UNIT: V

CHAPTER :1

NANOMATERIALS

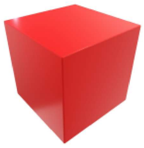
INTRODUCTION

* Nanomaterials place an important role in many fields of science and technology.

*1 nano means $10^{-9}m$ is the billionth part of the meter. Nanotechnology deals with the designed characterization, production, and applications of nanotechnology structures and nanodevices.

*****Nanomaterials exhibit different properties than the same materials in bulk form. Nanomaterials can produce different dimensionalities

1. 1-D Nanomaterial: if one dimension is reduced to the nano range then it is known as 1-D nanomaterial.
   Ex: thin films, surface coatings



2. 2-D Nanomaterial: if two dimensions are reduced to nano range then it is known as 2-D nanomaterials.

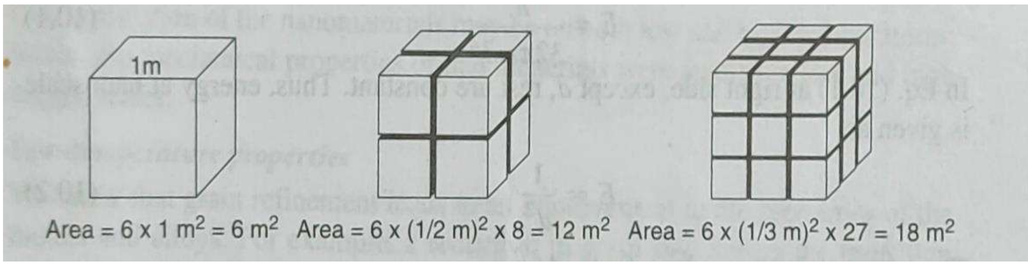
   Ex: quantum wires, nanotubes

3. 3-D Nanomaterials: if all three dimensions are reduced to nanorange then it is known as 3-D Nanomaterials.

Ex: quantum dots, precipitates, and collides.

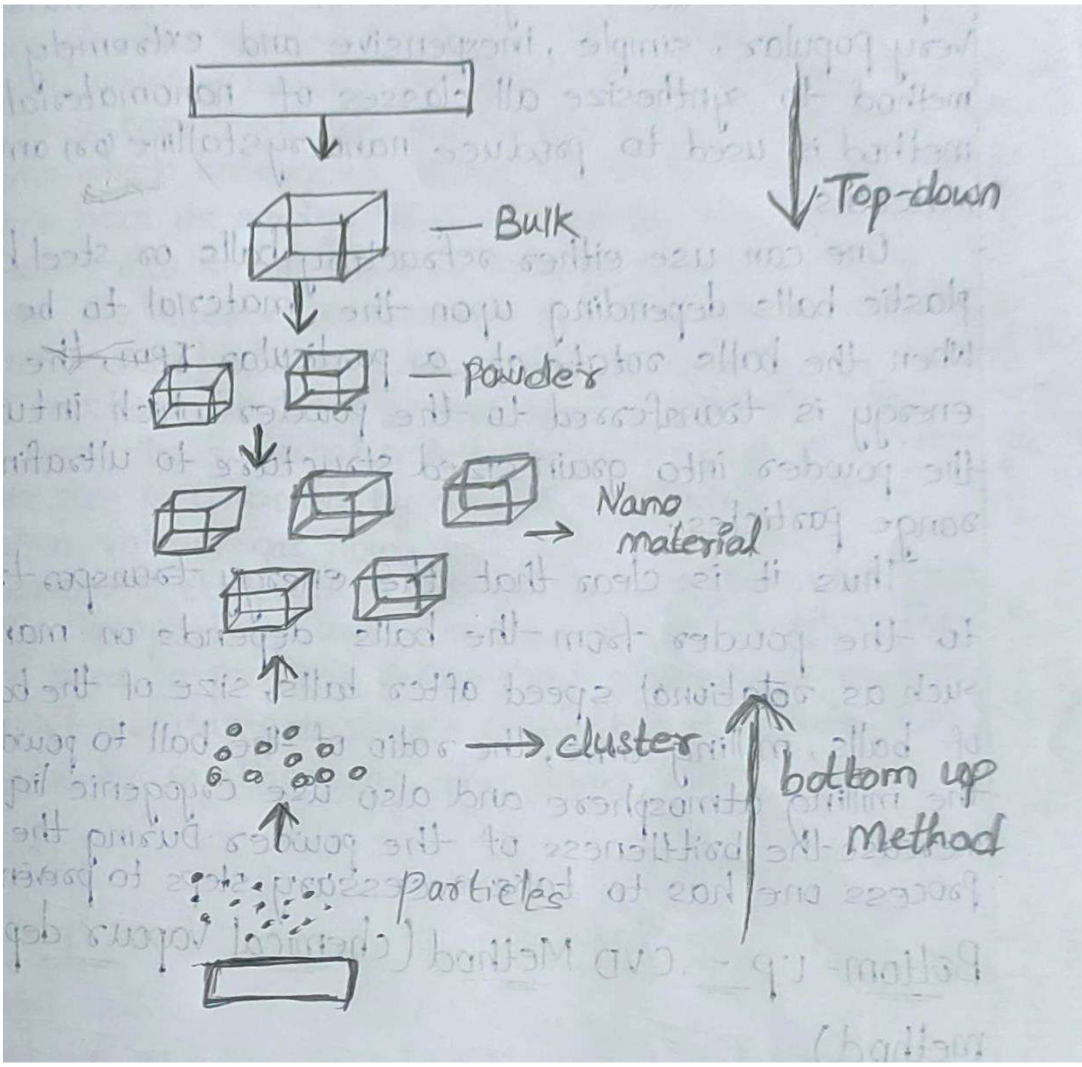
PRINCIPLES OF NANOMATERIALS: Two principal factors cause the properties of nanomaterials to nanomaterials to defer significantly from other materials.

1) INCREASING SURFACE AREA TO VOLUME RATIO: Due to increasing surface area, more atoms will appear on the surface in comparison to those inside. For example, a nanomaterial of size 10nm has 20% of its atoms on its surface, and at 3nm has 50% of its atom. This makes nanomaterials more chemically reactive.

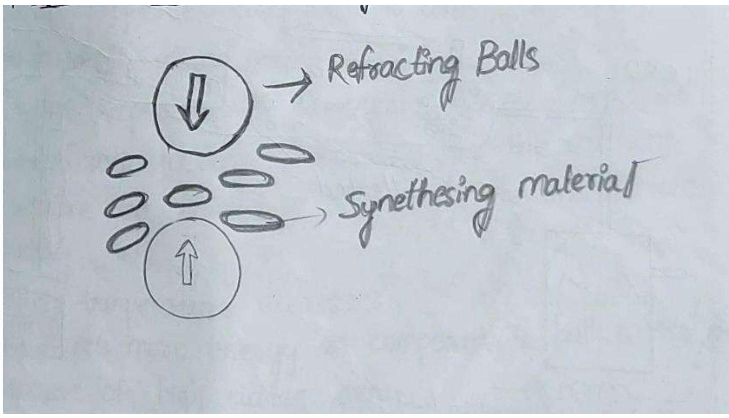


2) QUANTUM CONFINEMENT: The properties of materials can be studied based on their energy levels. When atoms are isolated their energy levels are decreased for materials consisting of a large number of closed atoms, the energy levels are split and form bands. Nanomaterials are intermediate to the above cases. As a result, their energy levels are changed. When the material size is reduced to nano size energy levels of electrons are changed. This affects the optical, called quantum confinement. This affects the optical, electrical, and magnetic properties of nanomaterials.

FABRICATION OF NANOMATERIALS:



TOP-DOWN METHOD-BALL MILING METHOD:

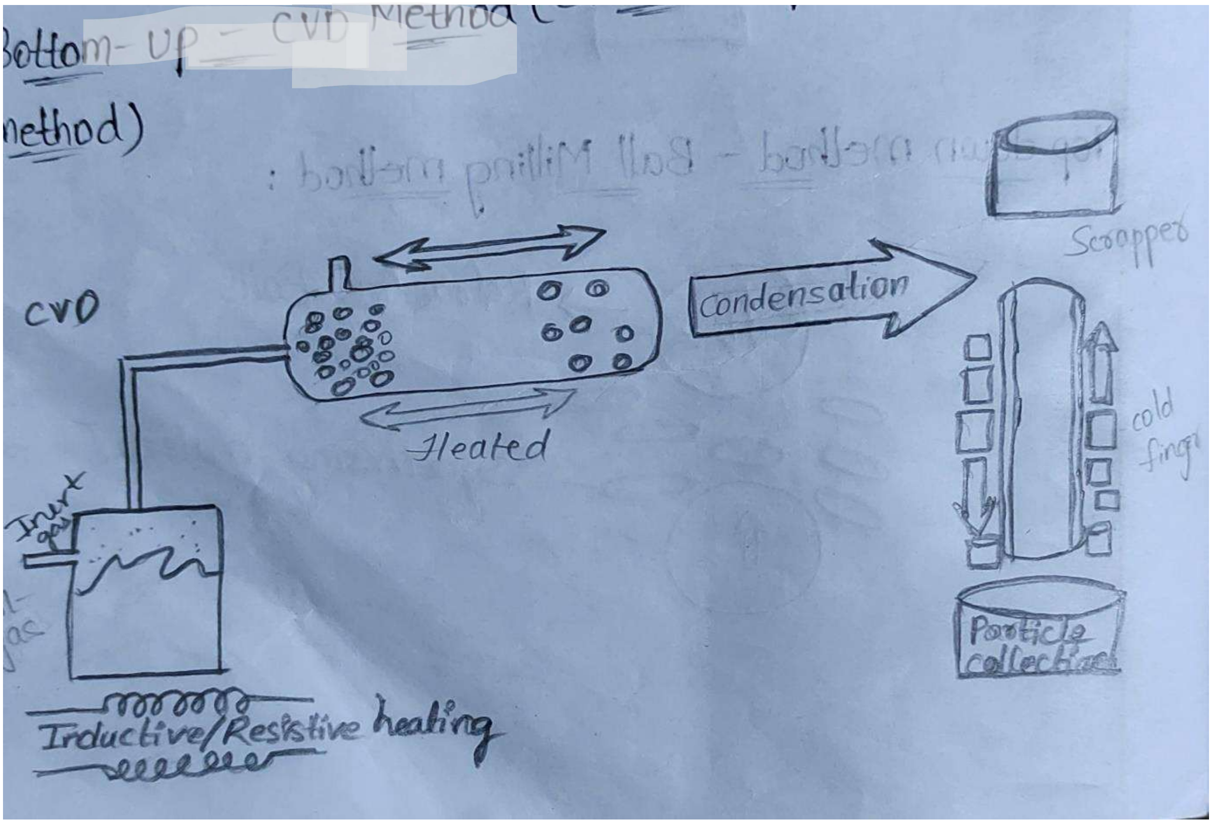


The ball milling method is a typical example of the top-down method of synthesis of nanomaterials. This is a very popular, simple, inexpensive, and extremely scalable method to synthesize all classes of nanomaterials this method is used to produce nanocrystalline (or) amorphous materials.

One can use either refractory balls or steel balls or plastic balls depending on the material to be synthesized. When the balls rotate at a particular rpm, the necessary energy is transferred to the powder which in turn reduces the powder into a grain-sized structure to ultrafine nano-range particles.

Thus it is clear that the energy transferred to the powder from the balls depends on many factors such as rotational speed after balls, size of the balls, number of balls, milling time, the ratio of the ball to powder mass and the milling atmosphere and also use cryogenic liquids to increase the brittleness of the powder during the milling process one has to take necessary steps to prevent oxidation.

BOTTOM-UP-CVD METHOD(CHEMICAL VAPOUR DEPOSITION METHOD)



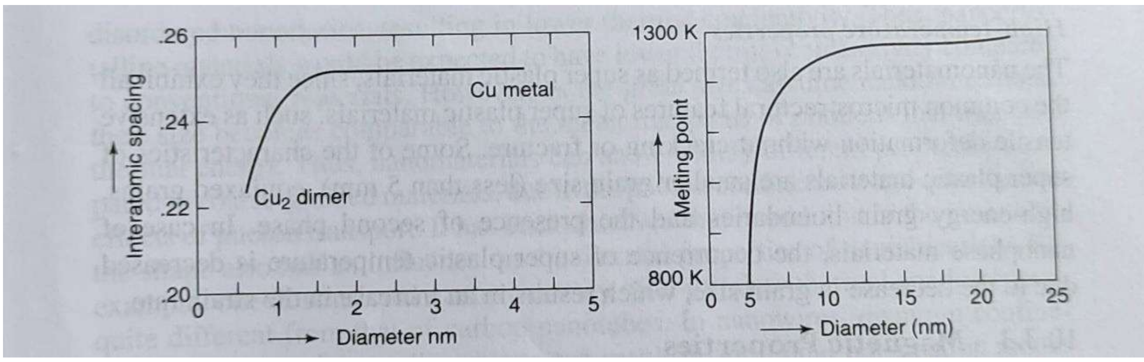
The schematic representation of the CVD method is shown in fig. the metal-organic precursor is introduced into the hard zone of the reactor. The precursor is vaporized by the inductive and resistive heating methods. In an inert gas like argon, neon is used as a carrier gas. The evaporated matter consists of hot atoms which undergo collisions with the cold gas atoms and hence losses their energy. Thus the colloidal atoms undergo condensation into small clusters through homogeneous nucleation. The clusters continue to grow in a supersaturated region. Other reactants are added to the clusters to control the chemical reactions. In order to control the size the clusters are removed from the supersaturated region through a carrier gas. The cluster size is controlled by the rate of evaporation, rate of condensation, and rate of gas flow.

The condensed clusters are allowed to pass through a cold finger. The nanoparticles are collected using a scrapper. The CVD method is used to produce detect-free nanoparticles. From this method, we get single-phase nanoparticles, and two-phase nanoparticles by synthesizing the CVD method.

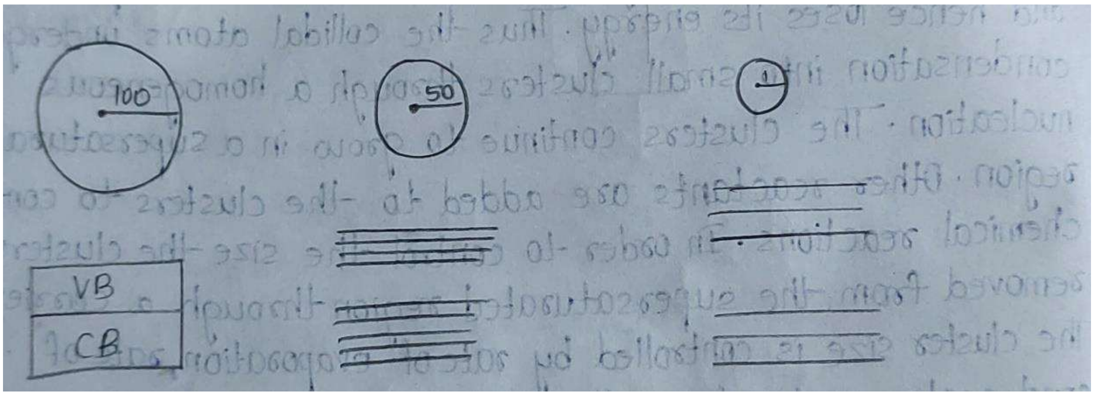
PROPERTIES OF NANOMATERIALS:

Nanomaterials exhibit different properties, compared to bulk materials even though in the same materials.

1. **Physical properties:** At the nanoscale, the surface area to volume ratio increases, this changes the surface pressure and results In a change in the interatomic spacing.
   - **Melting** temperature decreases.
   - it stores more energy as compared to bulk material because of its high surface area.
   - Structure is the same for both nano and bulk materials, but lattice parameter is different.



2. **ELECTRICAL PROPERTIES:**
   Let us a copper solid material that has a radius of 1 meter. Generally in solids valency band and conduction band overlapped with each other



   If we take the small part of the material of radius r=50m the energy levels are discrete. If the size of the material decreases then the density of the material also decreases. These energy levels separate the size of the nanoparticle.
3. **OPTICAL PROPERTIES:**
   Nanomaterials have special optical properties depending upon the size of the nanoparticles. Generally, the colors are observed by the wavelength of the light absorbed and emitted by it.
   Ex: At 100nm gold appears in orange color.
   At 50nm gold appears in green color.
   At 2-5nm gold appears in yellow colour.
4. **MECHANICAL PROPERTIES:**
   Mechanical strength, toughness, and Young's modulus of the nanomaterials are very high.

MATERIAL	YOUNG'S MODULUS	TENSILE STRENGTH
Pinewood	>0.01	0.00004
Stainless steel	0.18 to 0.21	0.38 to 1.55
Carbon/nanotube	1.5	13.53

MAGNETIC PROPERTIES:

Nanomaterials exhibit excellent magnetic properties. In nanostructures, the magnetic moment of each atom will interact with magnetic moments aligned in one direction. Hence it is suitable for magnetic storage.

APPLICATIONS OF NANOMATERIALS:

Due to the different properties of nanomaterials, they can be used for a wide variety of applications.

1. **MATERIAL TECHNOLOGY :**
   - Aerogels are used for insulation in offices, homes, etc.
   - Cutting tools made of nanocrystalline materials are much harder, more resistant, and last longer.
   - Nanocrystalline materials are used for high-energy-density batteries.
   - Nanocrystalline ceramics are used in the automotive industry as high-strength springs and ball bearings.
   - sensors made from nanocrystalline materials are used for smoke detectors, ice detectors o aircraft wings.
2. **INFORMATION TECHNOLOGY:**
   - **N**anoscale fabricated magnetic materials are used in data storage.
   - Nanoparticles are used for information storage.
   - Nano-thickness controlled coating is used in electronic devices.
   - Nano photonic crystals are used in chemical optical computers.
   - Nano computer chips reduce the size of the microprocessor.
3. **BIO-MEDICALS:**
   - In the medical field, nanomaterials are used for disease diagnosis and drug delivery.
   - Bio-sensitive nanomaterials are used for tapping DNA, DNA chips.
   - Nano-structured ceramics interact with bone cells and hence used as implant material.
4. **ENERGY STORAGE:**
   - Nanoparticles are used in hydrogen storage devices.
   - Nano particles are used in refrigeration.
   - Metal nanoparticles are useful in fabrication of ionic batteries.
   - Nanoparticles improves the fuel economy