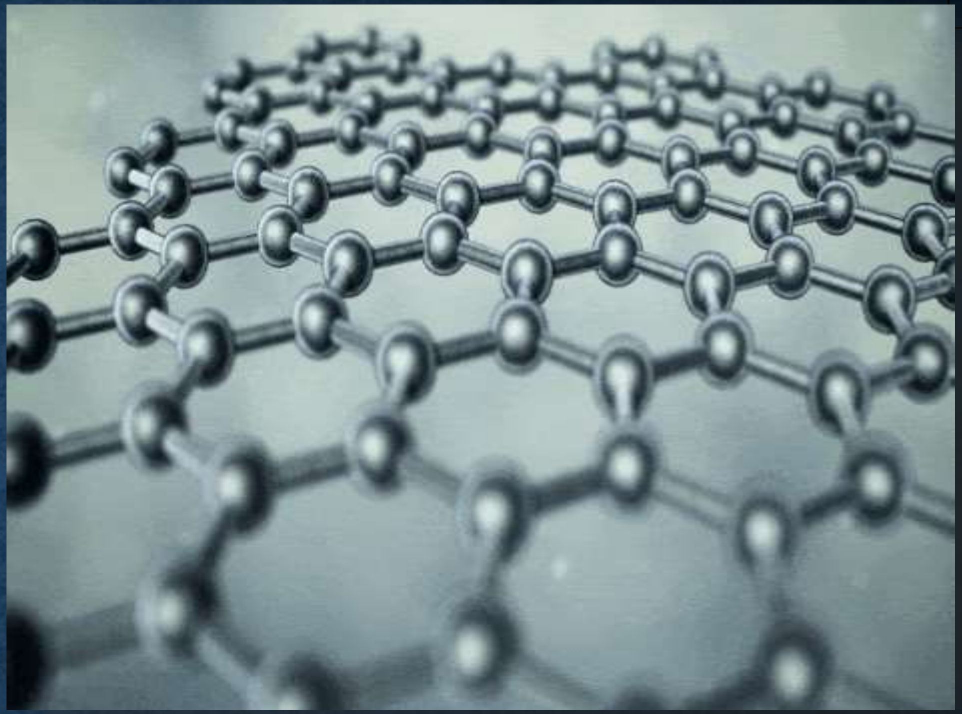
WHAT IS CARBON NANOTUBES?





"It can be described as a sheet of graphene rolled into a cylinder."



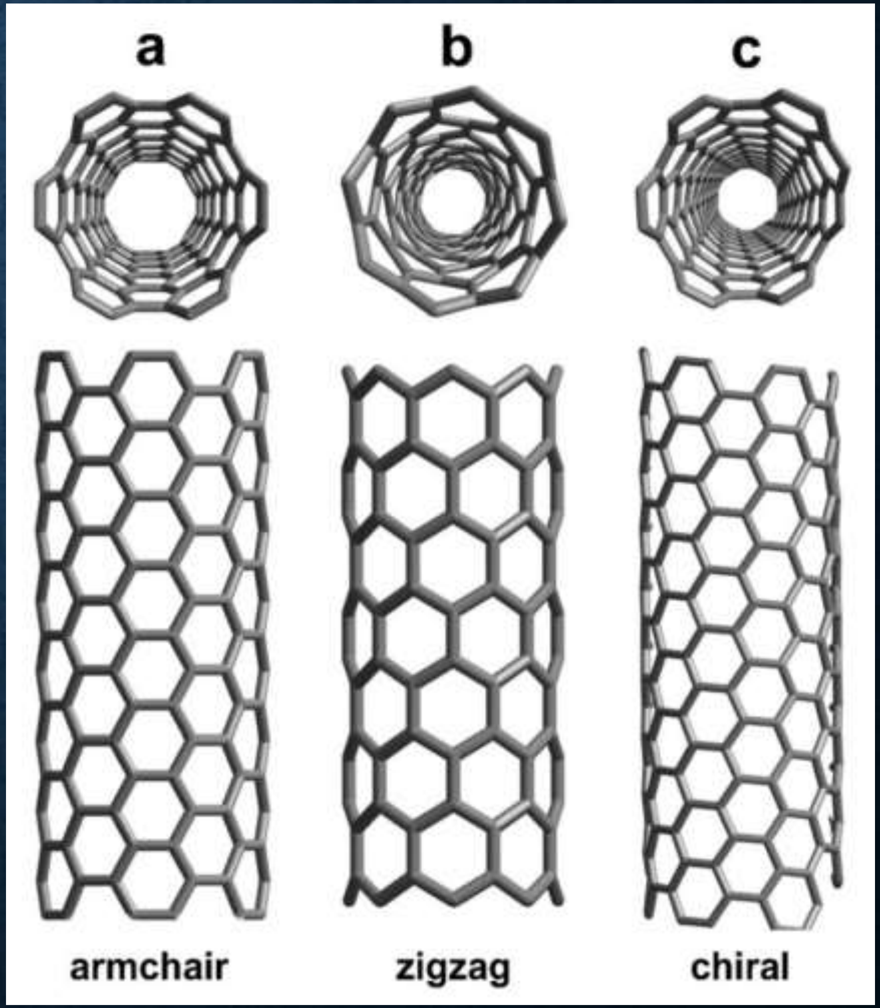


- **The worlds strongest known substance is graphene and it is mainly made up of hexagonal ring of carbon.**

CLASSIFICATION

- **Single Walled Carbon Nanotubes(*SWCNTs*):**

- This nanotubes are made of a single graphene sheet rolled upon itself with a diameter of 1-2 nm.
- Band gap: 0-2eV
- Single walled carbon nanotubes can be formed in three different designs: Armchair, Zigzag, and Chiral.
- The design depends on the way the graphene is wrapped into a cylinder.

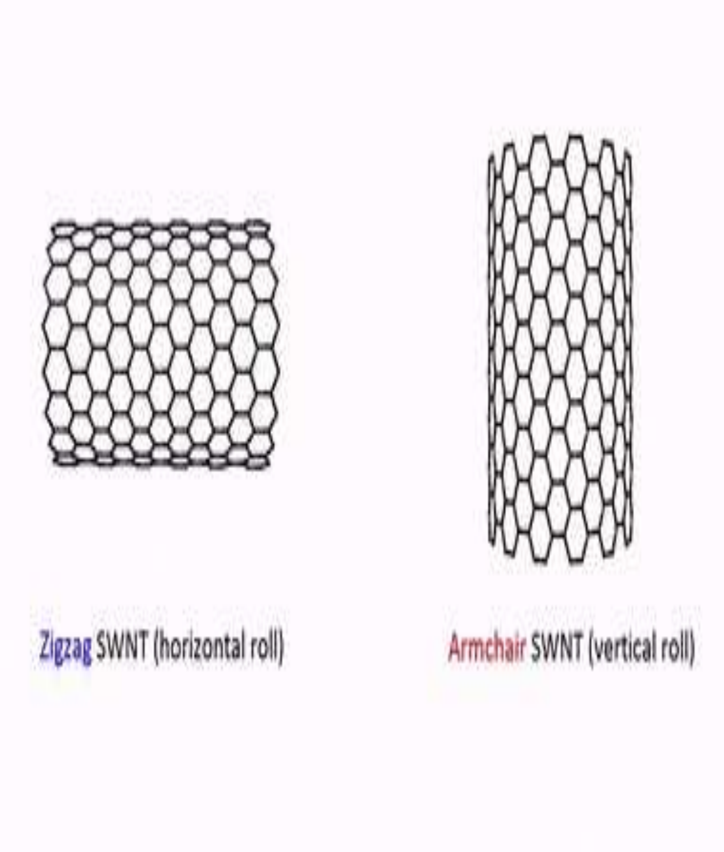


- Theoretical calculation of diameter of carbon nanotube expressed by,

$$\mathbf{D} = \mathbf{a}\sqrt{n^2 + m^2 + nm/\pi}$$

Where, $a = (3)^{\frac{1}{2}}d$ and $d = 0.142$ nm , and n and m are chiral indices.

- ❑ If m = 0 , the nanotubes ae called Zigzag nanotubes
- ❑ If n = m, the nanotubes are called Armchair nanotubes.
- ❑ Otherwise, they are called as Helical (Chiral).



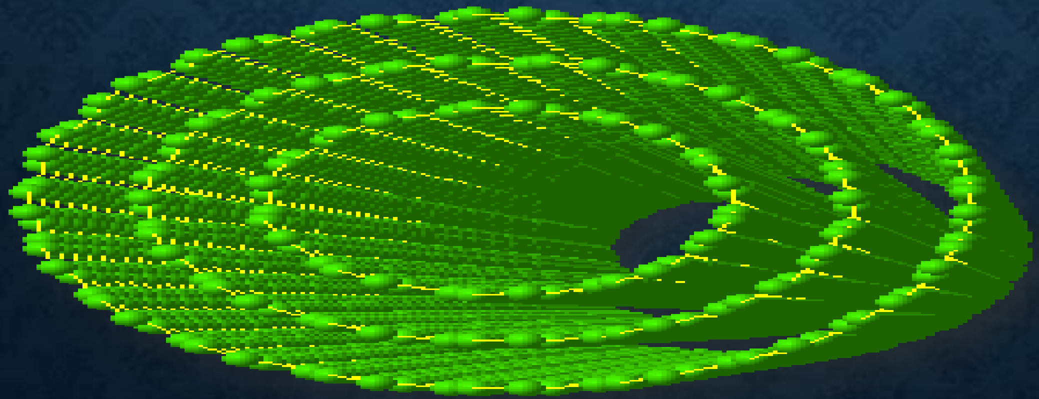
➢Multi-Walled Carbon Nanotube (*MWCNTs*):

➢This nanotubes consist of multiple layers of graphene rolled upon itself diameters ranging from 2 to 50 nm depending on number of graphene tubes.

➢Interlayer distance in MWCNTs is close to the distance between graphene layer in graphite approximately 0.34 nm.

➢To describe the structure of MWCNT there are two models:-

1. Russian doll model: In the Russian doll model, a carbon nanotubes contains another nanotubes inside it (the inner nanotube has a smaller diameter than the outer nanotube).
1. Parchment model: In the Parchment model a single graphene sheet is rolled around itself multiple times, resembling the scroll of parchment or a rolled newspaper.



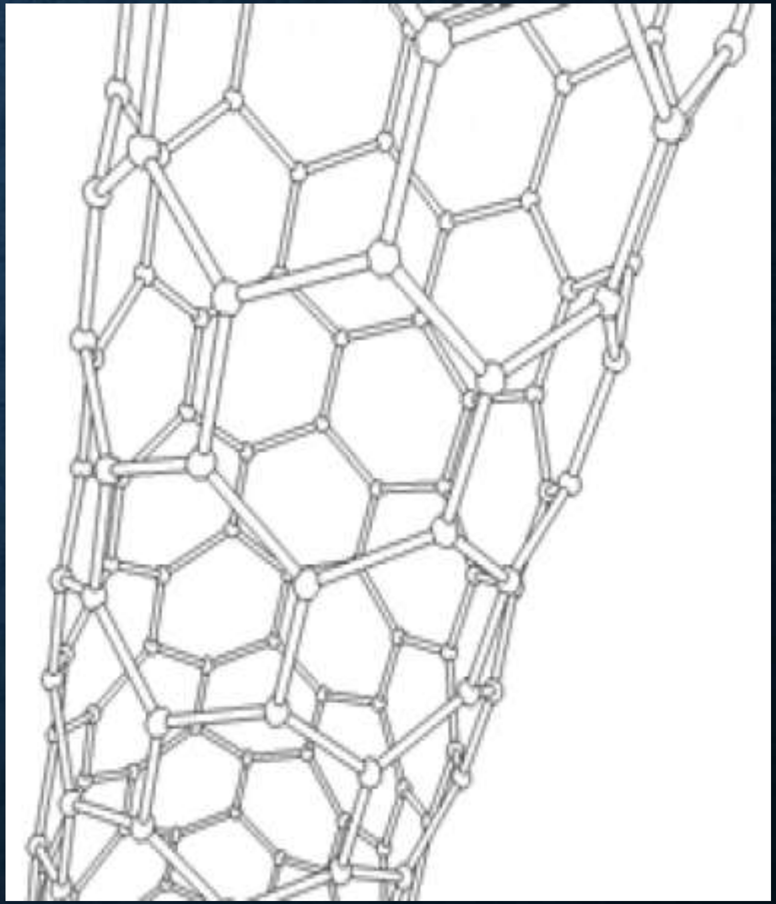
SYNTHESIS

➢PHYSICAL METHOD:

- *Arc Discharge Method.*
- *Laser Ablation Method.*

➢CHEMICAL METHOD:

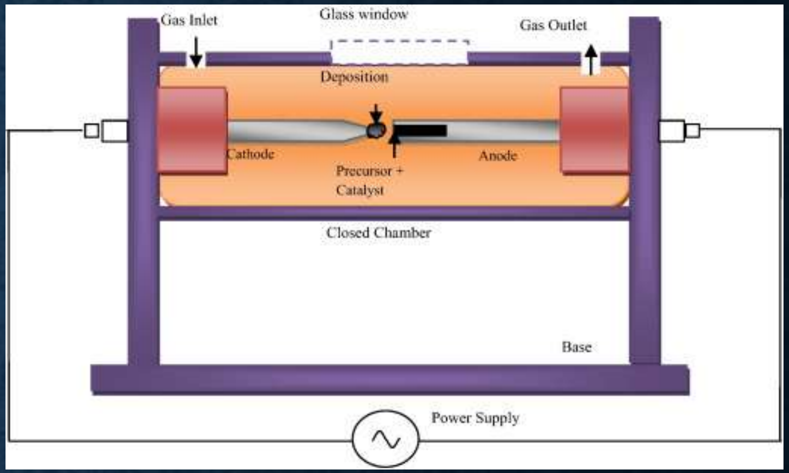
- *Chemical Vapor Deposition Method.*

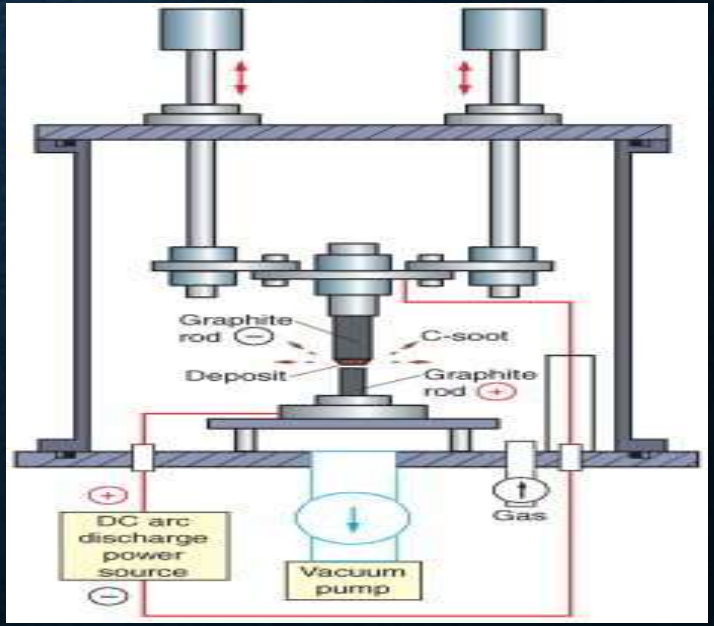


ELECTRIC ARC DISCHARGE

- Arc discharge (plasma) created between graphite electrodes by applying electric current under an inert gas of pressure 200 torr.
- Graphite Electrodes (cathode and anode) are kept separated by 1 mm.
- At 100 Amp, carbon vaporize in a hot plasma, means carbon atoms are ejected from the anode and accumulate in the form of nanotubes on the cathode.
- MWCNTs are produced by arc discharge without the requirement of catalyst.
- But for the preparation of SWCNTs, catalysts (Fe, Co, and Ni) are required, depending on the size of metal catalyst, the diameter of SWCNTs can be optimized.

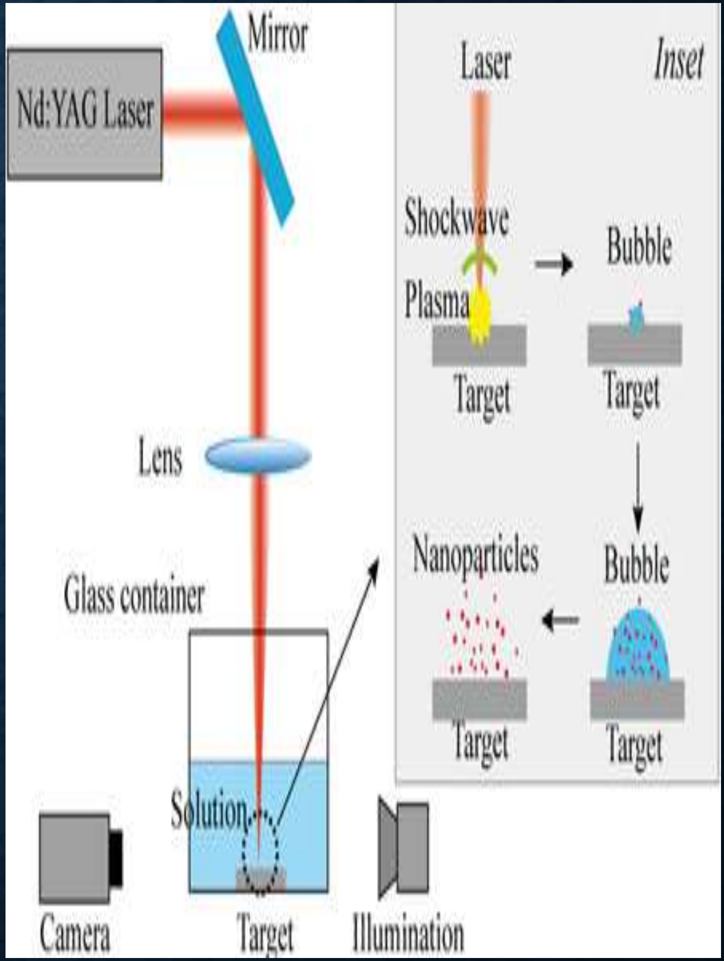
- Temperature of the chamber 3000°C is the main drawback of this method.





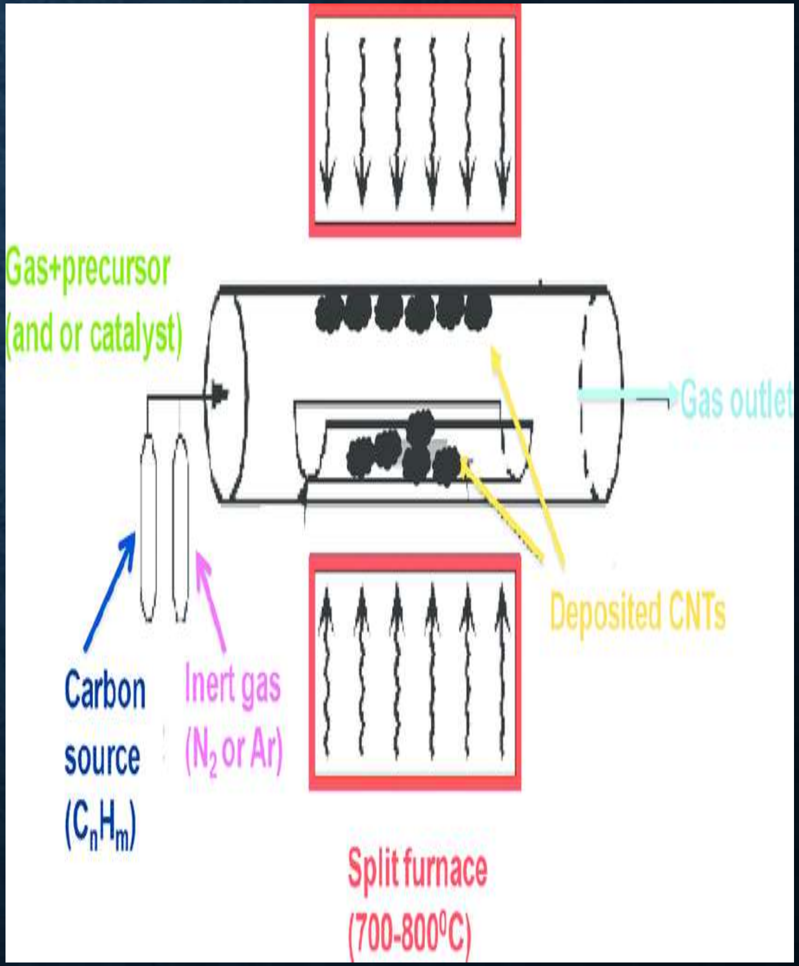
LASER ABLATION

- In this method, the ablation or vaporization of the bulk material by laser beam of high power in UV range of wavelength is used to produce the nanoparticles film deposited on the substrate.
- When the laser beam is focused on the target, the temperature of the irradiated spot increases and evaporates the atoms from the target.
- The interaction of evaporated atoms with the atoms of inert gas creates plasma plume near to target.
- Sufficient pressure of gas carry the vaporized atoms towards the cool substrate for condensation on the surface of the substrate to produce film of nanoparticles.



CHEMICAL VAPOR DEPOSITION

- In this method, precursor gases diluted with carrier gas (inert gas) and delivered to reaction chamber (quartz tube) at ambient temperature and react with processing gas or decompose to form solid phase to be deposited on the heated substrate place on quartz boat at the middle of the tube furnace.
- It does not require very high temperature for gases to decompose to form solid phase.
- CVD needs carefully handling as it deals with some toxic gases in the form of byproducts.



PROPERTIES

➢ Mechanical properties:-

- CNTs are elastic:- Tensile strength of CNT is 200 giga pascal hence CNTs can be stretched 20% of their rest length and can be bent and even tied a knot with no resulting effect.
- CNTs are very strong:- Youngs modulus of CNTs is 1 Tela Pascal which makes it 10 times stronger than steel.
- Hardness:- The hardness and bulk modulus of carbon nanotubes are greater than Diamond, which is considered the hardest material.

➢ Thermal Properties:-

- All nanotubes are expected to be very good thermal conductors along the tube, but in insulators laterally to the tube axis.
- They have very high thermal capacity so thermal expansion produced in CNT is very small.
- CNTs is thermally stable up to 4000K.

➢ **Electrical properties:-**

- Because of symmetry and unique electronic structure of graphene, nanotubes has a very high current carrying capacity.
- CNT have very few defects so that can carry billions ampere of current/cm^2.
- CNT field effect transistors (CNTFETs) based nanoelectronics is a Big Hit.
- CNTs can be metallic or semiconducting, depending on chirality.

➢ **Field emission:-**

- Excellent field emitter, high aspect ratio and small tip radius of curvature are ideal for field emission.

APPLICATIONS

- ➢Composite material containing CNTs are beings use in sporting goods.
- ➢CNTs are used to make bullet proof jackets .
- ➢CNT Can be reduced the weight of aircrafts and spacecrafts up to 30%.
- ➢It Can be used to build high performance nanoscale the film transistor to replace silicon based transistor.
- ➢CNT based FET can used to manufacture biosensors, electrochemical sensors, these can detect gases like green house gases in environment applications.
- ➢CNTs have been used to make electrodes to study electrochemical reactions because of their excellent electrical properties

- The high Aspect ratio of CNTs process unique electrical conductivity .
- CNTs presents the opportunity to work with effective structures that have high drug loading capacities and good cell penetration qualities.
- Because of their tube structure, CNTs can be made with or without end caps, meaning that without end caps the inside where the drug is held would be more accessible.
- CNTs have been identified as possibly being able to meet specific strength requirements for an Earth Space Elevator.
- The field of research for CNTs has become so broad over the past 20 years that they are being tested for use fields.

CHALLENGES

- **Toxicity:-**

Under some condition nanotubes can cross membrane barriers, which suggested that if row materials reach the organ they can induce harmful effects such as inflammatory and fibrotic reactions.

- **Crystallographic defects:-**

As with any materials, the existence of a crystallographic defect affects the material properties. Defects can occur in the form of atomic vacancies.

CONCLUSION

- Carbon nanotubes have very different properties compared to the other carbon allotropes. These unique properties offer huge potential in product development.
- Nanomaterials, particularly carbon nanotubes, hold great promise for a variety of industrial, consumer, and biomedical applications, due to their outstanding and novel properties.
- Scientists are still working on finding ways to make carbon nanotubes a realistic option for transistors in microprocessors and other electronics.