Nanomaterials

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Introduction

Terminology

History

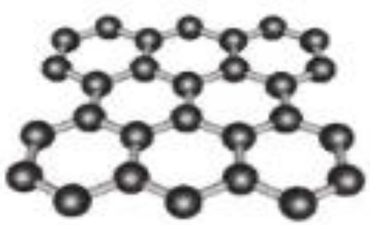
Terminology

What is Nanoscience?

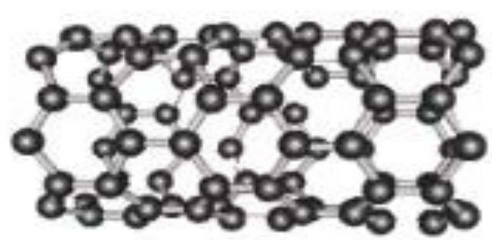
When people talk about Nanoscience, many start by describing ***things***

- Physicists and Material Scientists point to ***things*** like new nanocarbon materials:

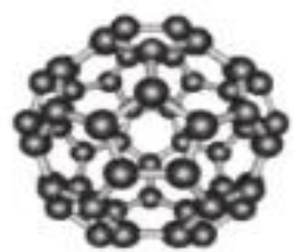
- They effuse about nanocarbon's strength and electrical properties



Graphene



Carbon Nanotube



C60 Buckminster Fullerene

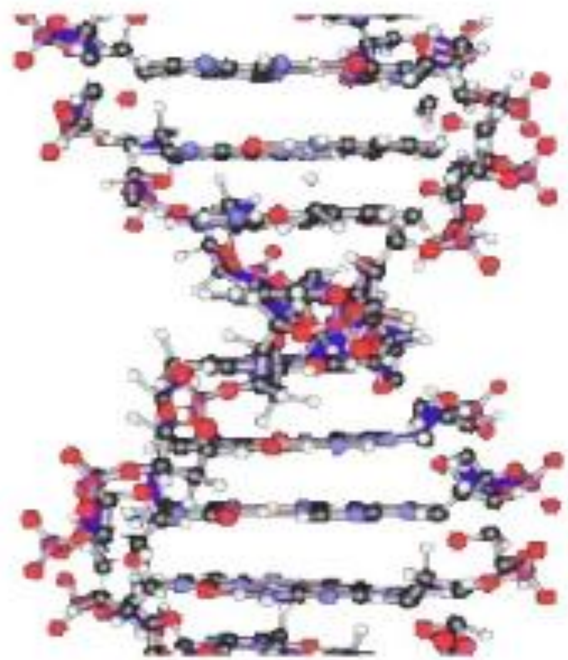
"We're not in Kansas Anymore!" - A Hands-on Introduction to Nanoscience

Nano

Biologists counter that nanocarbon is a recent discover

THEY'VE been studying DNA and RNA for *much* longer

(And are *already* using it to transform our world)



Terminology

Indeed, they are all about the size of a nanometer:

Nano = 10^{-9} = 1/ 1,000,000,000 = 1 / Billion **A nanometer is about the size of ten atoms in a row**

This leads to ONE commonly used definition of nanoscience:

*Nanoscience is study of nanometer size **things** (?)*

Why the question mark? Because what is so special about a nanometer?

A micrometer is ALSO awfully small:

Micro = 10^{-6} - 1/1,000,000 = 1 / Million

A micrometer (or "micron") is ~ size of light's wavelength

What is Nanotechnology

- While many definitions for nanotechnology exist, the [National Nanotechnology Initiative] NNI calls it "nanotechnology" only if it involves all of the following:

  1. Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range.

  2. Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.

  3. Ability to control or manipulate on the atomic scale.

History

- Michael Faraday 1857
- Rohrer 1981
- Don Eikler and Erhard Shcucizer 1990
- Curl, Kroto, Smalley 1985
- Iijima 1991
- Gem and Nevoselve 2004

Optical properties of Nanomaterials

Semiconducting nanoparticles

Metallic nanoparticles

Semiconducting nanoparticles

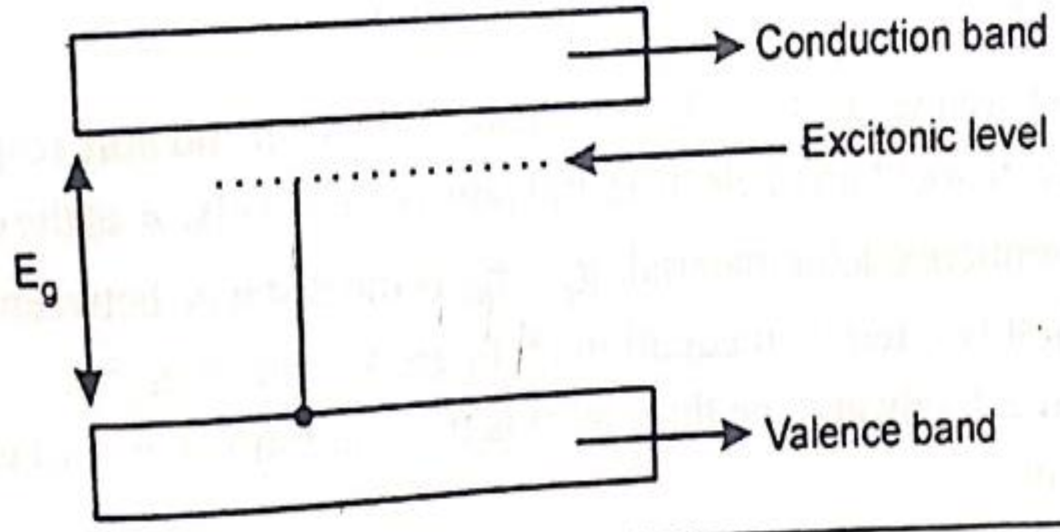


Fig. 5.1 : Energy level diagram for semi conductor

Semiconducting nanoparticles

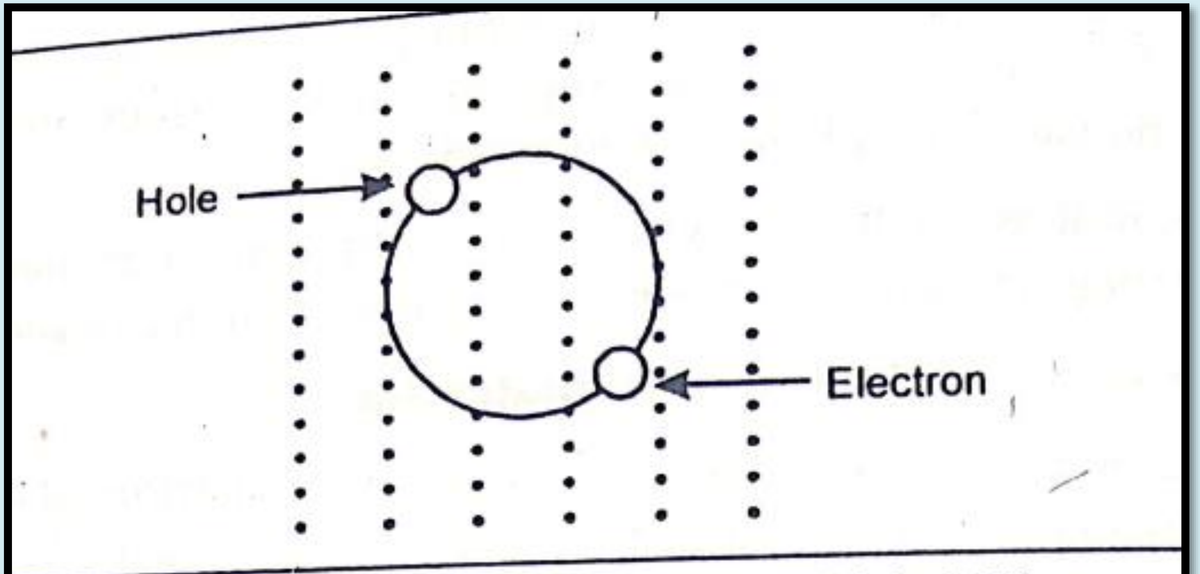


Fig. 5.2 : Exciton (electron-hole pair) in lattice

Semiconducting nanoparticles

The Hamiltonian for Mott-Wannier exciton is given as,

$$\widehat{H} = \frac{P_e^2}{2m_e} + \frac{P_h^2}{2m_h} - \frac{e^2}{\in |r_e - r_h|}$$

Then the Bohr radius of such exciton is given as,

$$r_B = \frac{h^2 \in}{e^2}\left[\frac{1}{m_e} + \frac{1}{m_h}\right]$$

r_B is the Bhor radius of exciton.

Semiconducting nanoparticles

$$\Delta E = E_g^{\text{effective}} = \frac{h^2\pi^2}{2R^2}\left[\frac{1}{m_e} + \frac{1}{m_h}\right] - \frac{1.8e^2}{4\pi \epsilon_0 \epsilon R} + \text{Potential energy} \quad \dots (5.3)$$

where, $\Delta E = E_g^{\text{effective}}$ = effective band gap of particle of radius R

= exciton energy

R = the radius of the cluster in which exciton can be created

ϵ = dielectric constant of medium

ϵ_0 = dielectric constant of free space.

The Total Energy Gap (ΔE) = $h\nu$ = $E_{g(bulk)} - E_{exciton}$

Characterization of Semiconducting nanoparticle

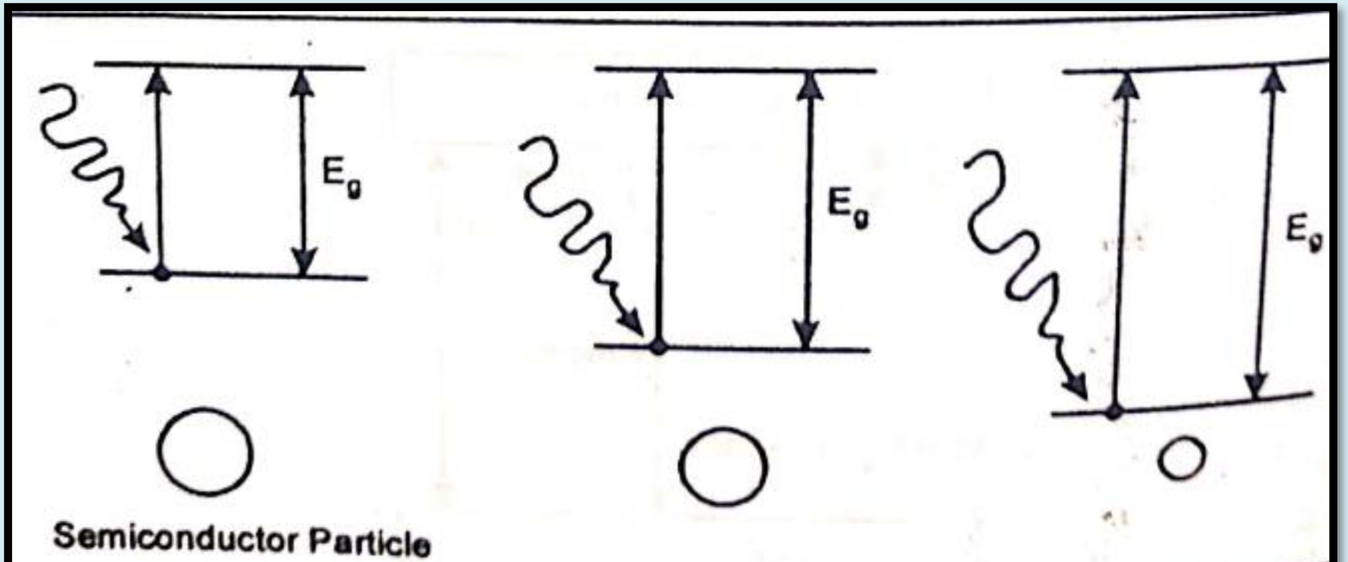


Fig. 5.4 : Increasing energy gap with decreasing particle size

Characterization of Semiconducting nanoparticle

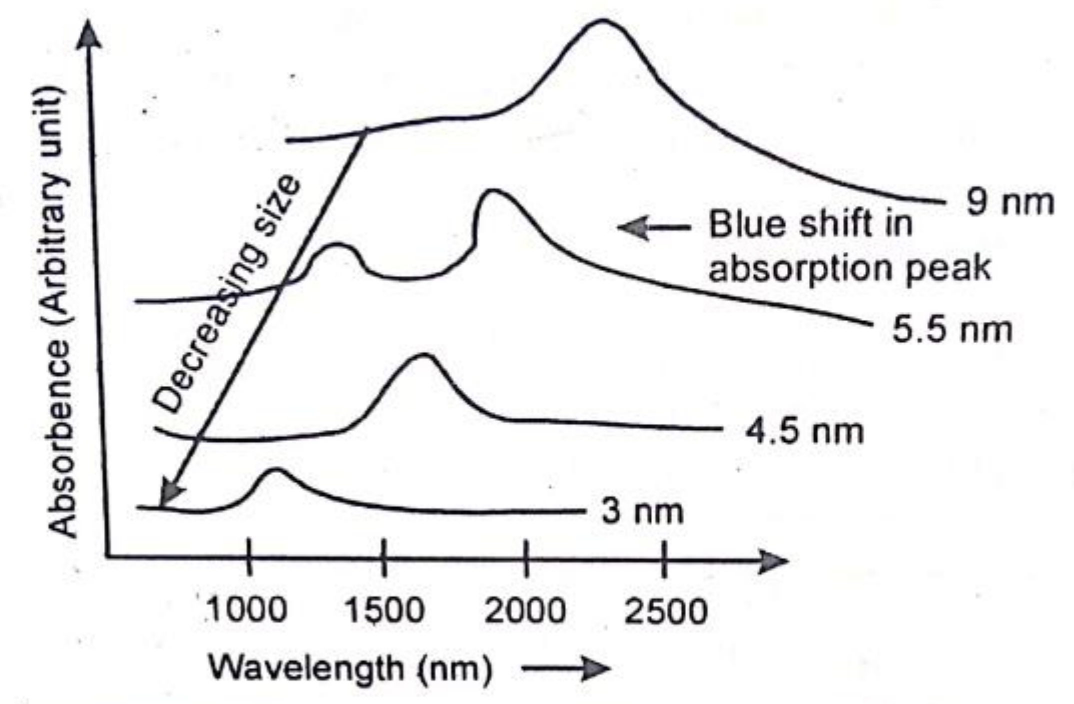


Fig. 5.5 : Blue shift absorption peak for PbSe

Metallic Nanomaterials

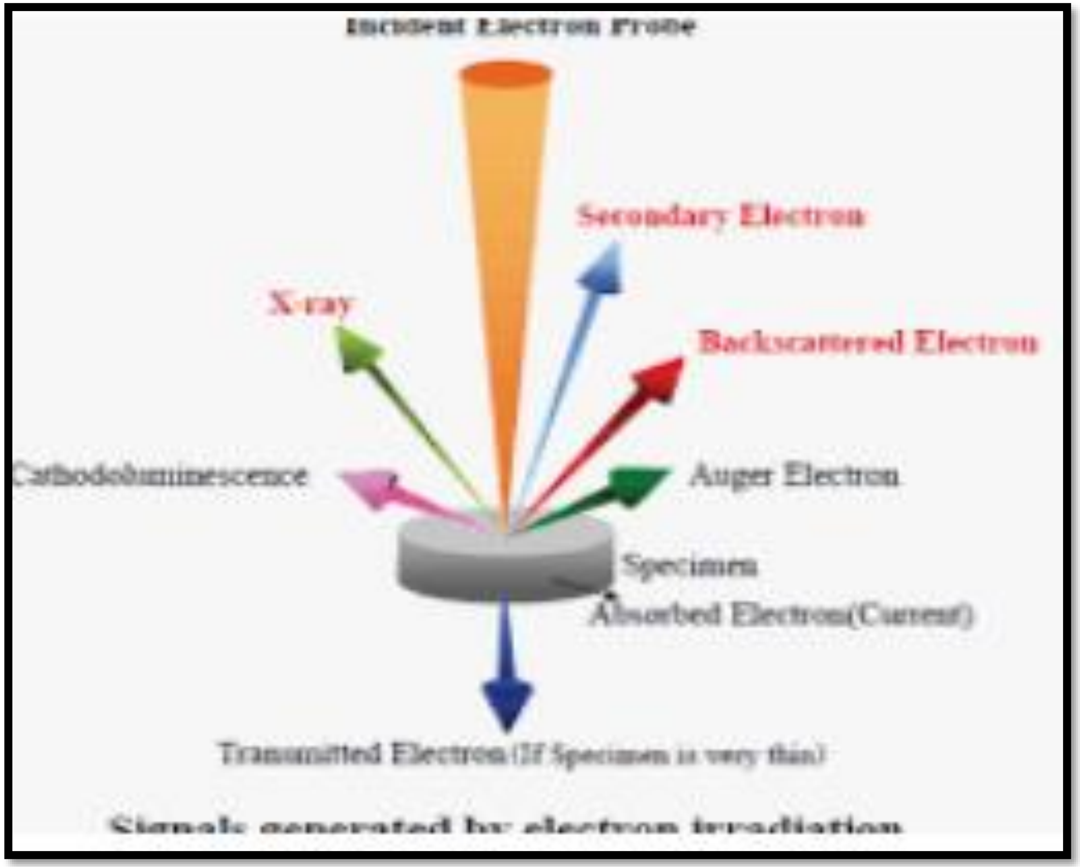
Surface Plasma Resosnace (SPR)

Chracterization and Fabrication

- Characterization methods:-

XRD | FTIR | SEM
TEM | AAS | ESR

Electron Microscopy



Electron Microscopy

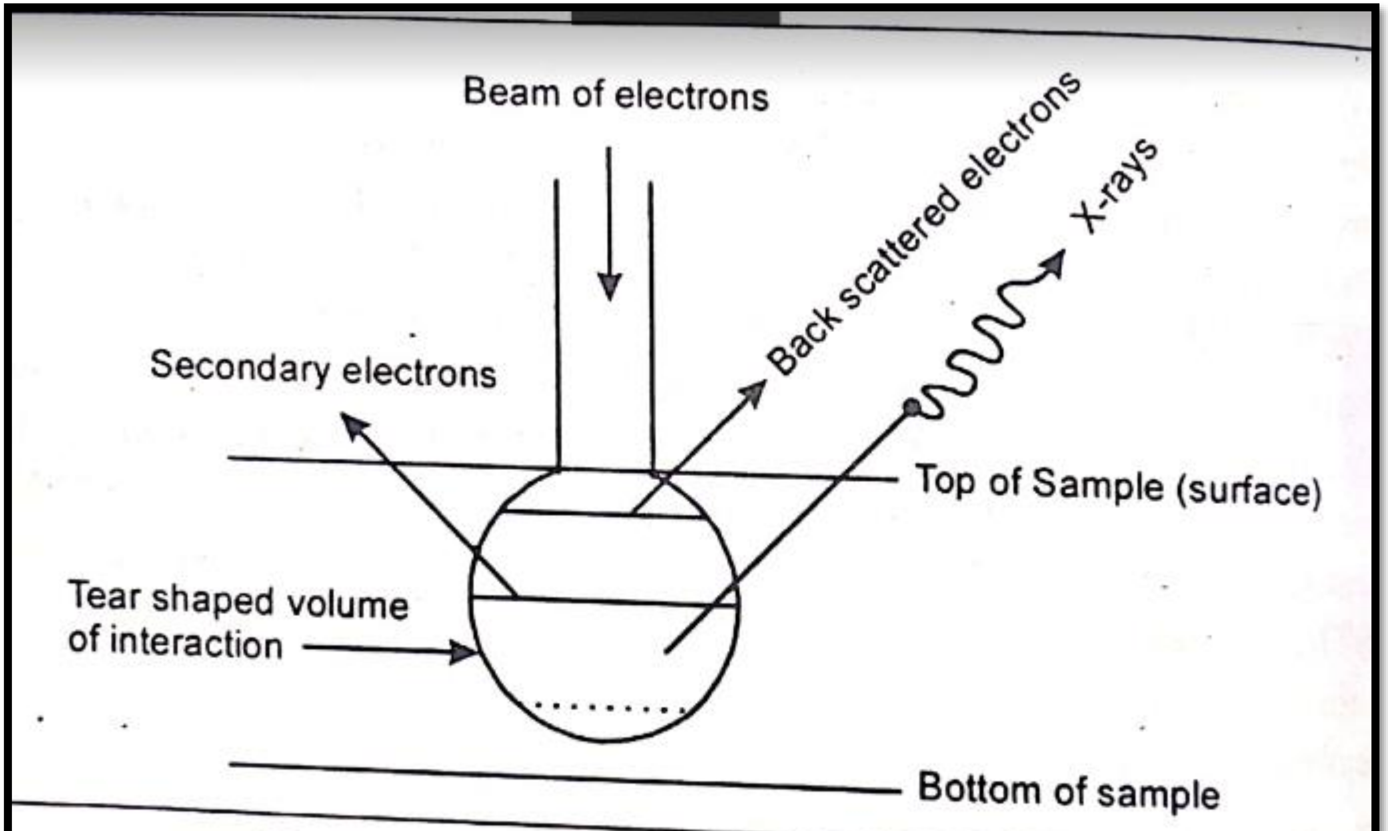
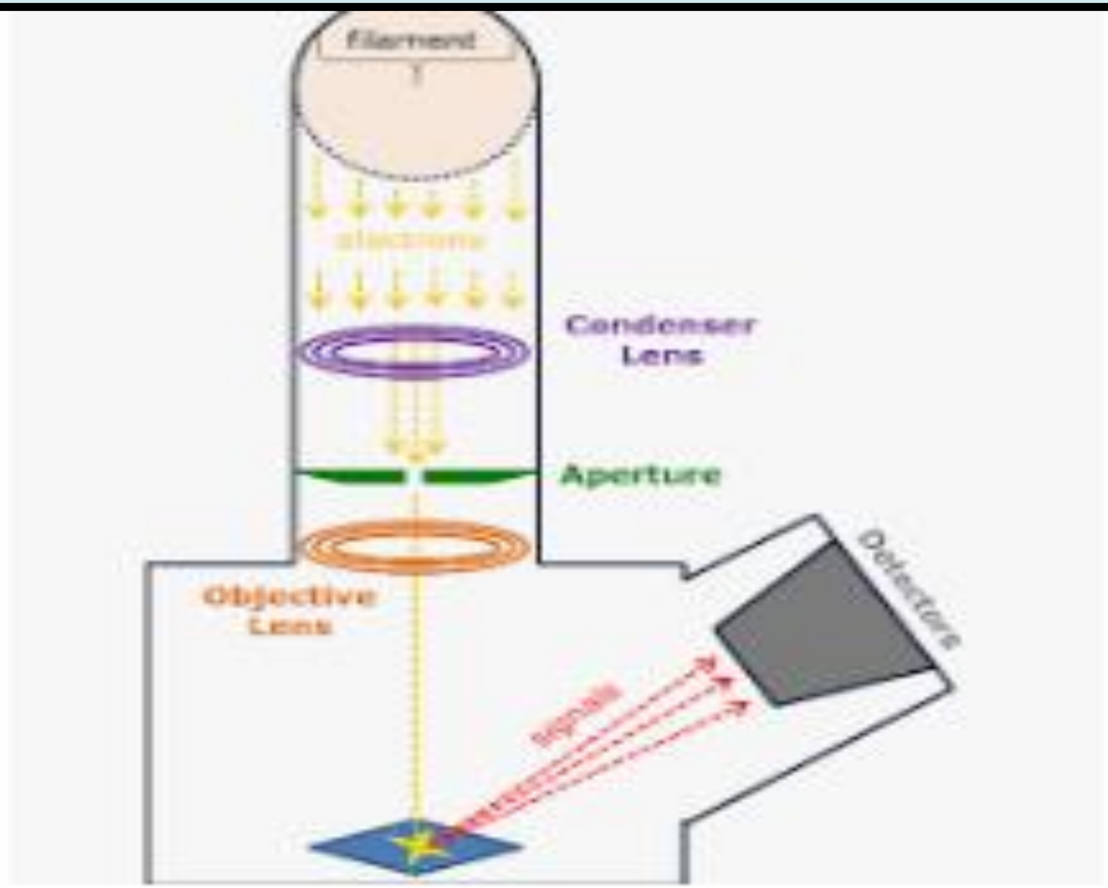


Fig. 5.8 : Interaction of electron with sample

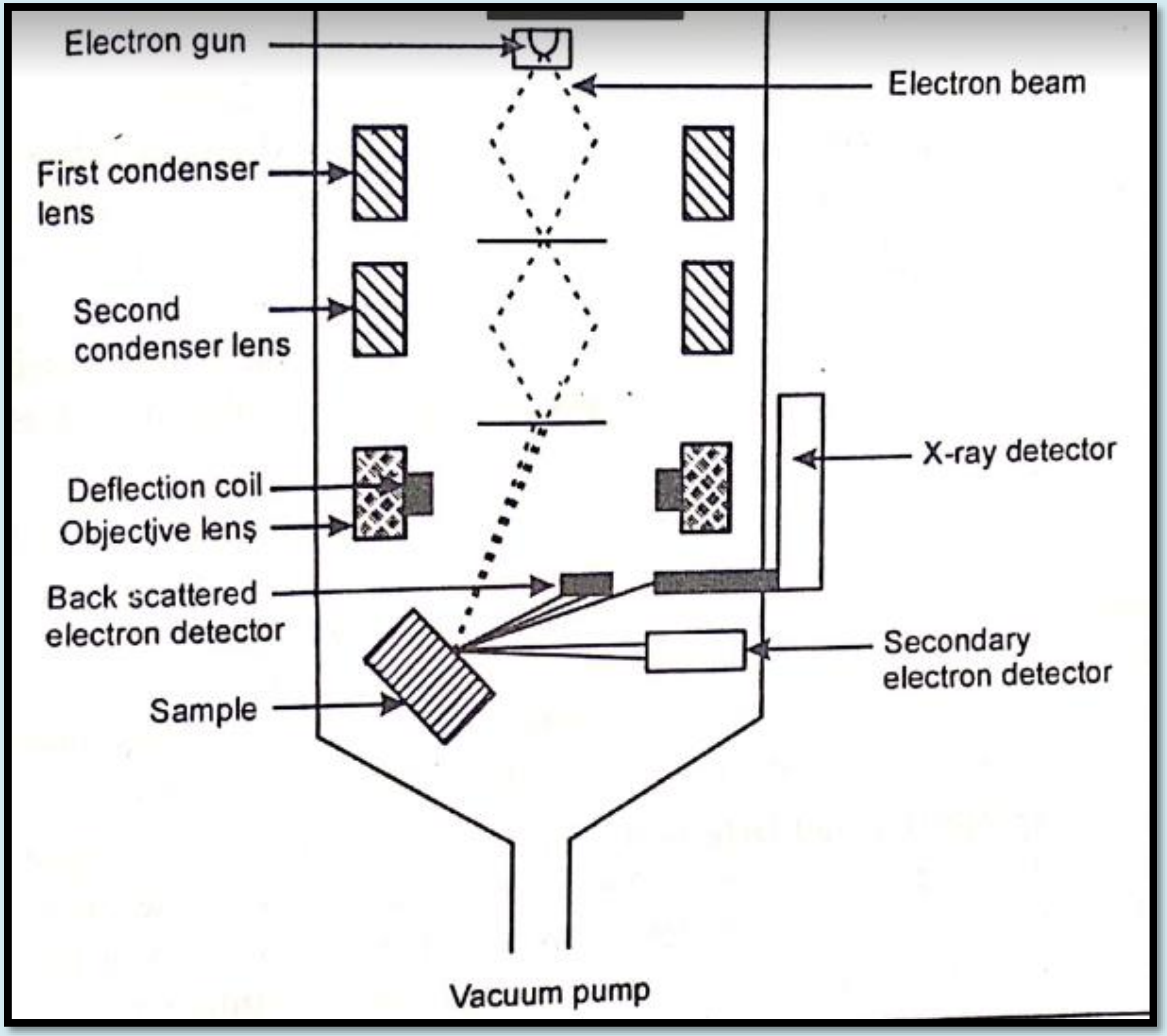
Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM)



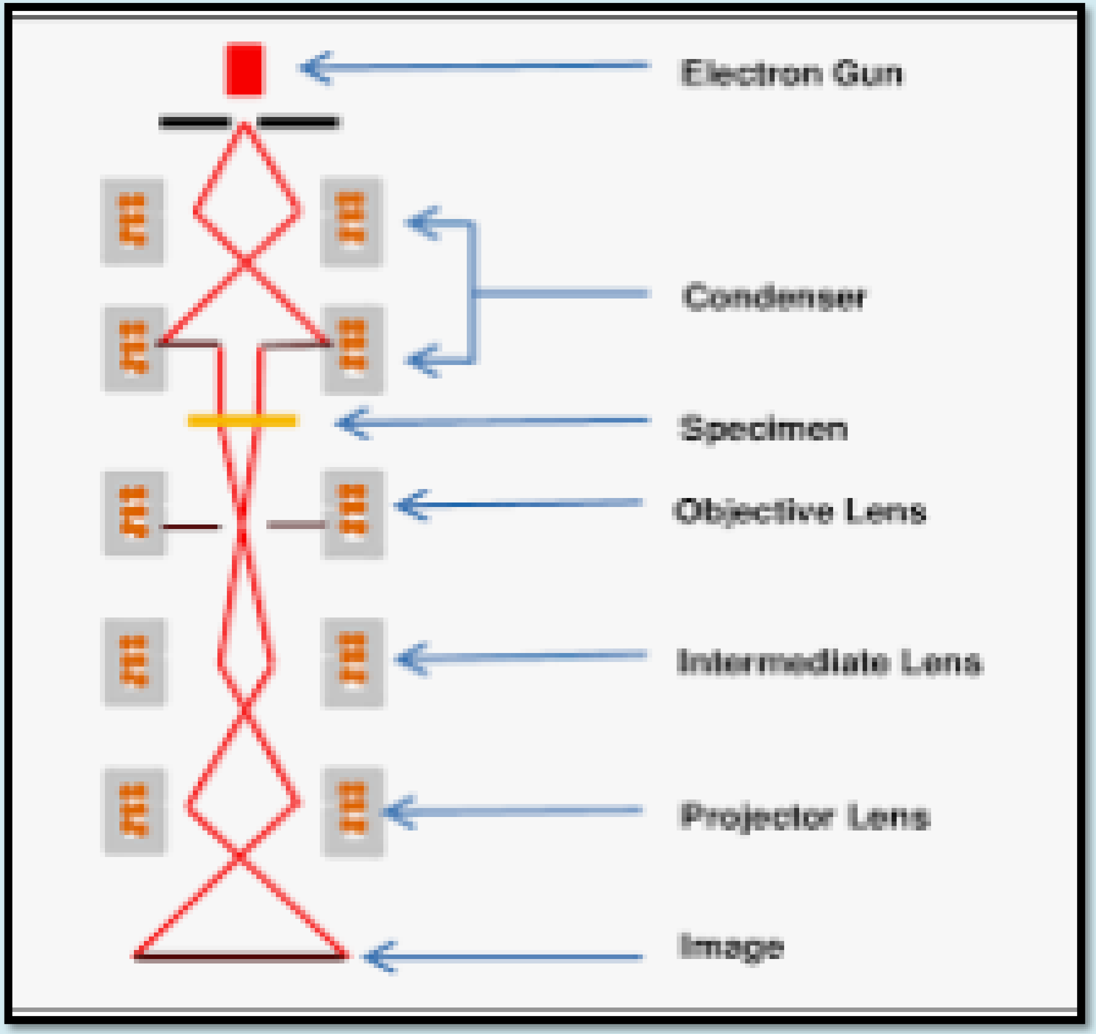
Scanning Electron Microsco...

Scanning Electron Microscopy (SEM)



Transmission Electron Microscopy (TEM)

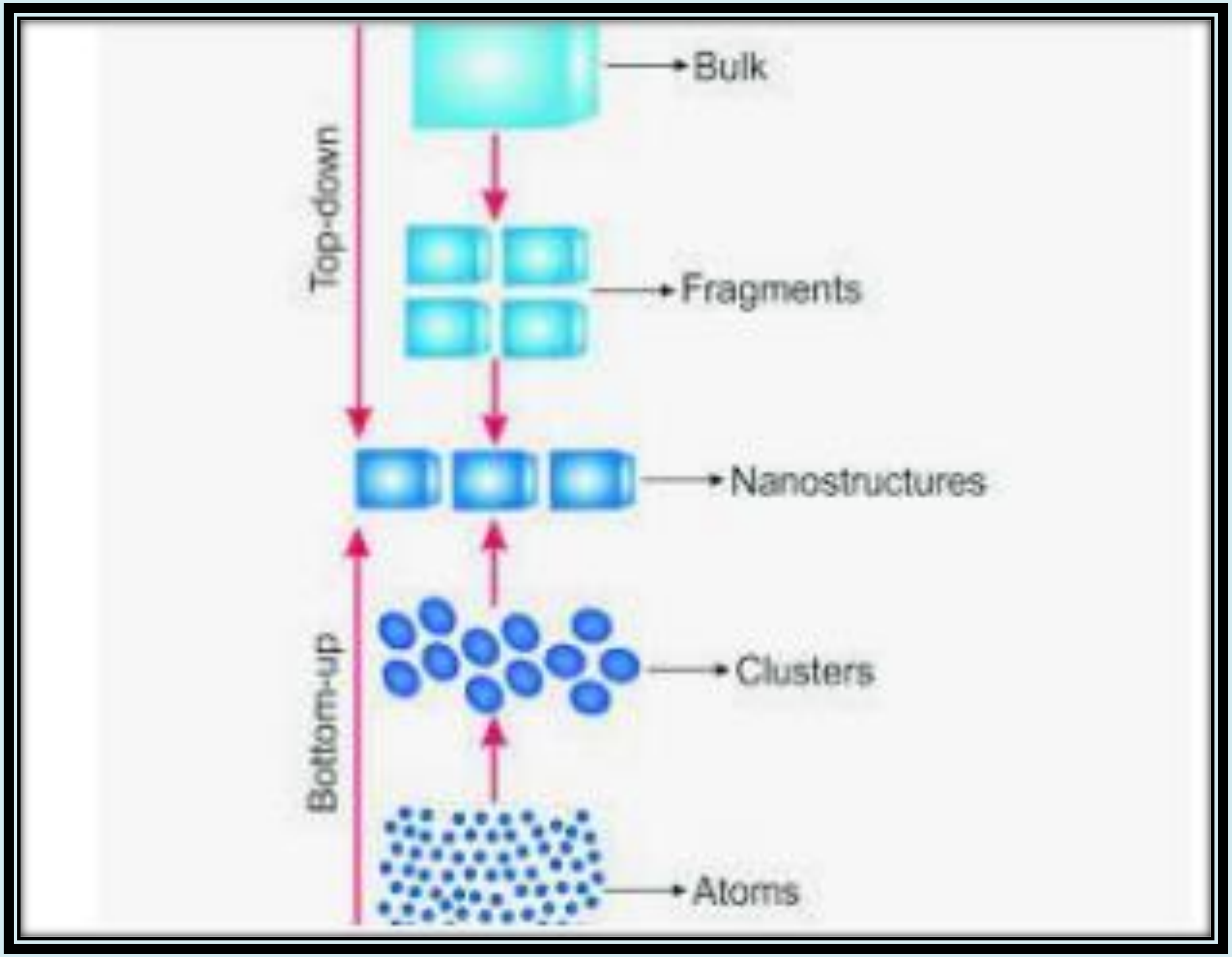
Transmission Electron Microscopy (TEM)



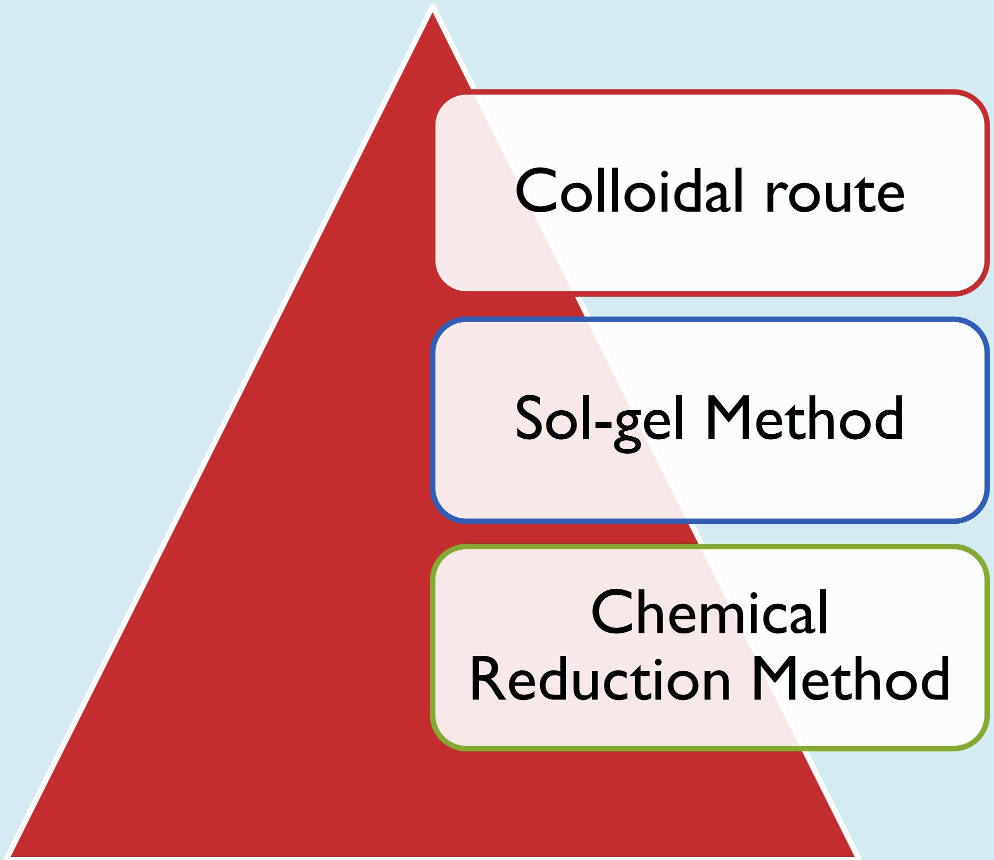
Difference between SEM and TEM

SEM Scanning Electron Microscope	TEM Transmission Electron Microscope
(i) In SEM electron beam scans over surface of sample.	(i) In TEM electron beam passes through thin sample.
(ii) Sample can be of any thickness and is mounted on stub.	(ii) Specially prepared thin samples are supported on TEM grids.
(iii) Specimen stage is in the chamber of the bottom of column.	(iii) Specimen stage is at the half way down the column.
(iv) Image is of the surface of the sample.	(iv) Image is two dimensional projection of the sample.
(v) Image shown on TV monitor.	(v) Image shown on fluorescent screen.

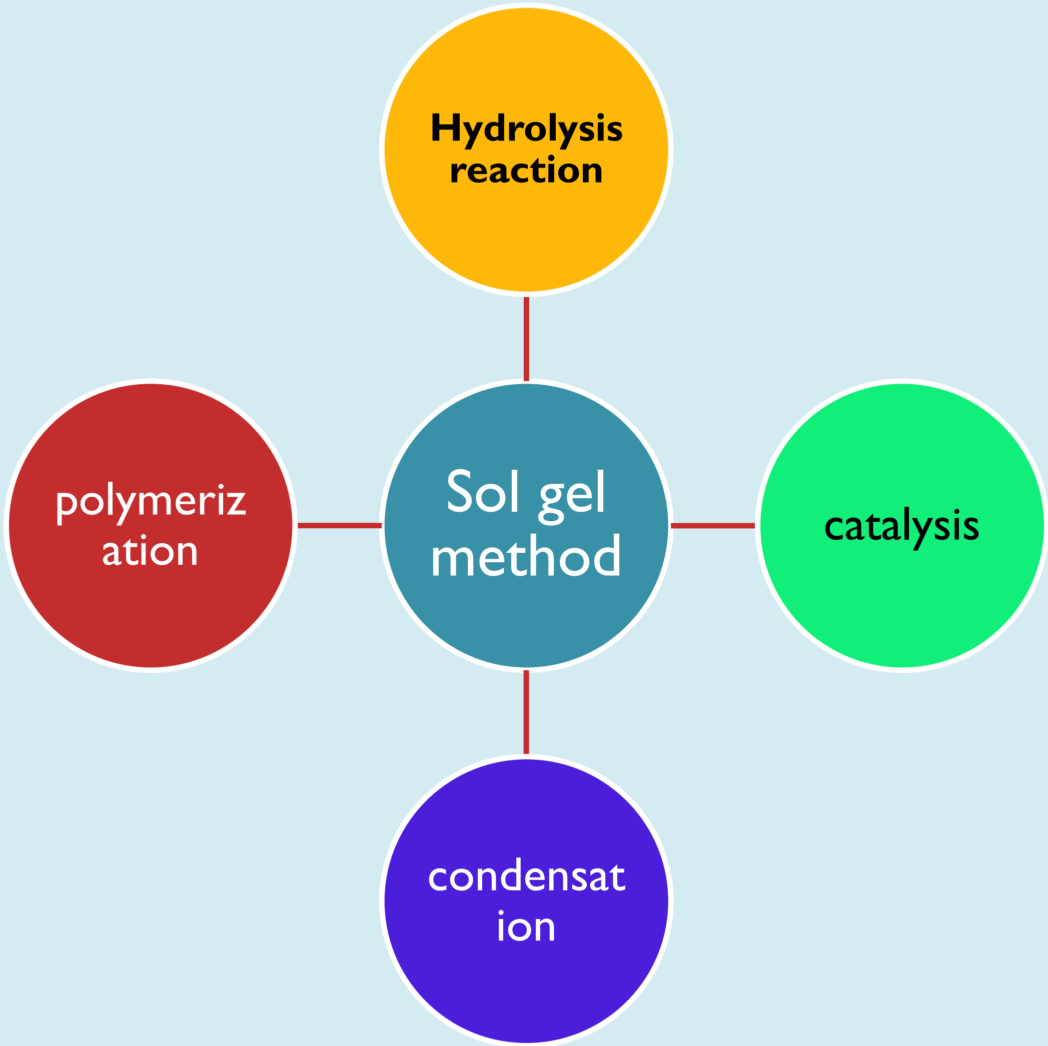
Top up and bottom down fabrication



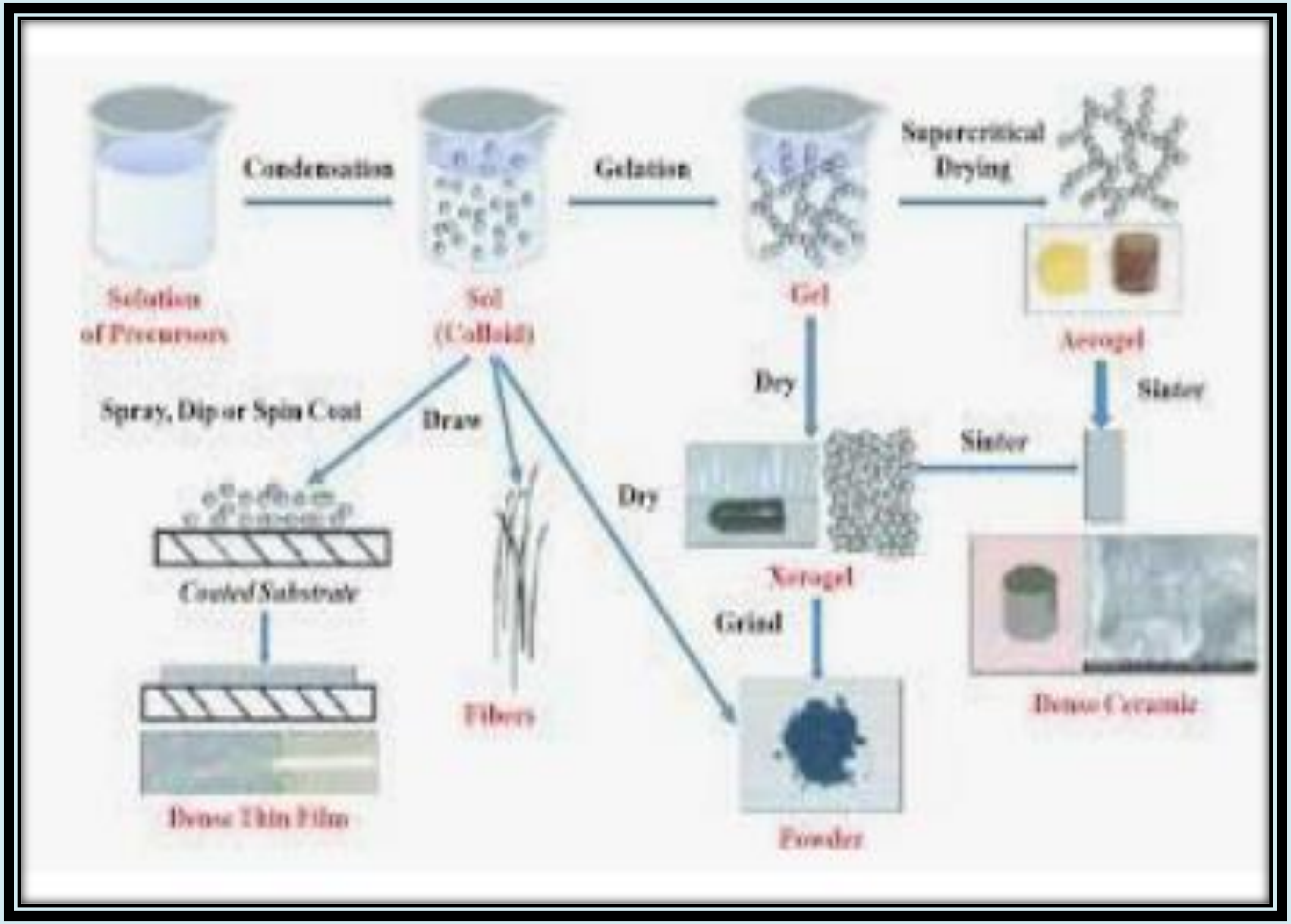
Top up and bottom down fabrication



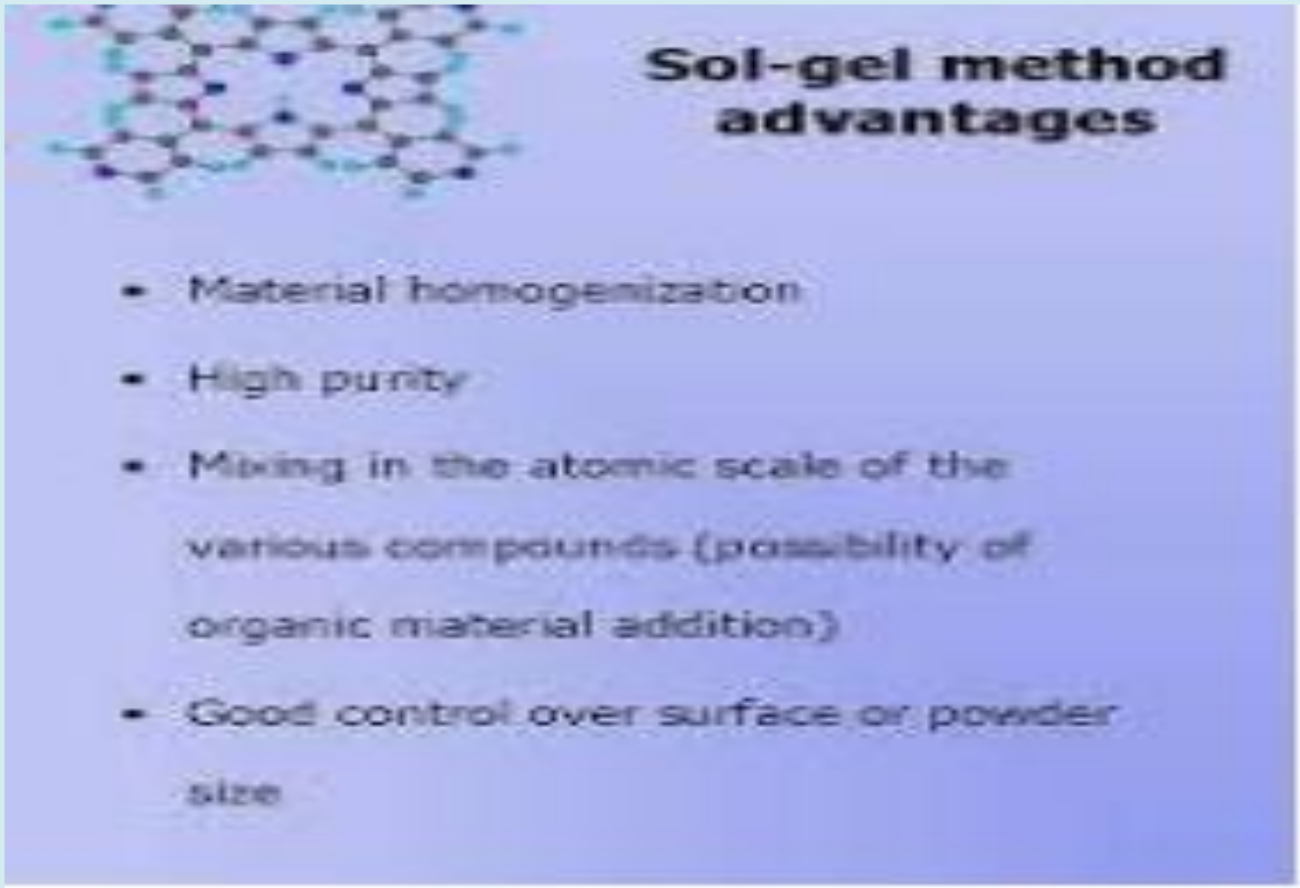
Sol-gel Method



Sol-gel Method



Sol-gel Method



Colloidal Route

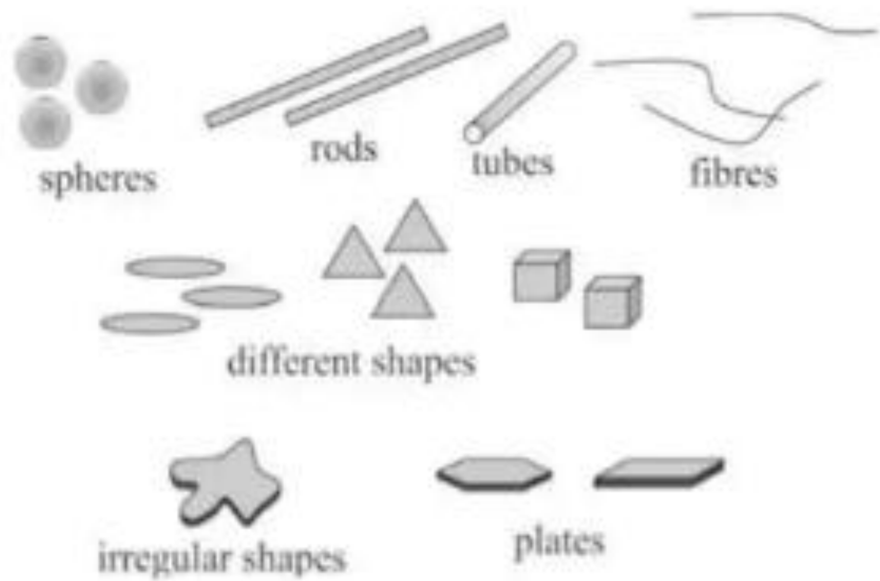
Colloids

- As in many cases nanoparticles synthesized by chemical methods form what is known as 'Colloids'
- A class of materials, in which two or more phases (solid, liquid or gas) of same or different materials co-exist with the dimensions of at least one of the phases less than a micrometre (μm) is known as colloids.

- Nanomaterials are a subclass of colloids, in which one of the dimensions is in nanometre range.
- Examples of Colloids: liquid in gas (fog), liquid in liquid (fat droplets in milk), solid in liquid (tooth paste), solid in solid (tinted glass), gas in liquid (foam).

Colloidal Route

- Colloids may be particles, plates or fibres



Applications of Nanaomaterilas

- 1. Electronics
- 2. Energy
- 3. Industry
- 4. Health care
- 5. Food Agriculture
- 6. Textile
- 7. Environment
- 8. Cosmetics
- 9. Domestic Appliances

Colloidal Route

- Colloids may even form networks. For example aerogels are a network of silica colloidal particles, pores of which are filled with air.

Colloidal Route

Advantages

- Simple and Inexpensive, less instrumentation compared to many physical methods
- Low temperature (<350ºC) synthesis
- Doping of foreign atoms (Ions) is possible during synthesis by either coupling, coating, chemical capping.
- Large quantities of the materials can be obtained with a variety of sizes and shapes.
- Materials are obtained in the form of liquid but can be easily converted into dry powder or thin films
- Self assembly or patterning is possible