UNIT 5- NANOMATERIALS

FABRICATION OF NANOMATERIALS

Nanoparticles are fabricated by two process,
- Top-down approach
- Bottom-up approach

In top-down approach nanomaterials are obtained by breaking bulk materials into small entities. Whereas in bottom-up approach materials are built atom by atom or molecule by molecule.

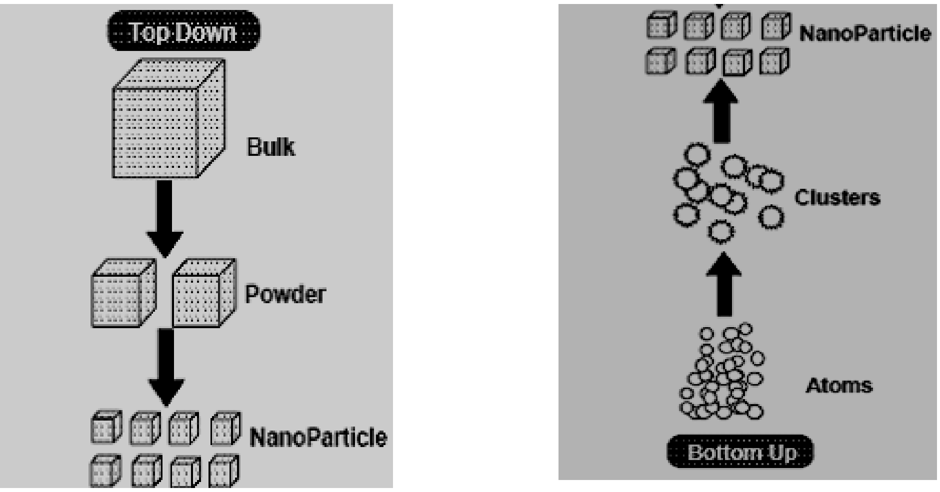


Fig. 2 Top-down and Bottom-up approach

Top-Down process

In this process, bulk materials are broken into nano-sized particles. In this approach there is no control over the size and the morphology of particles. There are many methods in top-down approach to get nano-sized particles from bulk materials, some of the common methods are

- **Ball milling**
- **Plasma arcing**
- **Laser sputtering**
- **Vapour deposition method**

The major disadvantage of this technique is imperfection in the surface structure and crystallographic damage to the processed patterns. These imperfections leads to the extra challenges in the device design and fabrication.

Bottom-Up process

This refers to the building of materials from the bottom, i.e., atom by atom, molecule by molecule or cluster by cluster. Some methods of bottom up process are

- **Sol-gel method**
- **Colloidal method**
- **Electro deposition**
- **Solution phase reductions.**

BALL MILLING

It's a typical top-down method for nanoparticle preparation. The basic working principle of ball milling method is making use of small hard balls to rotate inside a container and then it is made to fall on a solid with high force to crush the solid into nanoparticles.

Working

- Hardened steel or tungsten balls are put in a container along with the power of desired material.
- The container is closed with tight lids.
- The container is rotated around the central axis.
- The material is forced to press against the walls of the container.
- The milling ball imparts energy on collision and produce smaller grain size of nanoparticles.

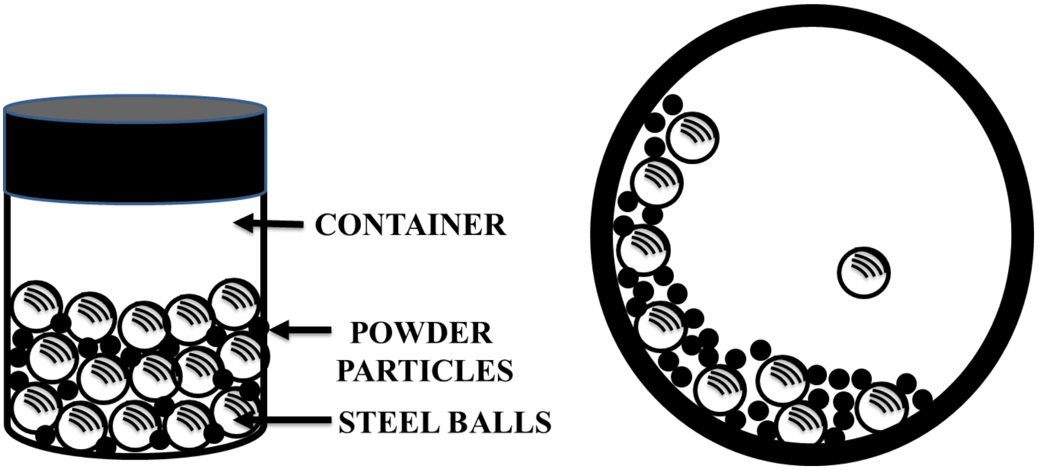


Fig. 3. Ball milling process

Various types of Balls used

- Chrome steel
- Stainless steel
- Zirconia
- Tungsten carbide
- Ceramic
- Rubber

The main advantage of this method is few milligrams to several kilograms of nanoparticles can be prepared in a short period of time. This technique is operated in large scales.

Applications

Some important applications of Ball milling technique is,

- It is used for elemental preparation metal oxide nanocrystals like cobalt, chromium, iron, aluminium ferrites etc.
- A variety of intermetallic compounds of nickel and aluminium can be formed.
- This method is useful to produce new types of building materials, fire proof materials, glass ceramics etc.

PLASMA ARCING

When potential difference is applied between two electrodes having air or any other gas between them, the air or gas will be ionized. This ionized gas is called plasma. When potential difference is applied the ions are deposited on the electrodes in the form of nano particles. This method is used to produce "*carbon nano tubes*".

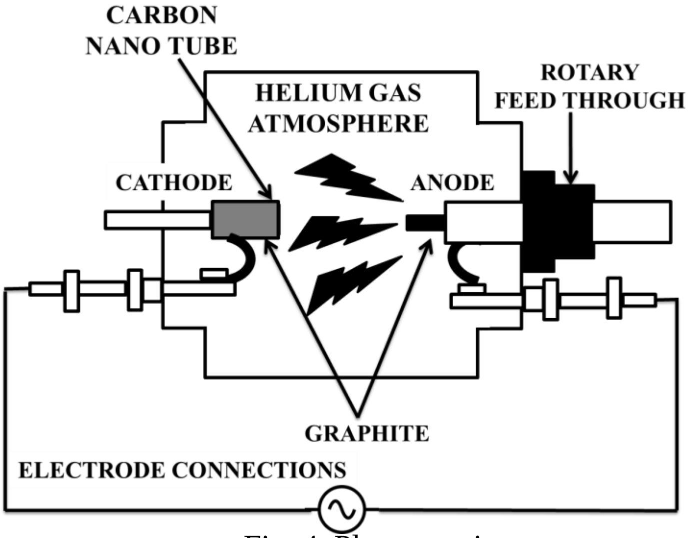


Fig. 4. Plasma arcing

•Two electrodes (cathode and anode) are placed in an inert helium atmosphere.
•When DC current is passed anode is consumed and materials forms on cathode.
•Arc evaporation technique involves evaporation of graphite anode rod and condensation of the deposit on the cathode rod under inert atmosphere.
•A plasma is achieved by making a gas to conduct electricity by providing a potential difference across two electrodes.
•Electrodes are made of conducting materials.

CHEMICAL VAPOUR DEPOSITION

•In this method the materials is heated at very large temperatures (around 2000^0C) in vacuum to form gas.
• This gas is slowly cooled and is allowed to condense; hence nano particles of the material are deposited.
• This gas is deposited on solid surface.
• The deposition may be physical or chemical. In deposition by chemical reaction new product is formed.

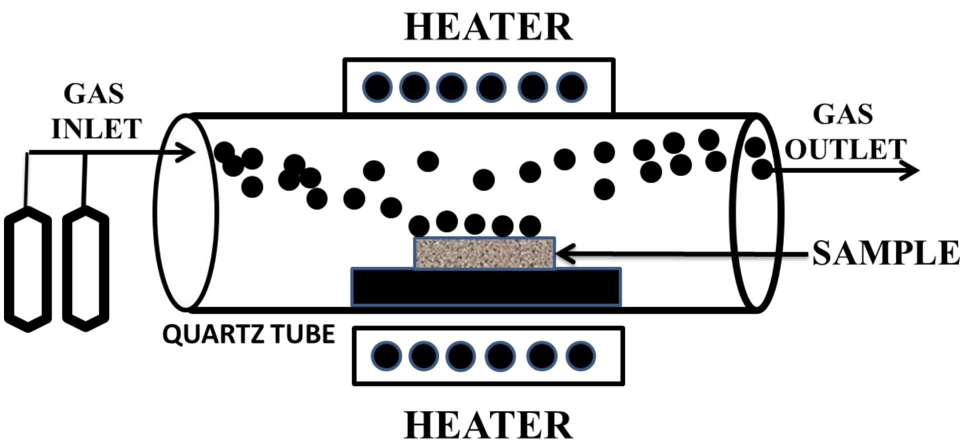


Fig. 5. Chemical vapour deposition

ELECTROLYTIC DEPOSITION

In electrolytes when current is passed through two electrodes immersed inside the electrolyte certain mass of substance liberated at one electrode gets deposited on the surface of the other. even a single layer of atoms can be deposited by controlling the current and other parameters.

Nano structured films of copper, platinum, nickel, gold...etc can be produced by electro deposition. The films thus obtained are mechanically robust, highly flat and uniform. These are used in batteries fuel cells, solar cells, magnetic read heads etc....

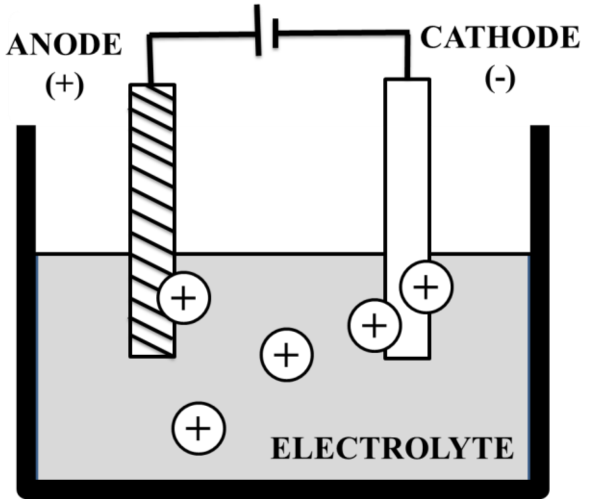
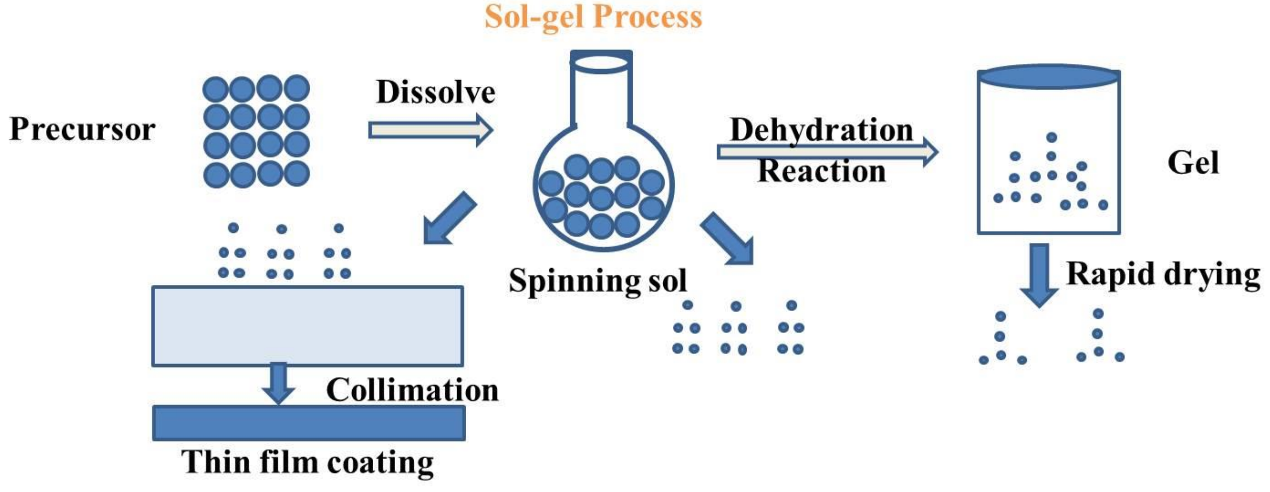


Fig. 6. Electro deposition

Sol-Gel

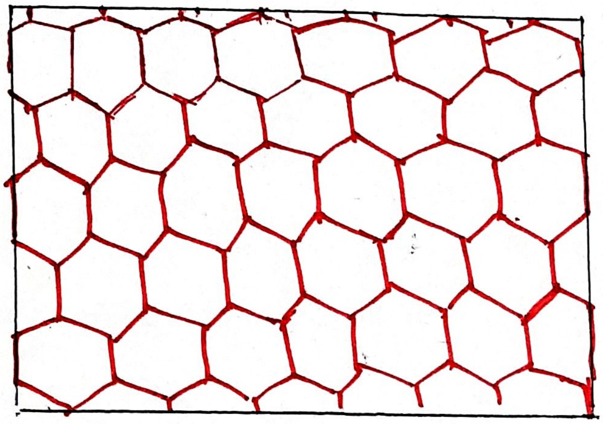
Initially a homogeneous solution (sol) of a material is prepared and used as a precursor indication for nano fabrication. The sol is deposited on a suitable substrate by spraying (or) dipping. It is kept for a while for gelation (gel). During this 'gelation time' the material gradually loses its fluidity and undergoes a transition from viscous liquid state to elastic solid state. The desired nano particles are finally fabricated from the gel.



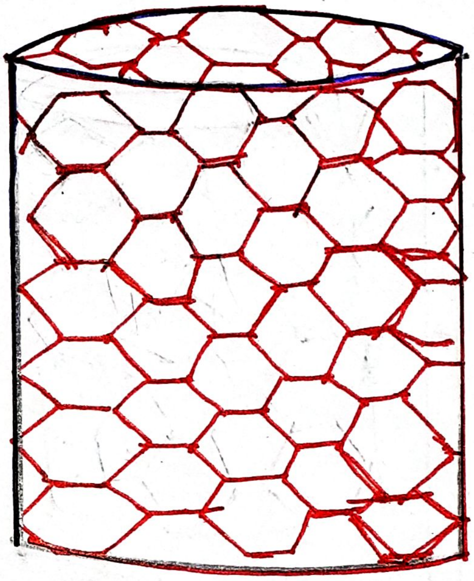
CARBON NANOTUBES

A carbon nanotube is a tube shaped material made of carbon with a diameter in nanometer scale range.

Graphene sheet is being rolled in the form of tube with a diameter in 10^{-9}m range.



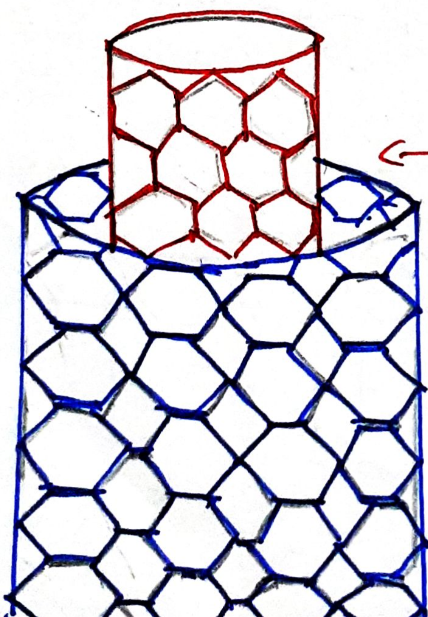
GRAPHENE SHEET



CARBON NANOTUBE

carbon nanotubes are categorized as,

* Single walled nanotube (SWNT)
* Multi walled nanotubes (MWNT)



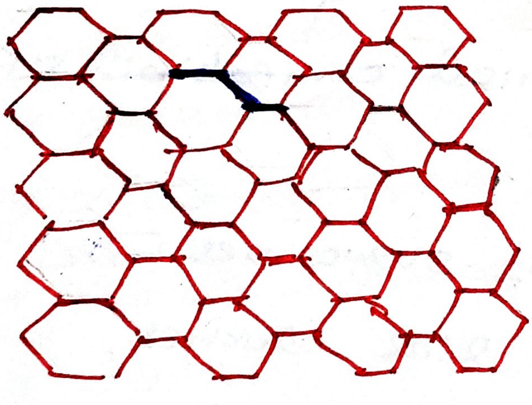
← MWNT

SWNT

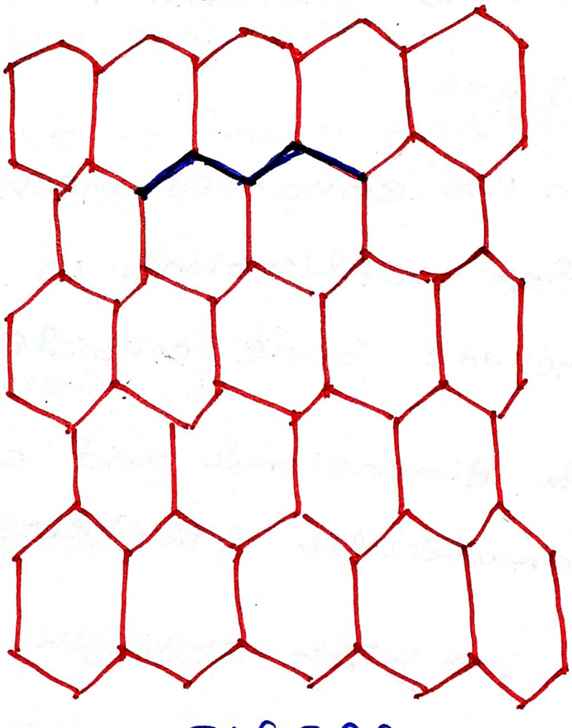
A single walled carbon nanotube is just like a regular straw. It has one layer, multi walled carbon nanotubes are a collection of nested tubes of continously increasing diameters. They can range from one outer and one inner tube to as many as 100 tubes (walls) or more. Each tube is held at a certain distance from its neighbouring tubes by interatomic forces.

Based on symmetry carbon nanotubes are classified as,

* Arm chair
* Zig-Zag
* Chiral

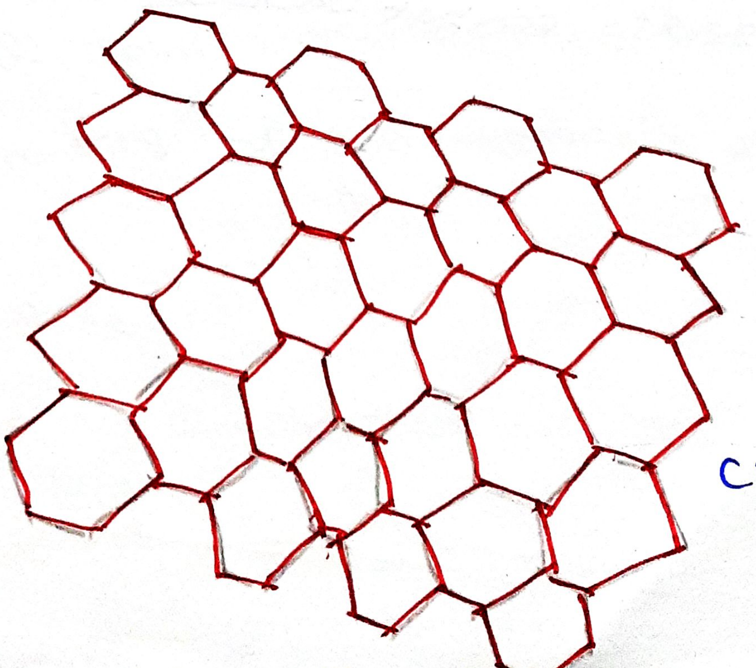


ARM CHAIR



ZIGZAG

It is based on rolling graphene sheet.



CHIRAL

PROPERTIES

Carbon nanotubes have

* High electrical conductivity
* High tensile strength
* Flexible without any damage
* Highly elastic
* High thermal conductivity
* Low thermal expansion coefficient

APPLICATIONS

Due to its enhanced mechanical strength it is used for applications in tissue engineering which include bone, muscle and nerve tissues.

* It has dimensional and chemical compatibility with biomolecules & proteins.
* Due to its high strength many structures have been proposed in everyday items like clothes, sport gears, combat jackets & space elevators.
* CNTs are used in energy storage
* for Air & water filtration | Purification
* Nanotube chemical ~~sensors~~ sensors & actuators.
* Flat Panel display
* Magnetic recording media, rocket propellants, fuel additives, DNA chips, biosensors etc...