UNIT – IV NANO TECHNOLOGY

(1) what is nano material? (2M)

The materials having particles or constituents of nano scale dimensions, or one that is produced by nano technology is called nano materials.

(2) what is Nano Technology? (2M)

Nano Technology is the design, characterization, production and application of structures devices and systems by controlling shape and size at the nano meter scale.

(3) what is Nano Scale? (2M)

The materials are converted into 1 – 100nm range or 10^{-9} meters is called nano scale.

(4) Mention the examples of one-dimensional nano particles? (2M)

The example of one dimensional nanostructures like fibers, rods, tubes, wires, belts & rings.

(5) What is Nano Science? (1M)

Nano Science is the study of pheno -mena and manipulation of materials at atomic, molecular and macromolecular scales, where propertiy differ significantly from those at a large scale.

(1) Discuss the surface to volume Ratio? (3M)

Ans Nano Materials have a relatively larger surface area when compared to, the larger form of the material of same volume.

Ex: For a sphere of radius r, the surface area and its volume can be given as

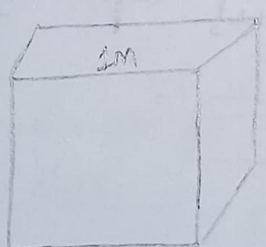
$$\text{Surface area} = 4\pi r^2$$

$$\text{Volume} = \frac{4}{3}\pi r^3$$

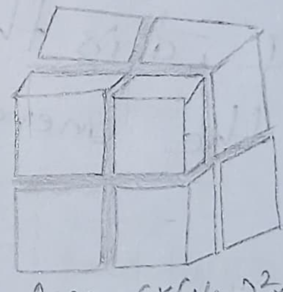
Now surface area to volume ratio $= \dfrac{4\pi r^2}{\frac{4}{3}\pi r^3} = \dfrac{3}{r}$

Thus we find that when the given volume is devided in to smaller parts, surface area increases:

(2) ~~Explain~~



Area = $6 \times 1m^2$
= $6m^2$



Area = $6 \times (1/2m)^2 \times 8$
= $12m^2$

Single box ratio

$$\frac{6m^2}{1m^3} = 6m^2/m^3$$

Smaller boxes ratio

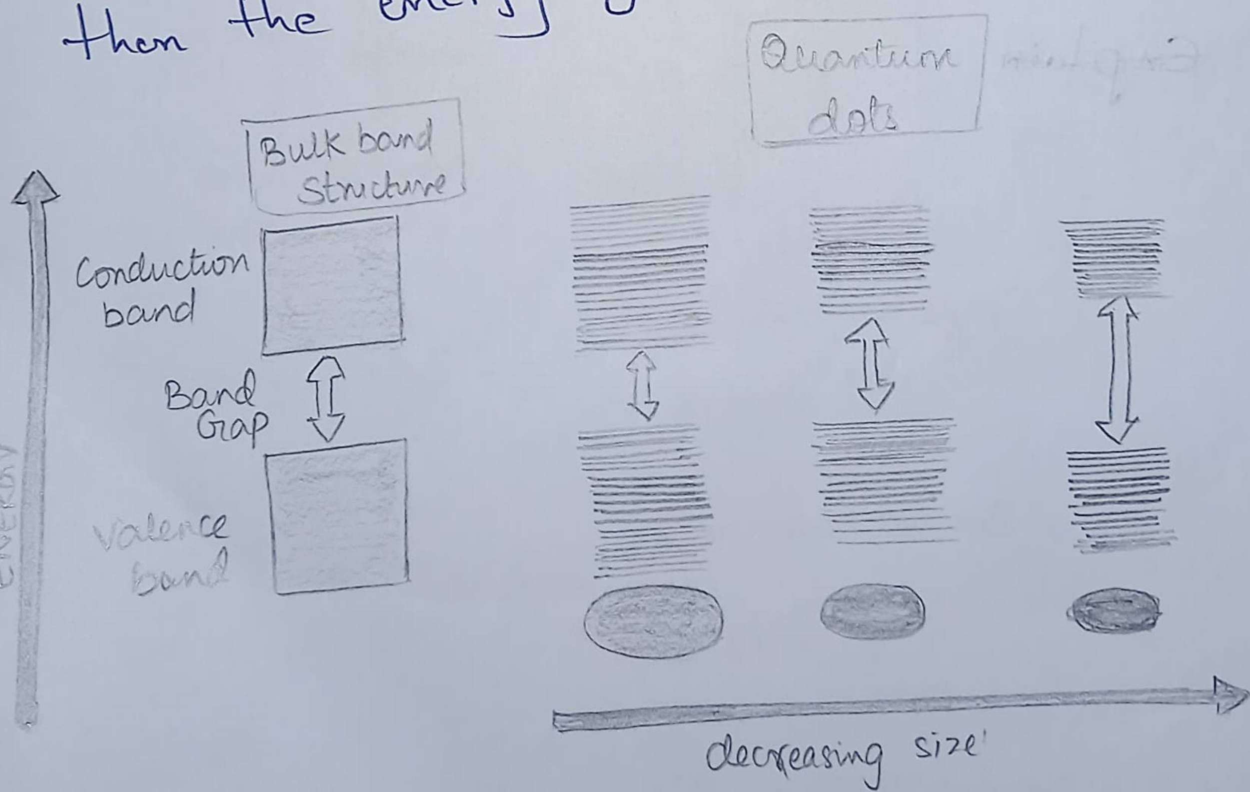
$$\frac{12m^2/3}{1m} = 12m^2/m^3$$

(2) Explain Quantum Confinement? (3M)

Ans) when the dimensions of a potential well or a Box concerned with a particle are reduced to the order of debroglie wavelength of electron then energy levels of electron change. This effect is called Quantum Confinement.

The physics at these dimensions is entirely diffrent. Actually when the size of the grains is reduced to nano level then overlapping of wave function and Quantum confinements occurs.

If d is the diameter of the grain size then the energy goes up by factor $1/d^2$.

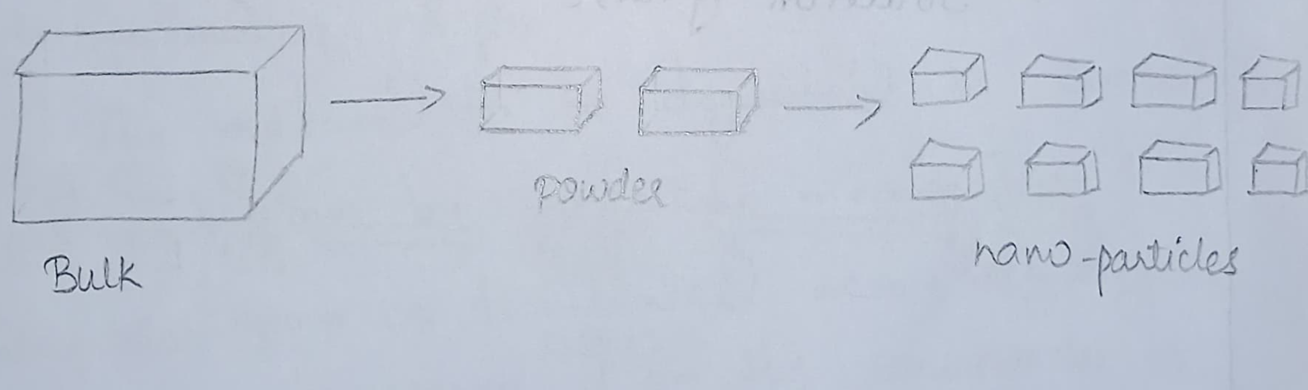


(3) Discuss the top-down Approach? (3M)

In Top-Down Approach the fabrication of bulk materials are broken into nano-sized particles. In this process there is no control over the size and the morphology of particles.

Some common methods of top-down approach are as follows.

1) Ballmilling Method
2) plasma arcing
3) Laser sputtering
4) Vapour deposition Method.



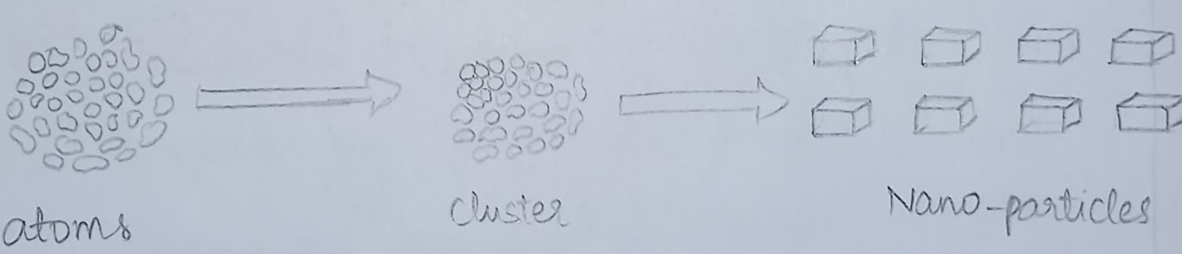
(4) Discuss the bottom-up approach? (3M)

Ans Bottom up approach refers to the building up of a material from the bottom i.e atom by atom, molecule by molecule (or) cluster by cluster.

Colloidal dispersion is a good example used of bottom-up approach in the synthesis of nano particles.

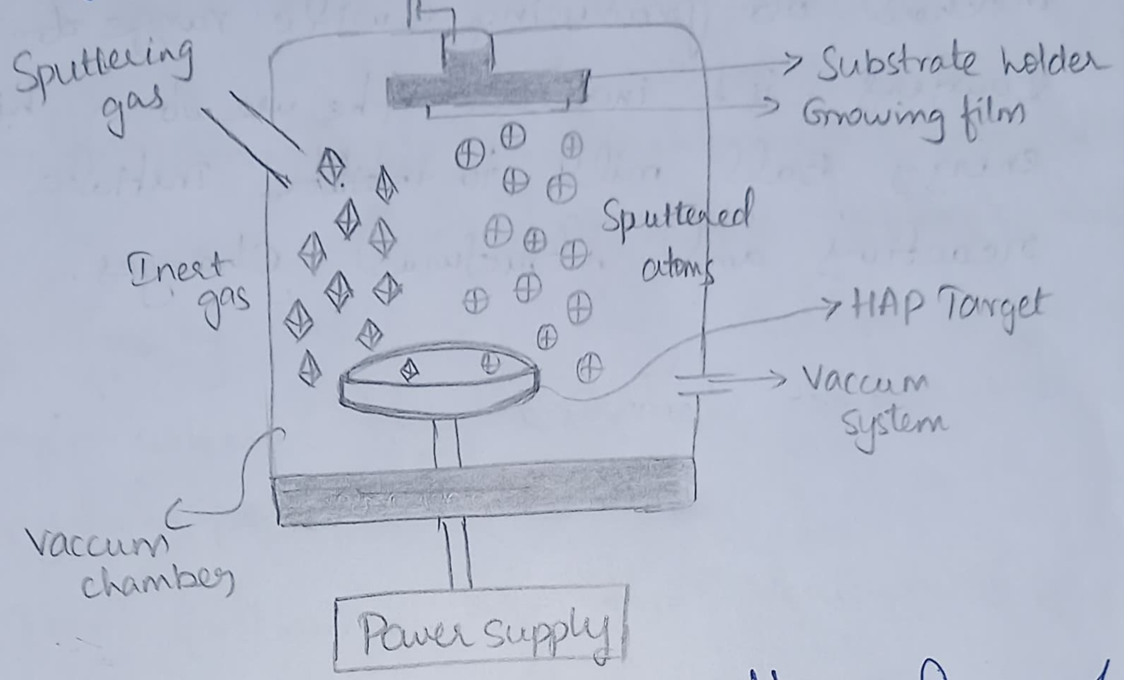
There are different methods used for the synthesis are:

1) sol-gel method
2) colloidal method
3) Electro deposition
4) Solution phase reductions.



5) Explain the physical Vapor deposition? (3M)

Ans) Physical vapor deposition is fundamentally a vaporization coating technique, involving transfer of material on an atomic level.



PVD is a process by which a thin film of material is deposited on a substrate according to following steps.

1) The material to be deposited is converted into Vapour by physical means
2) The Vapour is transported across a region of Low pressure from its source to the substrate.
3) vapour undergoes condensation on the substrate to form the thin films.

High Energy Ball mill method:

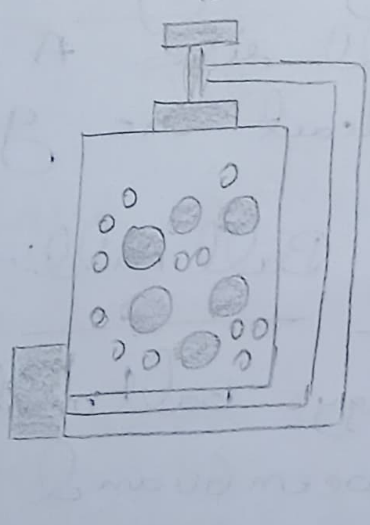
In high Energy Ball milling Mechano-~~cal~~-chemical processing is a novel & cost effective method of producing a wide range of nano Powders. It involves the use of a high energy Ball mill to ~~initiate~~ initiate chemical reactions and structural changes.

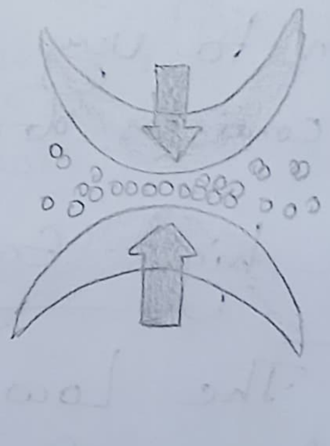
(1) Discuss the Ball milling Method Briefly? (5M)

Ball milling is a method to production of nano materials by the process of a mechanical crushing. The mills are equiped with grinding media composed of wolfram carbide (or) steel. small balls inside a drum-like cavity are rotated at high speeds and by gravity actions, they settle on a solid layer where they crushed into nano crystals.

The following are the various types of Ball milling methods.

1) Attrition Ball mill
2) Vibrating Ball mill
3) Planetary Ball mill
4) Low and high energy ball mill





Nano-TiAl, PdFe, CuFe

1) Attrition Ball mill:

The milling procedure takes place by a stirring action of a agitator which has a vertical rotator central shaft with horizontal arms. The rotation speed was later increased to 500 rpm. The milling temperature was in greater control.

2) Vibrating Ball Mill:

It is used mainly for production of amorphous alloys. The changes of powder and milling tools are agitated in the perpendicular direction at very high speed (1200 rpm).

3) planitary Ball Mill: planetary ball mills are smaller than common ball mills and mainly used in laboratories for grinding samples materials down to very small size. A planitary Ball mill consists of at least one graindling jar.

4) Low and high Energy Ball mill:-

The Low energy Ball mill succesfully run at speeds between 60 and 90 percent of critical speed.

(2) write the Applications of Nano Materials? (05M)

AH 1) Automotive Industry:-

Light weight construction, Painting as filler (or) Base coat, catalyst, Tires as fillers, Sensors.

2) chemical Industry:-

Fillers, adhesives, magnetic fluids, coating etc.

3) Engineering:-

Lubricant free bearings, wear protection for tools and machines like scratch resistant coatings.

4) Electronic Industry:-

Data Memory, Displays (like OLED), Laser diodes, Glass fibers, optical switches, Conductive coatings etc.

5) Medicine:-

Drug delivery system, Active agents, Medical rapid test, Anti microbial agents

Antimicrobial coatings, Agents in cancer therapy.

Energy storage:-

Fuel cells, Solar cells, Batteries, capacitors, Magnetic refrigeration etc.

Cosmetics:-

Sun protection creams, Lip sticks, skin creams, tooth pastes etc.

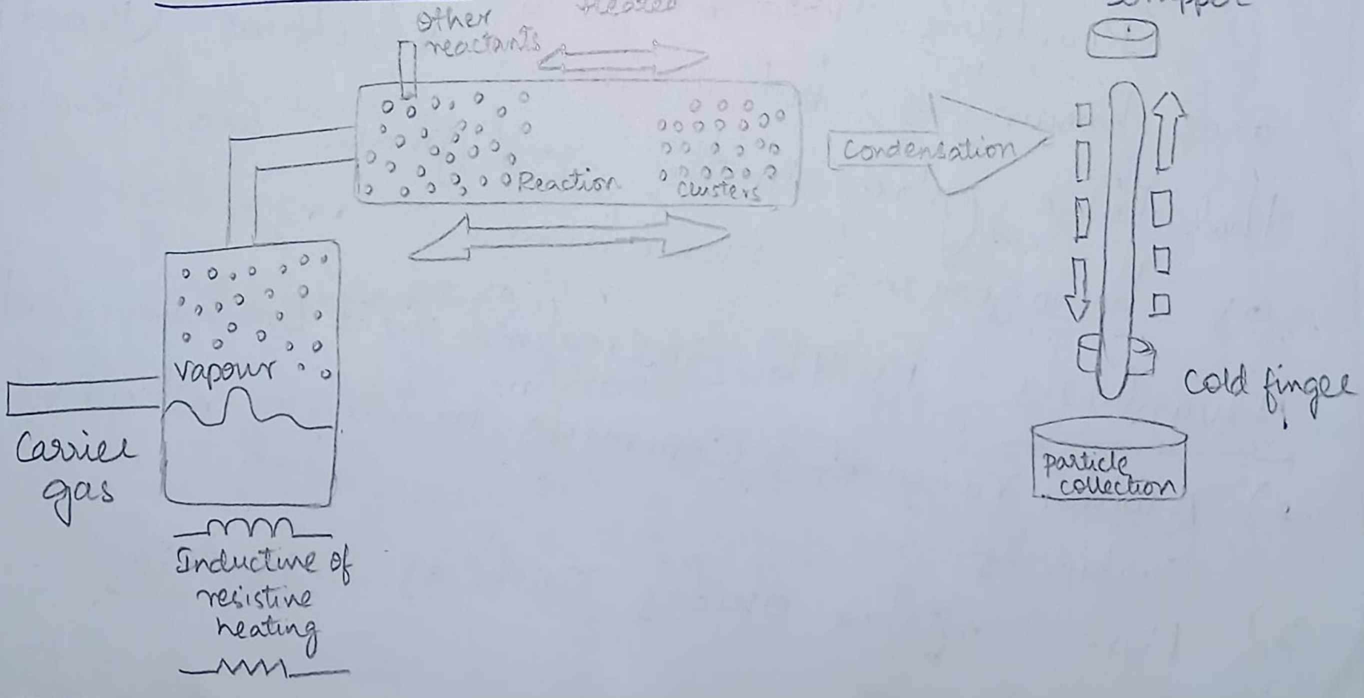
(3) Discuss the chemical vapour Deposition (CVD) Method briefly? (5M)

Nano particles are deposited from the gas Phase. Materials are heated to form a gas and then allowed to deposit on solid surface usually under vacuum condition.

The deposition may be either physical (or) chemical. In deposition by chemical reaction new product is formed. Nano powder of oxides and carbides of metals can be formed, if vapour of carbon (or) oxigen are present with the metal.

These materials include, Si, carbon fiber, Carbon nano fibers, filaments, carbon nano tubes, SiO_2, tungsten, silicon carbide.

~~Work~~ Construction :-



Working: A material often a metal is evaporated from a heated metallic source into a chamber which has been previously evacuated to about 10-7 torr and back filled with inert gas to a low preassure.

The metal vapour cools through collisions with the inert gas atoms, becomes supersaturated and then nucleates homogeneously, the particle size is usually in the range 1-100nm and can be controlled by varing the inert gas pressure.

The particles are collected and may be compacted to produce a dense nanomaterial.

The process of chemical vapor deposition, the reactant gases not only react with the substrate material at the wafer surface but also in gas phase in the reactor's atmosphere.

Reactions that take place at the substrate are known as heterogeneous reactions. Reactions that take place in the gas phase are known as homogeneous reactions.

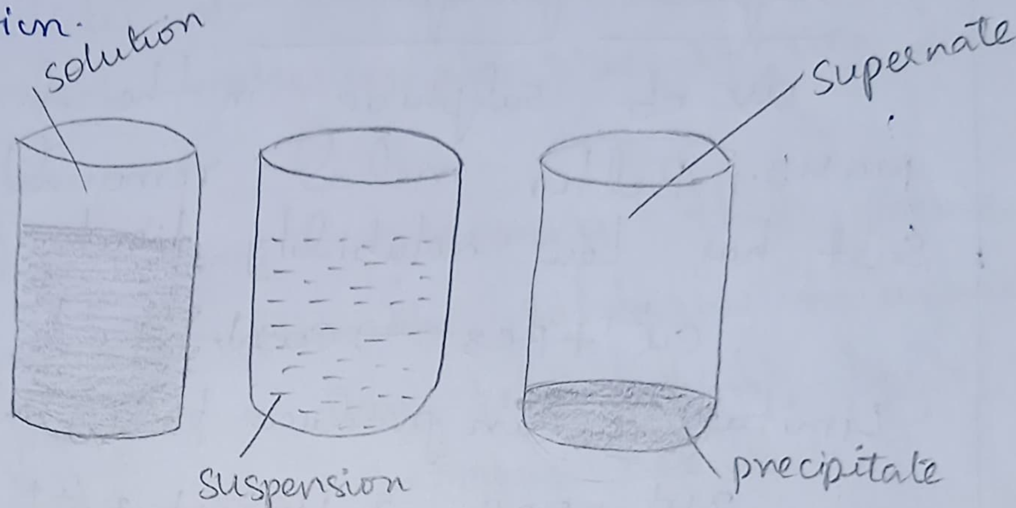
Advantages: 1) The increased yield of nanoparticles

2) A wider range of ceramics including nitrides & carbides.

3) More complex oxides such as $BaTiO_3$.

(4) Discuss the chemical (co) precipitation method with neat illustration? (5M)

Removal of metal ions from solution by changing the solution composition, thus causing the metal ions to form insoluble metal complexes is called chemical precipitation.



<u>chemical precipitation Types:</u>

1) Heavy metals removal
   Hydroxide precipitation (OH^-)
   sulphide precipitation (S^{2-})
   carbonate precipitation (CO_3^{2-})

2) Phosphorus removal
   Phosphate precipitation (PO_4^{2-})

3) Hydroxide precipitation
   Add lime (or) sodium hydroxide ($NaOH$) to waste stream to precipitate heavy metals

in the form of metal hydroxides.

$$Cd^{2+} + Ca(OH)_2 \rightarrow Cd(OH_2) \downarrow + Ca^{2+}$$

CaO in the form of slurry ($Ca(OH)_2$) while NaOH in the form of solution.

NaOH is easier to handle but is very corrosive will form floc and settle in clarifier.

4) <u>Sulphide precipitation</u> :-

use of sulphide in the form of FeS, Na_2S, NaHS. Better metal removal as sulphide salt has low solubility limit.

$$Cu^{2+} + FeS \rightarrow CuS \downarrow + Fe^{2+}$$

Limitations can produce $H_2S(g)$ at low pH

$$2H^+ + FeS \rightarrow H_2S + Fe^{2+}$$

At low pH reaction will proceed to the right. Thus require pH > 8 for safe sulphide precipitation.

<u>Applications</u>: 1) Removal of metals from waste stream.

Ex: Plating and polishing operations, mining, electronics manufacturing, steel manufacturing, including arsenic, barium, chromium, lead.

2) Treatment of hard water removal of Mg^{2+} & Ca^{2+}

3) Phosphorus removal

4) Making pigment

5) Removing salts from water in water treatment.

(5) Discuss the ~~Sol~~ Sol-Gel method briefly? (5M)

Sol-Gel is a chemical process used to make Ceramic and glass materials in the form of thin films, fibers (or) powders.

A sol is a colloidal (or) molecular suspension of solid particles of ions in a solvent. The colloids in which molecules of size ranging from 20nm to 100nm.

A gel is a semi-rigid mass that forms when the solvent from the sol begins to vaporate and the particles or ions left behind begins to join together in a continous network.

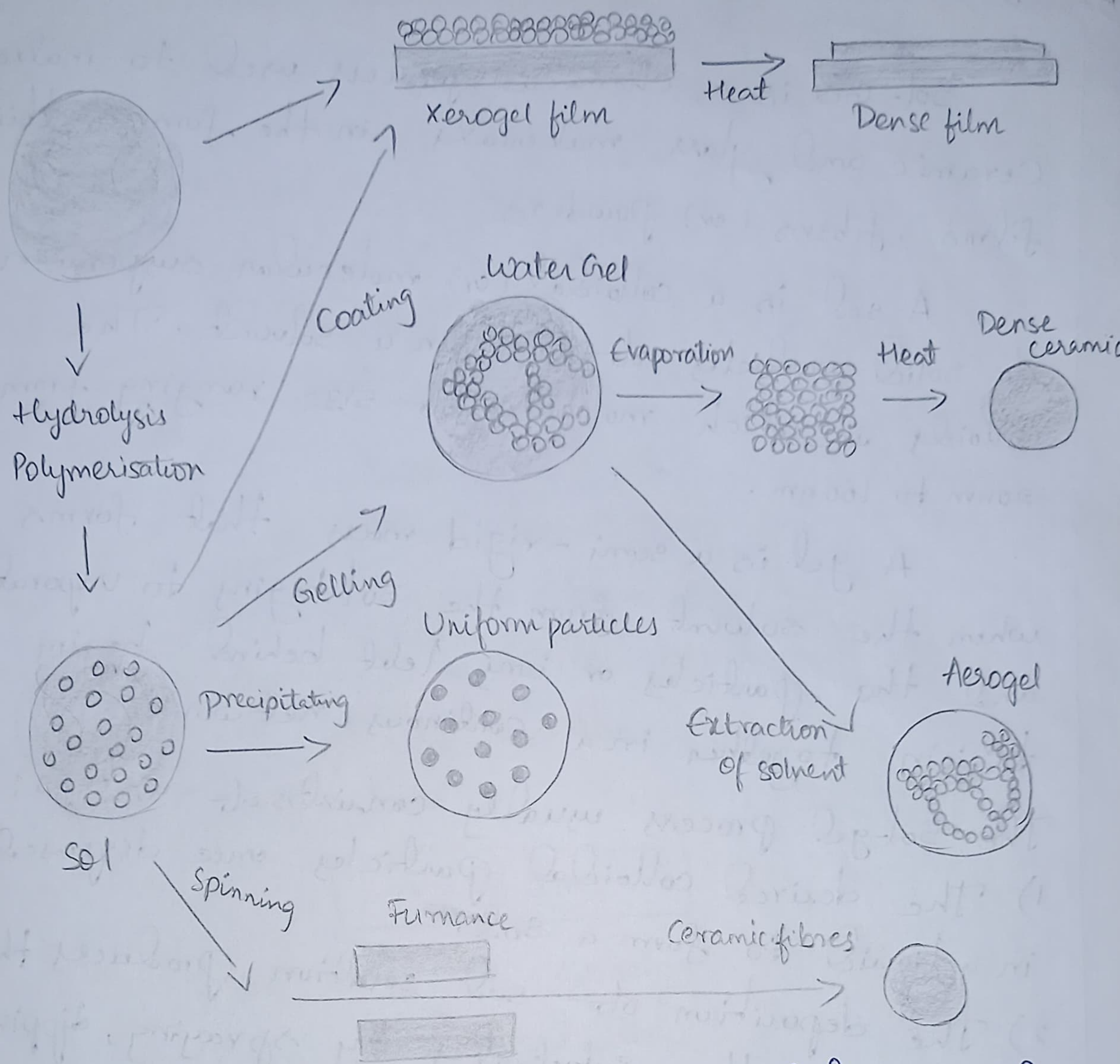
The Sol-gel process usually consists of 4 steps:

1) The desired colloidal particles once dispersed in a liquid to form a sol.

2) The deposition of sol solution produces the coatings on the substrates by spraying, dipping (or) spinning.

3) The particles in sol are polymerized through the removal of the stabilizing components & produce a gel in a state of a continous coating.

4) The final heat treatments pyrolyze the remaing organic (or) inorganic components



form an amorphous (or) crystalline coating.

The sol gel approach is easy and cheap low temperature technique that allows for the fine control on the product chemical composition like organic dyes and rare earth metals, can be introduced in the sol and end up in the final product finely dispersed.

1. Discuss the XRD technique for characterizing the Nano Materials ? (10M)

XRD is a very important experimental technique that has long been used to address all issues related to the crystal structure of solids including lattice constants and geometry, identification of unknown materials, orientation of single crystals, preferred orientation of polycrystalline defects, stresses etc. in XRD, a collimated beam of x-rays with a wavelength typically ranging from 0.7 to 2 A° is incident on a specimen and is diffracted by the crystalline phases in the specimen according to Bragg's Law.

$$\boxed{\lambda = 2d \sin\theta}$$

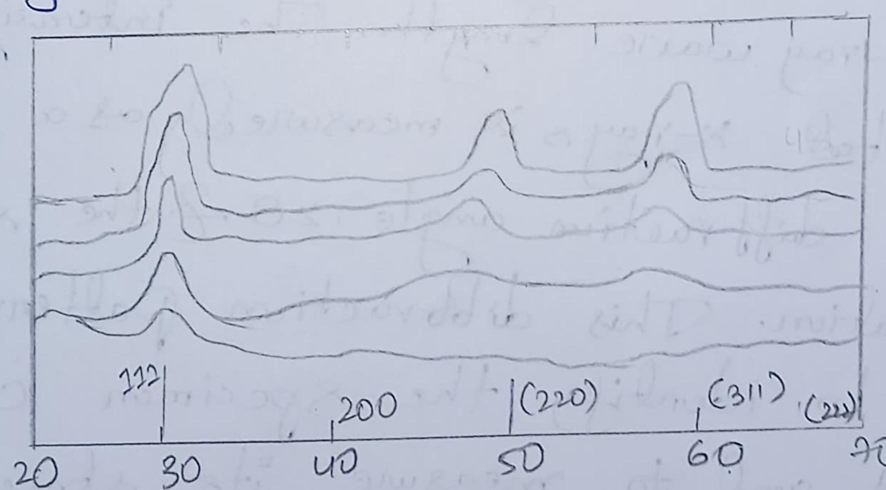
when d is the spacing between atomic planes in the crystalline phase and λ is the x-ray wave length. The intensity of the diffracted x-rays is measured as a function of the diffraction angle 2θ & the specimen orientation. This diffraction pattern is used to identify the specimen crystalline phases and to measure its structural properties.

XRD is non destructive and does not require elaborate sample preparation, which partly explains the wide usage of XRD method in materials charecterization.

If there is no inhomogeneous strain, the crystalline size D, can be estimated from the peak width with the scherrer's formula

$$\boxed{D = \frac{k\lambda}{B\cos\theta_B}}$$

where λ is the X-ray wave length, B is the full width of height maximum of a diffraction peak, θ_B diffraction angle, k is the scherr's constant of the order of unity for usual crystal. similarly the film thick ness of epitaxial and highly textured thin film can also be estimated with XRD.



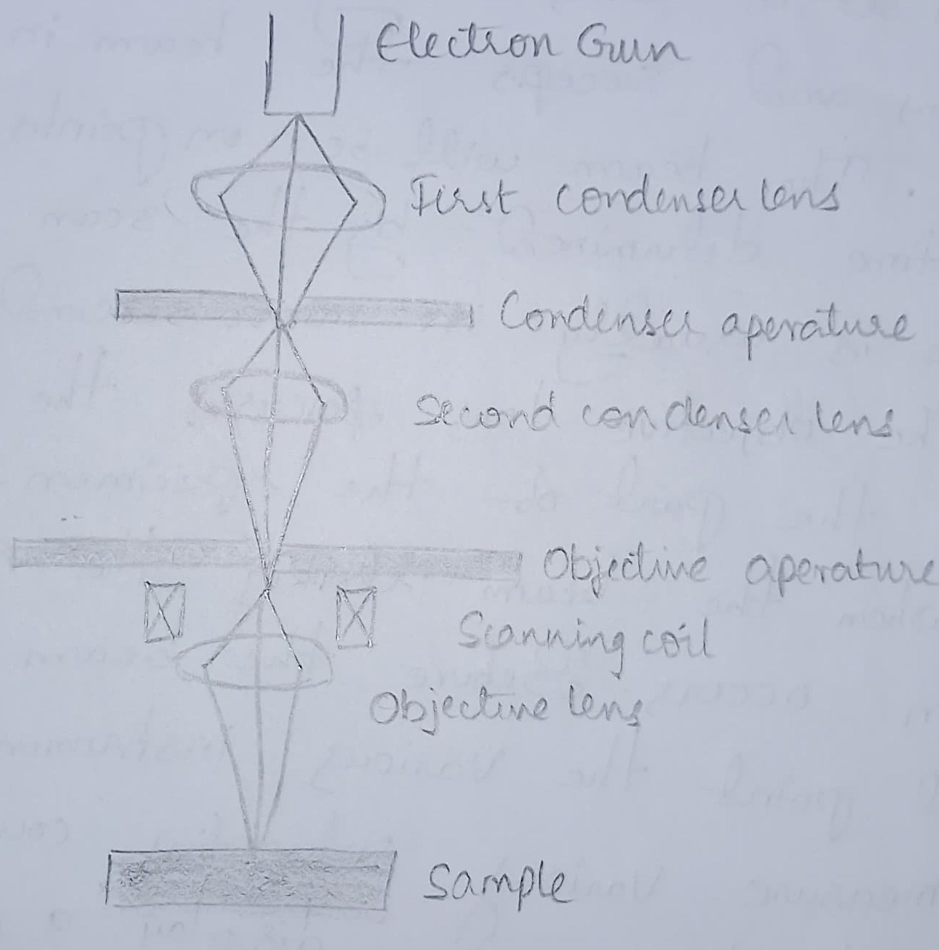
Advantages: The possibility of synthesizing non metallic, inorganic materials like glasses, glass ceramics (or) ceramic materials at very low temperatures.

Disadvantages: controlling the growth of the particle is difficulty.

(2) Discuss the scanning electron microscope with neat diagram? (10M)

Principle: A Scanning electron microscope is a type of electron microscope that images a sample by scanning with a high energy beam of electrons in a scan pattern.

Construction: The electrons interact with the atoms that make up the samples producing signals that contain information about the samples surface topography, composition and other properties.



<u>working</u> : 1) The electron gun produces a stream of monochromatic electrons.

2) The electron stream is condensed by the first condenser lens. It works in conjuction with the condenser aperture to eliminate the high-angle electrons from the beam.

3) The second condenser lens forms the electrons into a thin light coherent beam.

4) objective aperture further eliminates high angle electrons from the beam.

5) A set of coils acting as electro static lens scans and sweeps the beam in a grid fashion. The beam will be on points for a period of time determined by the scan speed. Dwell time is usually in micro second range.

6) The objective lens focuses the scanning beam onto the part of the specimen.

7) when the beam strikes the sample interaction occurs. Before the beam to the next dwell point the various instruments housed to measure various interacting count the number of interactions and display a pixel on a ~~display a pixel on~~ CRT. The interactions and display number is determined by the interaction number, More interactions give a brighter pixel.

8) This process is repeated until the grid scan is finished and then repeated. The entire pattern can be scanned 30 times per second.

Applications:

(1) Topography
(2) Morphology
(3) Composition
(4) crystallographic Information.

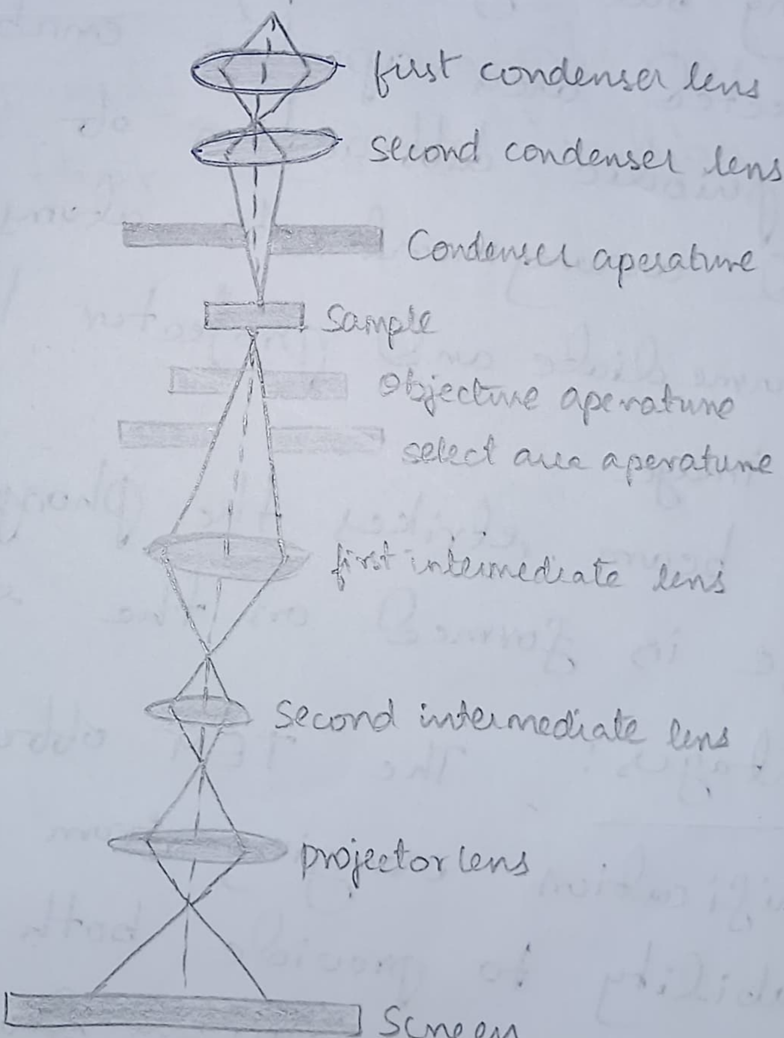
(3) Discuss the TEM with neat illustration? (10M)

Principle:

The Transmission electron Microscope (TEM) forms an image by Accelerating a beam of electrons that pass through the specimen.

Working: In TEM electrons are accelarated to 100 keV or higher (up to 1 Mev), projected onto a thin specimen (Less than 200 nm) by means of the condenser lens system, penetrate the sample thickness either undeflected (or) deflected.

Construction:



→ The Electron gun produces a stream of mono chromatic electron.

→ This stream is focused to a small coherent beam by the first and second condense lens.

→ The condenser aperture knocks off high angle electrons.

→ The beam strikes the specimen.

→ The transmitted portion is focused by the objective lens into an image.

→ objective aperture enhances the contrast by blocking out high-angle diffracted electrons.

→ Selected area aperture enables to examine the periodic diffraction of electrons by an ordered arrangment of atoms in the sample.

→ Intermediate and projector lenses enlarge the image

→ The beam strikes the phosphor screen and image is formed on the screen.

Advantages: The TEM offers are the high magnification ranging from 50 to 10^6 and its ability to provide both image and diffraction information from a single sample.

Applications :-

1) <u>Morphology</u> : The size, shape and arrangement of particles as well as their relationship to one another on the scale of atomic diameters

2) <u>Crystallographic information</u>: The arrangement of atoms in the specimen and their degree of order, detection of atomic scale defects a few nanometers in diameter.

3) <u>Compositional Information</u> : The elements and compounds the sample is composed of and their relative ratios.