

Carbon-Based Nanomaterials

**Graphite, Graphene, Fullerenes,
Carbon Nanotubes & Carbon dots**

Introduction

- Carbon is one of the very interesting element , which constitutes a major part of the living as well as non living world .
- Carbon-based nanomaterials are composed primarily of carbon atoms arranged in different dimensional structures.
- Crystalline carbon can exist in diamond, graphite, fullerenes, graphene and carbon nanotubes.
- These materials exhibit unique electrical, mechanical, and thermal properties with wide applications.

Fullerene (C₆₀)

- Fullerenes are football shaped cage like structures of carbon atoms built up from pentagons and hexagons.
- Pure molecular form of carbon.
- The first discovered C₆₀ molecule called Buckminster Fullerene, has a soccer ball shape (buckyball)-60 carbon atoms are arranged as 20 hexagons and 12 pentagons.
- Discovered in 1985.
- Other examples: C₇₀, C₇₆, C₈₀ etc
- In short spherical Fullerenes are called buckyballs.
- In C₆₀, a hexagon is fused with pentagons or other hexagons, but a pentagon can only fuse with hexagons.
- The carbon atoms are SP₂ hybridised.

- The carbon atoms are SP_2 hybridised.
- Each carbon atoms forms 3 sigma bonds with 3 other carbon atoms in trigonal planar fashion. One valence electron remain in each carbon atoms (They are in the unhybridised p orbital – gives aromatic character)

- Preparation:

Evaporate graphite rods by applying an electric arc at about 130 bar in an atmosphere of an inert gas like He or Ar. The graphitic soot formed by the condensation of the vapour consist of mainly C_{60} with smaller quantity of C_{70} and traces of other fullerenes, they are separated by chromatography.

- **Properties:**

High stability and electron affinity

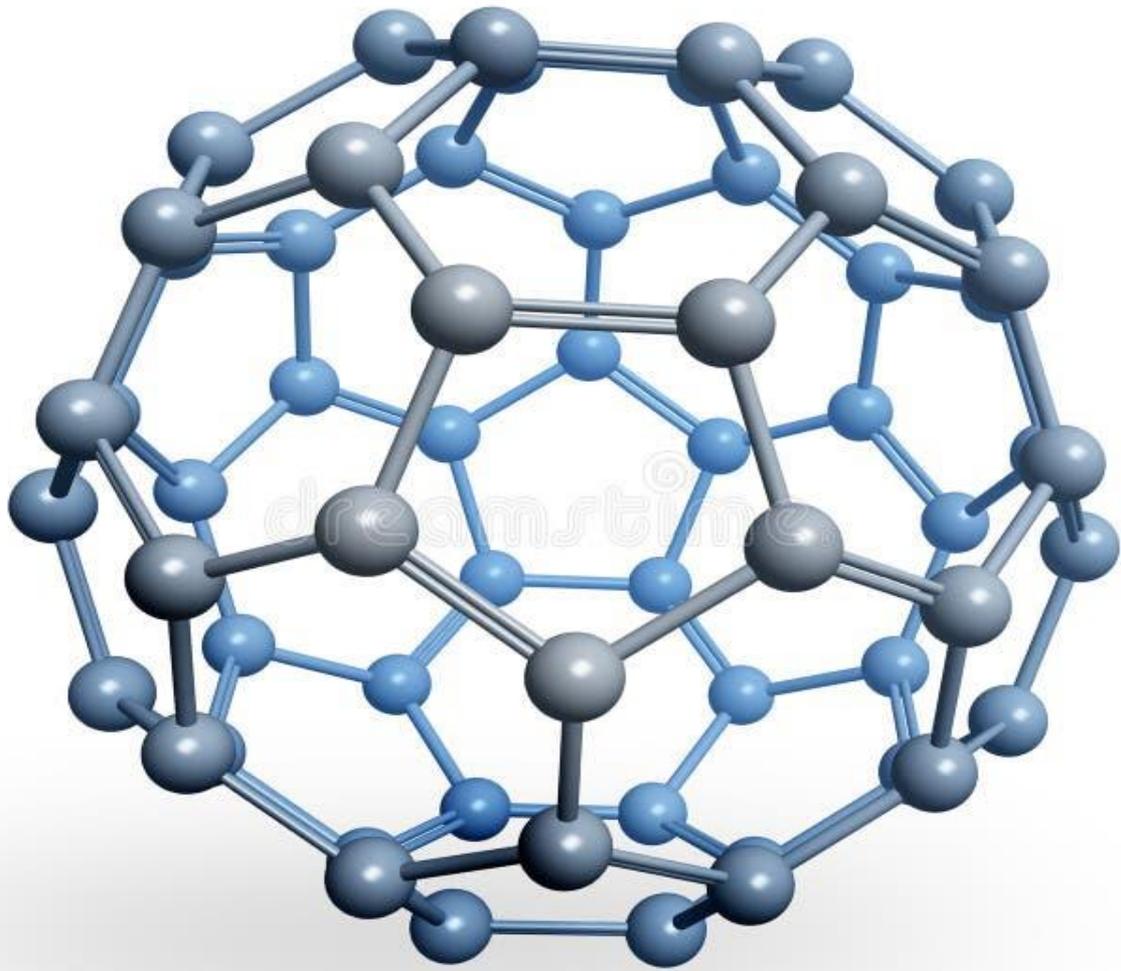
Capable of forming compounds with metals

- **Applications:**

Drug delivery systems.

Solar cells

Lubricants and superconductors



Graphene

- It is a form of carbon nanomaterial.
- Consist of 2 dimensional sheet of carbon atoms(monolayer of carbon atoms with 1 atom thickness, arranged in hexagonal lattice).
- It as an allotrope of carbon.
- Carbon atoms are SP_2 hybridised.
- C-C bond length is 0.142 nm
- Discovered in 2004
- Prior to 2004, it was long believed that strictly 2D arrangements of atoms would be unstable as thermal fluctuations would break apart the atoms. But this doesn't happen in graphene.

- There are various methods for the synthesis of graphene. It includes top down and bottom up methods.

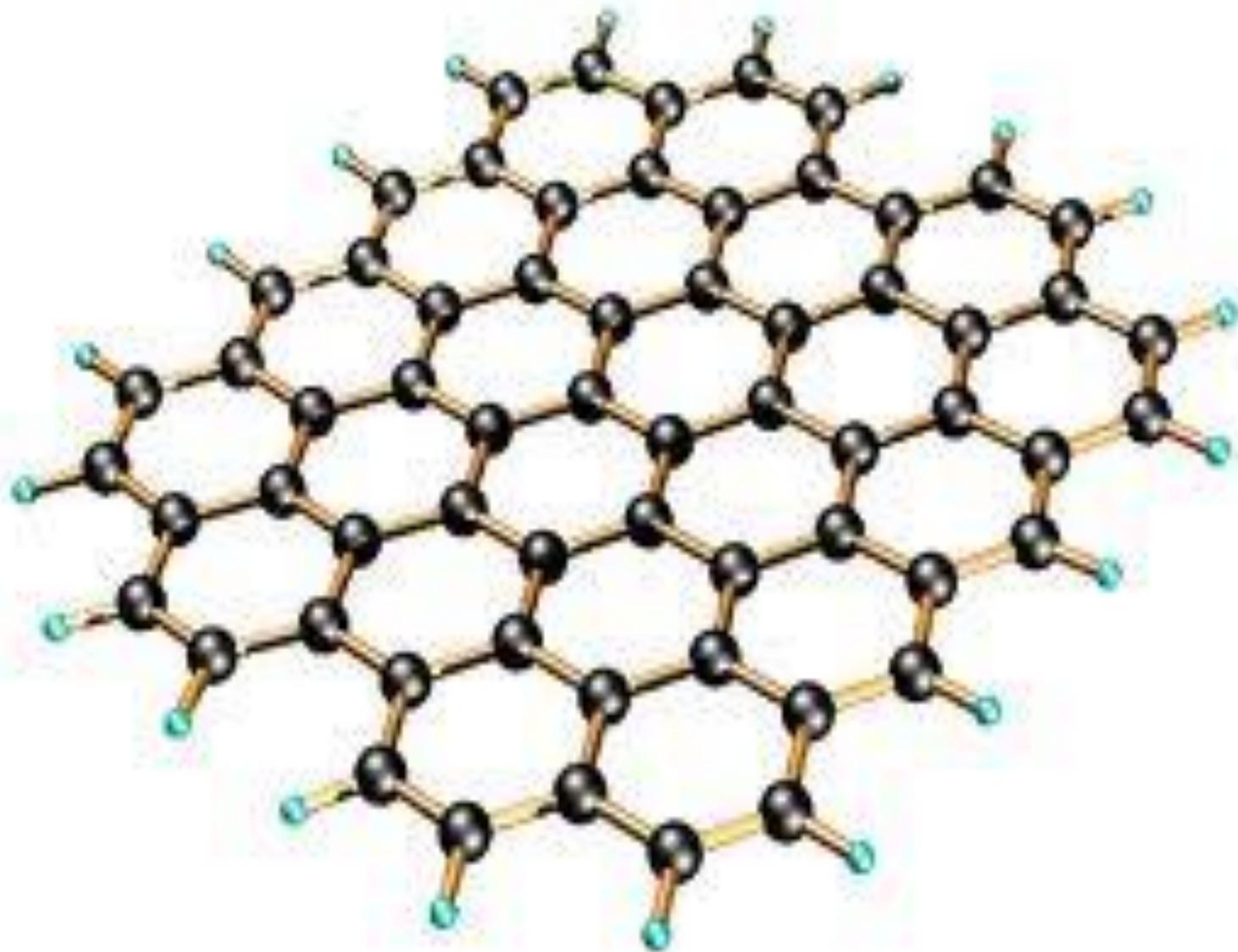
- **Properties.**

- ☆ It is a ‘wonder material’ based on its properties.

- ☆ It is the thinnest material & lightest man made material.

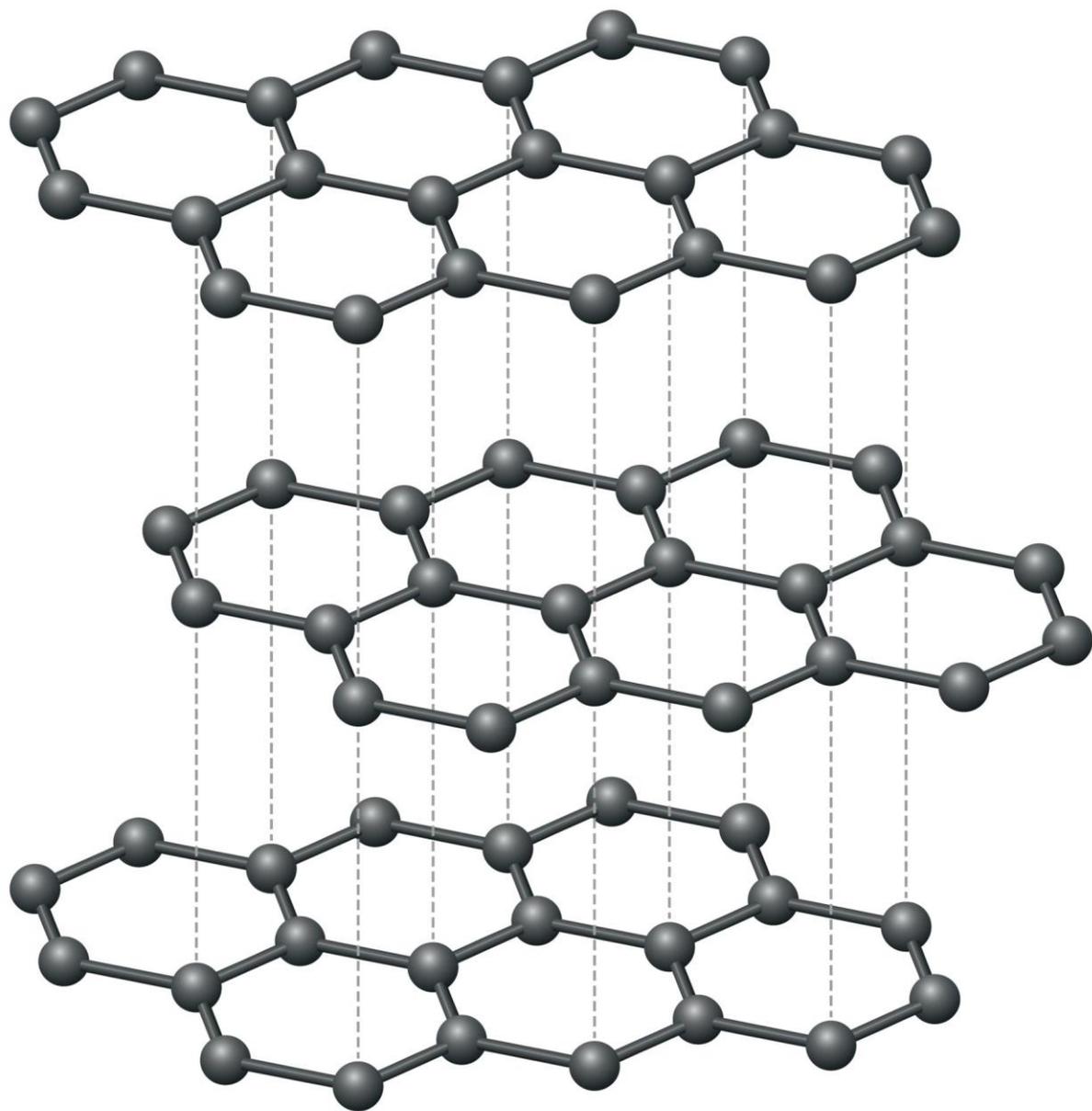
- ☆ It is flexible, transparent & about 200 times stronger than steel.

- ☆ Excellent conductor of heat and electricity & has interesting light absorption abilities.



Graphite

- Stable allotrope of carbon.
- 3D structure built up from layers of planar hexagonal rings of carbon atoms (stacking graphene sheets) with C-C bond length of 0.142 nm.
- The different layers held together by van der Waals force at distance of 0.340 nm.
- First isolated in 2004.



Carbon nanotubes (CNTs)

a) Structure and classification

- First observed in 1991 with the help of an electron microscope.
- Extended cylinders of rolled graphene sheets.
- Carbon- SP_2 hybridised state
- Some of these cylinders are closed at the ends and some are open.
- Each carbon atoms is bonded to 3 other carbon atoms producing hexagons, except near the end.
- For nanotubes with closed end, where the ends start to curve to form a cap forms pentagons.
- CNTs are two types-single walled (consisting of a single cylinder) or multi walled (consisting of concentric, nested cylinders).

b) Synthesis of CNTs

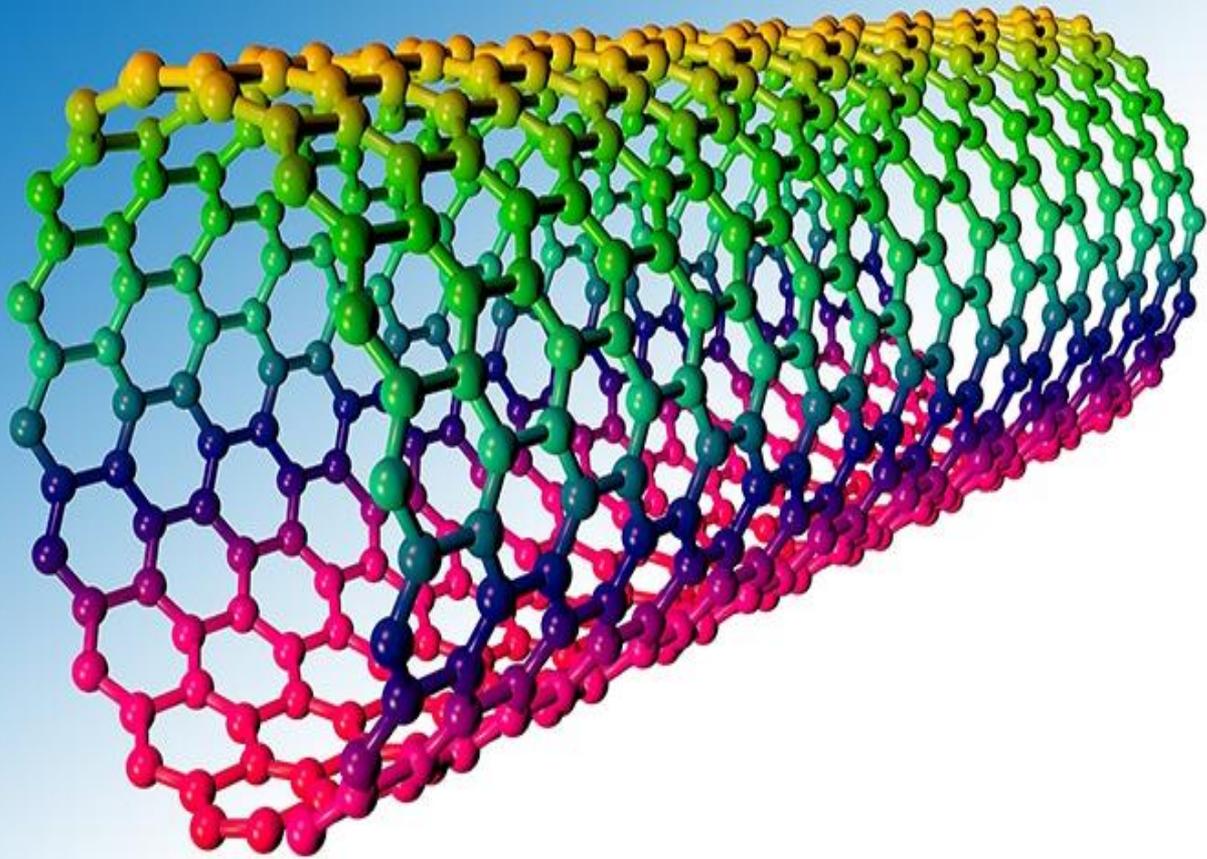
- Arc discharge method
- Laser ablation method
- Chemical vapour deposition

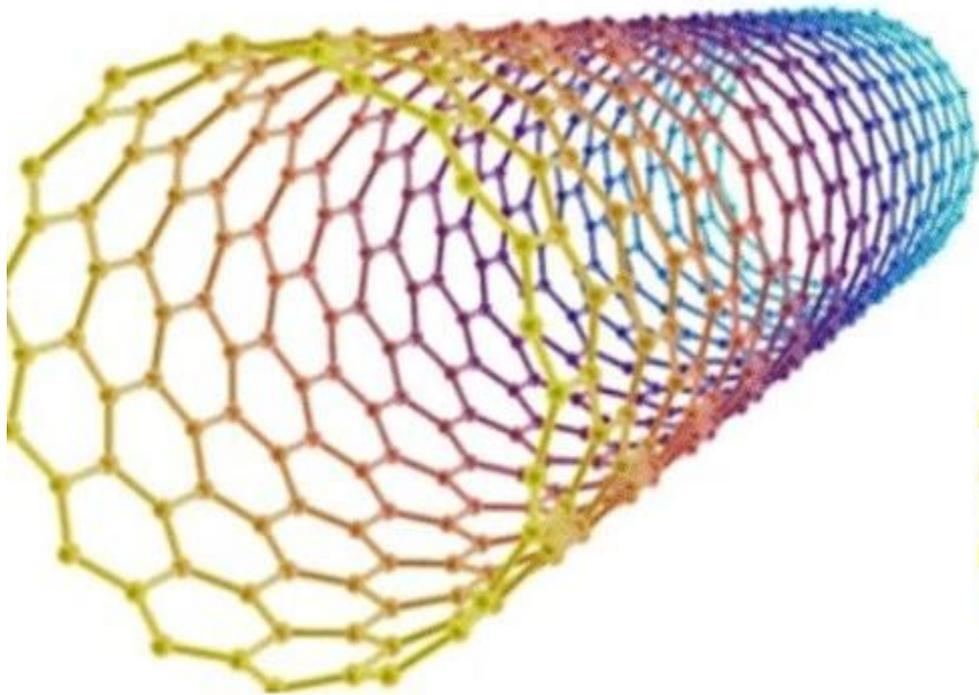
c) Properties of CNTs

- They are mechanically very strong and tough, but are flexible and elastic too.
- Light weight, with a density about one quarter of that of steel.
- Tensile strength is about 100 times greater than that of steel.
- Extreme conductor of electricity, but it varies sensitively with the diameter and helicity of the tube; slight changes can cause a shift from metallic to semiconducting state.
- High thermal conductivity- more than 10 times that of Ag.

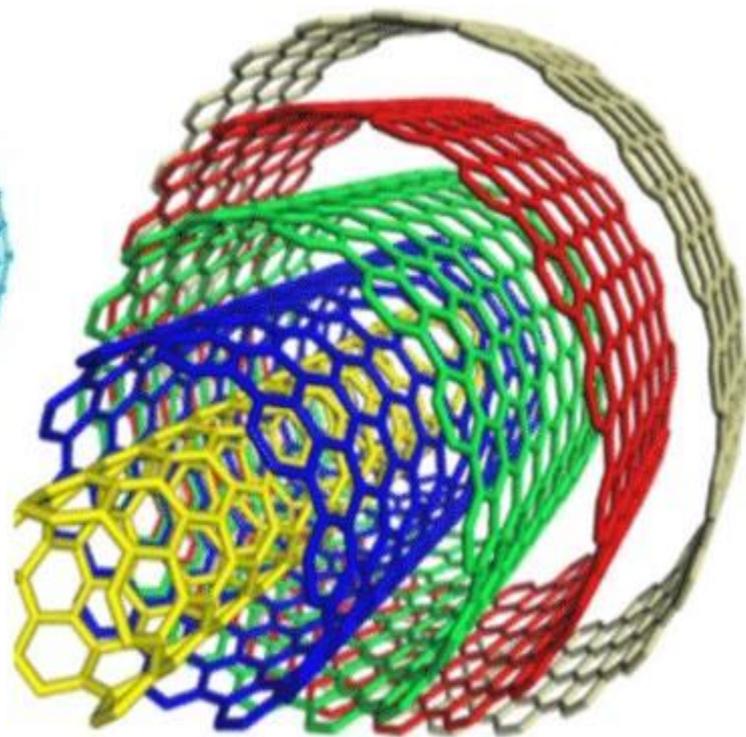
d) Applications of CNTs

- Electronics and Electrical Devices – Used in transistors, sensors.
- Batteries and super capacitors
- Composite Materials – Added to polymers, metals, or ceramics to enhance mechanical strength, elasticity, and thermal stability.
- Drug Delivery – Used as carriers to deliver drugs directly to targeted cells in biomedical applications.
- Water Purification
- Air filtration
- Catalyst
- Biosensors and diagnostics
- Tissue regeneration
- Aerospace and Automotive





(a) SWCNT



(b) MWCNT

Carbon dots (CDs)

- Group of fluorescent carbon nanomaterials.
- Composed of discrete, quasi spherical zero dimensional Nanoparticles.
- Size below 20nm, and have fluorescence.
- The building blocks are carbon, sometimes doped with some heteroatoms.
- Different types-graphene quantum dots, carbon nanodots, carbonized polymer dots.
- First discovered in 2004.

Applications:

- Sensors
- In photocatalysis
- LEDs
- Solar cells
- Lasers
- Carbon dots are less toxic, used in drug Delivery and cancer phototherapy.