LAQ'S

Q1) What is meant by super conductivity? Write few properties of super conductors?

Q2) Classify super conductors?

Q3) Elucidate BCS theory and write short notes on High Temperature Super conductors?

Q4) Illustrate Meissner effect? Write few applications of super conductors.

Q5) what are nano materials? Describe few properties of nanomaterials.

Q6) Enunciate the synthesis of nano material by using ball milling method.

Q7) explicate the synthesis of nano materials by using pulse laser deposition method.

SAQ'S

Q1) Differentiate between low temperature super conductors and high temperature super conductors?

Q2) Prove that super conductors exhibit perfect diamagnetism?

Q3) what are Cooper pairs?

Q4) Explain Meissner effect?

Q5) Write short notes on BCS theory?

Q6) List out applications of super conductors?

Q7) Discuss the characterisation technique of XRD.

Q8) Confer the characterisation technique of EDS.

Q9) Write the application of nano material.

Laq's

Q1) What is meant by superconductivity? Write few properties of superconductors.

Superconductivity:

Superconductivity is a phenomenon observed in certain materials where they **completely lose all electrical resistance** when cooled below a certain critical temperature (usually very low, close to absolute zero). When in the superconducting state, the material can conduct electric current **without any energy loss.**

Properties of Superconductors:

1. **Zero Electrical Resistance:**
    - Below the critical temperature, superconductors allow electric current to flow **without any resistance**, resulting in **no power loss.**
2. **Meissner Effect (Perfect Diamagnetism):**
    - Superconductors **expel all magnetic fields** from their interior when cooled below the critical temperature, a phenomenon known as the **Meissner effect.**
3. **Critical Temperature (Tc):**
    - Each superconducting material has a specific temperature below which it becomes

known as the Meissner effect.

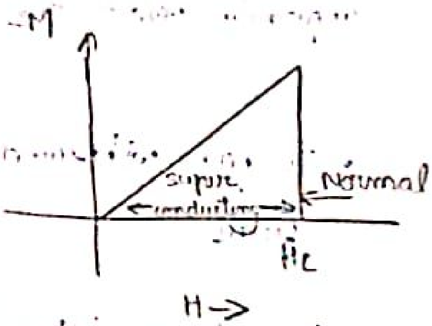
3. **Critical Temperature (Tc):**
    - Each superconducting material has a specific temperature below which it becomes superconducting. This is called its **critical temperature (Tc)**.
4. **Critical Magnetic Field:**
    - If an external magnetic field greater than a certain critical value is applied, the material **loses its superconducting properties**.
5. **Persistent Current:**
    - In a closed superconducting loop, current can flow **indefinitely without any decrease**, even if the power source is removed.
6. **Quantum Effects:**

5. **Persistent Current:**
   - In a closed superconducting loop, current can flow **indefinitely without any decrease**, even if the power source is removed.
6. **Quantum Effects:**
   - Superconductors exhibit macroscopic quantum phenomena like **flux quantization** and **Josephson effect**.
7. **Applications:**
   - Used in **MRI machines, maglev trains, particle accelerators**, and in **quantum computers**.

Types of Superconductors

2)

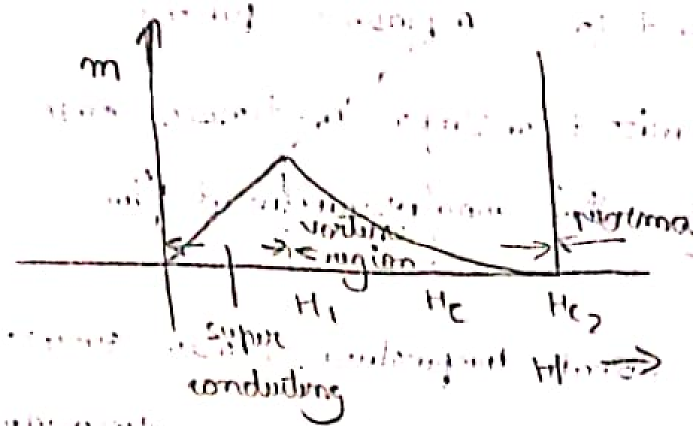
1) Type I Superconductor / Soft Super conductor



1. They exhibit complete meissner effect
2. They possess only one critical field
3. They are not used for commercial purpose
4. Due to low value of critical field makes these materials unsuitable to use in high field superconductivity magnets
5. The maximum critical field is 0.1 wb/m².
6. The critical field Hc is relatively low
7. it exhibits only one critical magnetic field

• Example : Lead (Pd), Mercury (Hg), Al, Zn etc

2. Type 2 Super Conductor / Hard Super Conductor



1. They do not show complete Meissner effect
2. They posses two critical fields
3. They are used for commercial purpose
4. Due to high value of critical field makes these material suitable to use in high field superconducting magnets.
5. The maximum critical field is 30 wb/m^2.
6. The value of H_{c_2} is very large
7. Ex Examples : Nb_3 (Neobium), Lead - Indium alloy etc

8.

3) Enumerate BCS Theory? Write short notes on different types of Super conductors.

Ans:- BCS Theory [Bordum - Cooper - Schreiffer Theory]

BCS theory explains Superconductivity in conventional (low-T_c) Superconductors.

* At low temperature, electrons from copper pairs due to interaction with lattice vibration (photons)
* Cooper pair condense into a single quantum state that can move without resistance.
* This pairing opens up air energy gap in the electronics states, preventing scattering.

High Temperature Superconductors – Short Note:

High temperature superconductors (HTS) are materials that exhibit **superconductivity** at temperatures **above the boiling point of liquid nitrogen (77 K or -196°C)**. Unlike traditional superconductors which require cooling with liquid helium (4.2 K), HTS are more practical and cost-effective due to cheaper cooling.

Key Points:

- Discovered in **1986** by **Bednorz and Müller**, who found superconductivity in a barium-lanthanum-copper oxide (a type of cuprate).
- Most HTS are **ceramic copper oxides (cuprates).**

Müller, who found superconductivity in a barium-lanthanum-copper oxide (a type of cuprate).

- Most HTS are **ceramic copper oxides (cuprates)**.
- Common example: $\mathbf{YBa_2Cu_3O_7}$ **(YBCO)** with Tc ≈ 92 K.
- They are used in **magnetic levitation (maglev trains)**, **power cables**, **MRI machines**, and **high-speed electronics**.
- Still under research due to challenges like **brittleness**, **complex manufacturing**, and understanding the **exact mechanism** behind high-Tc superconductivity.

Conclusion:
HTS offer great potential for future technologies, especially in energy transmission and magnetic applications, due to their higher operational temperatures and zero resistance.

4) 1. Meissner Effect

$T > T_c$, $H > H_c$ $T < T_c$, $H < H_c$

When a weak magnetic field is applied to the Super conductor below transition temperature or critical temperature, the magnetic flux ~~expense~~ expels out of the Specimen or material, this phenomenon. is said to be Meissner Effect.

Meissner Effect is the Standardized technique to know the super conductivity of the material. The mathematical relation b/w the critical magnetic field and the critical temperature that is

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

where

$H_c(T)$: Critical magnetic field at temperature (T)

$H_c(0)$: Critical magnetic field at zero ~~temp~~ (T)

T_c = Critical ~~ma~~ temperature or transition temperature.

Prove that super conductor exhibit perfect dia...

Applications of super conductors

1. **MRI Machines** – Superconducting magnets for high-resolution medical imaging.
2. **Maglev Trains** – Frictionless, high-speed travel using magnetic levitation.
3. **Particle Accelerators** – Superconducting coils guide particle beams at high energies.
4. **Quantum Computing** – Superconducting qubits enable ultra-fast data processing.
5. **SMES Systems** – Superconducting Magnetic Energy Storage for efficient power storage.
6. **Fault Current Limiters** – Automatically control high currents in power grids.
7. **SQUIDs** – Extremely sensitive magnetic sensors for medical and scientific use.

Q5) What are nanomaterials? Describe a few properties of nanomaterials.

Nanomaterials:

- Materials with at least one dimension in the **1–100 nanometers** range.
- Exhibit **unique physical and chemical properties** due to nanoscale size and large surface area.

Properties of Nanomaterials (7–8 Points):

1. **Large Surface Area** – Increases reactivity and catalytic activity.
2. **High Strength** – Nanotubes and nanowires are stronger than bulk materials.

1. **Large Surface Area** – Increases reactivity and catalytic activity.
2. **High Strength** – Nanotubes and nanowires are stronger than bulk materials.
3. **Optical Properties** – Display quantum effects (e.g., color changes in gold nanoparticles).
4. **Electrical Conductivity** – Some nanomaterials (e.g., graphene) conduct electricity exceptionally well.
5. **Magnetic Properties** – Exhibit superparamagnetism at nano size.
6. **Thermal Stability** – Some nanomaterials resist high temperatures.
7. **Light Weight** – Useful in aerospace and automotive industries.
8. **Biocompatibility** – Used in drug delivery and biomedical applications.

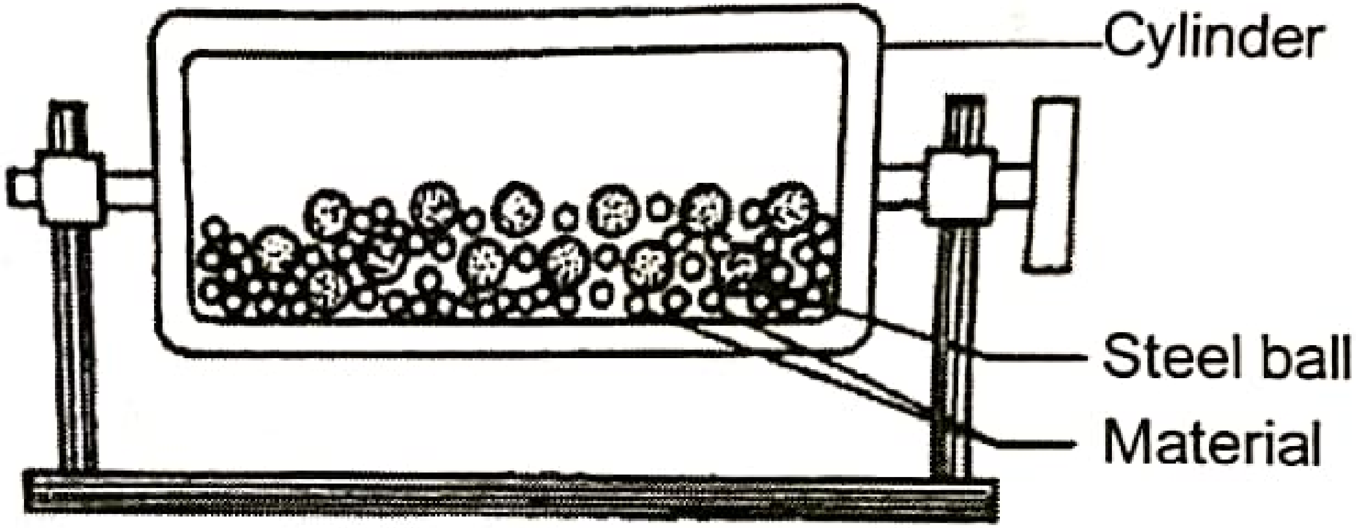
Q6) Enunciate the synthesis of nanomaterials using the ball milling method.

Ball Milling Method (Top-down Approach):

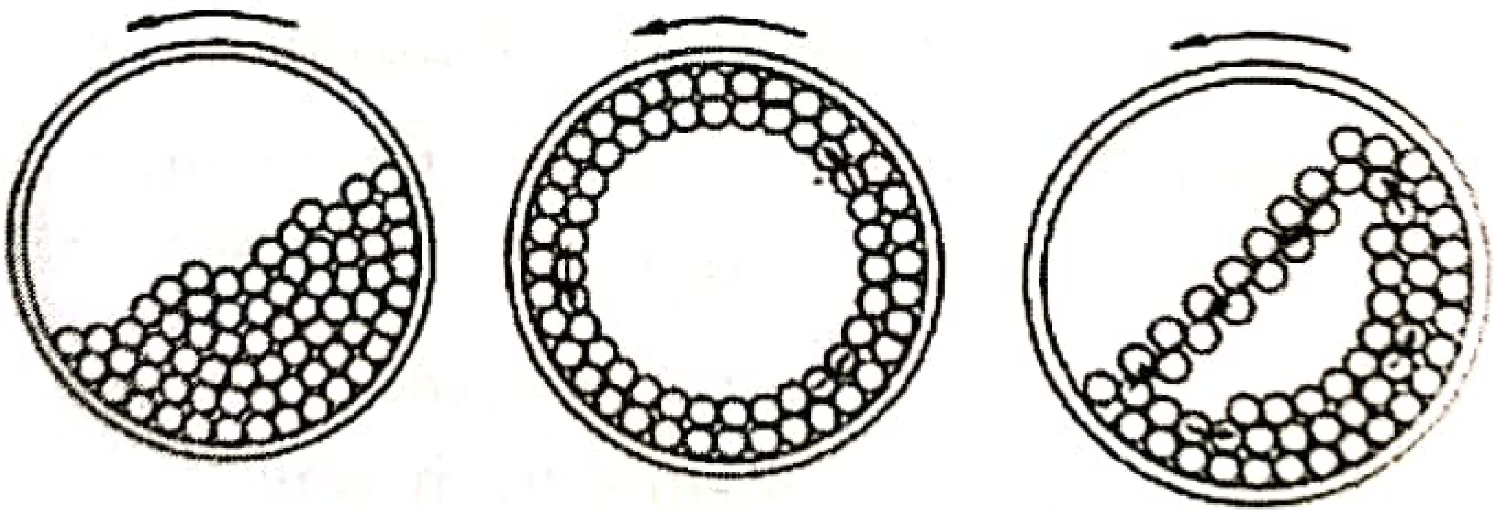
- A **mechanical technique** used to convert bulk materials into nanomaterials by grinding them using **high-energy balls**.

Process:

1. Place bulk powder in a **rotating cylindrical chamber** along with hard balls (e.g., tungsten).
2. Rotate the chamber at high speed.
3. Balls collide with the powder, applying **impact and shear forces**.



Ball mill



A
Low Speed

B
High Speed

C
Correct Speed

Process:

1. Place bulk powder in a **rotating cylindrical chamber** along with hard balls (e.g., tungsten).
2. Rotate the chamber at high speed.
3. Balls collide with the powder, applying **impact and shear forces.**
4. Continuous grinding breaks the particles into **nano-sized grains.**
5. Process is conducted in **inert atmosphere** (e.g., argon) to prevent oxidation.

Advantages (7–8 Points):

1. **Simple and cost-effective** process.
2. **Scalable** for industrial production.
3. Suitable for **metallic and non-metallic** materials.
4. Produces **uniform particle size.**
5. Can be done at **room temperature.**
6. Allows **mixing of multiple materials** for composites.
7. Environmentally friendly – **no chemical waste.**
8. Enhances properties like **hardness and wear resistance.**

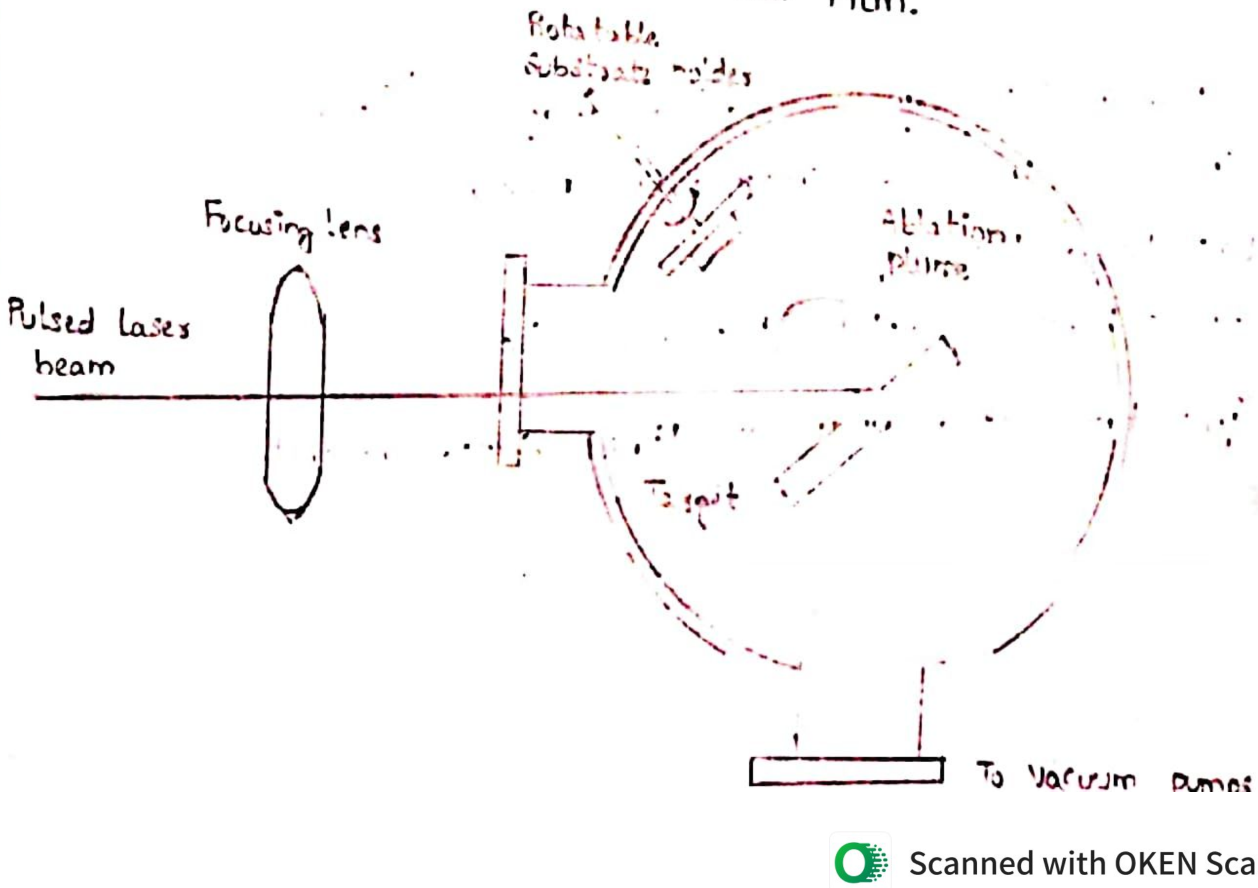
7) Enunciate the synthesis of nanomaterials by pulse-Laser Deposition Method.

Ans:- Pulse-Laser Deposition Method (PLD):-

It is a physical vapor deposition (PVD) technique used to synthesize thin films and nanomaterials by using high-energy laser pulses to ablate material from a target.

Steps in PLD process:-

1. Target preparation:- A solid target of the desired material is placed inside a vacuum or controlled gas chamber.
2. Laser Irradiation:- A high-power pulsed laser is focused onto the target surface.
3. Material Ablation:- The laser energy causes rapid heating and evaporation of the material, forming a plasma plume.
4. Plume Expansion:- The ablated material expands and moves toward the substrate placed opposite to the target.
5. Thin Film Formation:- The material condenses on the substrate surface, forming a nanostructured thin film.

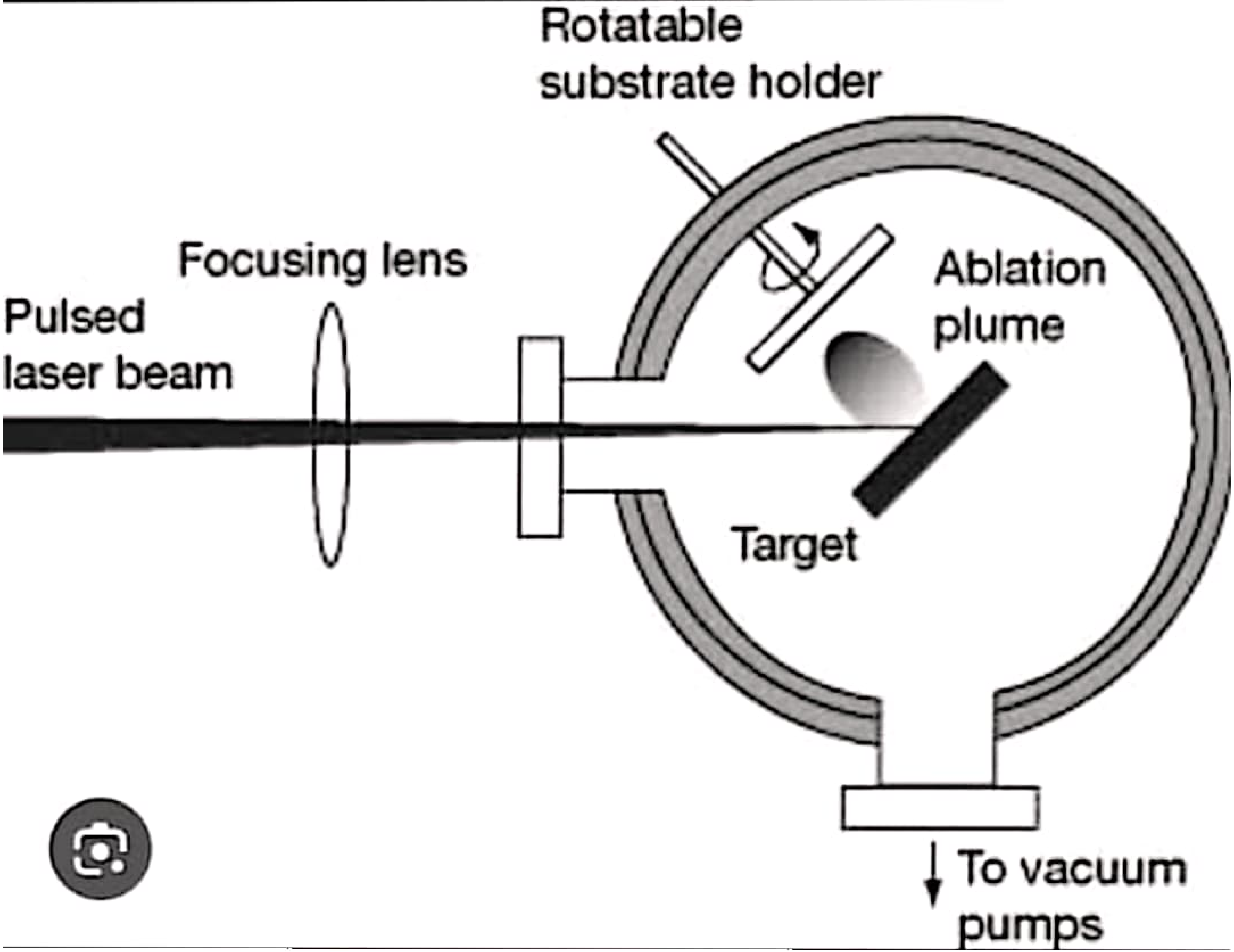


Advantages:-

* High purity and stoichiometric transfer.
* Layer - by - layer growth possible.
* Suitable for complex multicomponent materials.

Applications:-

* Thin film fabrication.
* Super Conductivity materials.
* Magnetic Materials.
* Protective coatings.


Rotatable
substrate holder
Focusing lens
Pulsed
laser beam
Ablation
plume
Target
To vacuum
pumps

Saq's

1) Diff b/w high and low temperature conductor superconductors

Low temperature Super conductor	High Temperature Super conductor
• The critical temperature temperature is less than or equal to 30Kelvin ($\leq$ 30 K (Kelvin))	• The critical temperature (T_c) are greater than or equal to 30K (Kelvin) and ($T_c \geq$ 30K (Kelvin)) some exceed 100K
• Pure Materials & simple alloy's (Pb, Hg, NbTi)	• Ceramic oxides (YBCO, BSCCO)
• Its mechanism is explained by BCS theory (cooper pairs)	• It's mechanism is still debated (may involve electron - phonon & magnetic interactions)
• It's magnetic field tolerance = lower critical fields	• It can withstand high magnetic fields
• Applications: i) MRI machines ii) particle accelerators	• Applications: i) Power cables ii) Maglev trains iii) fault current limiters.

transition temperature.

2) Prove that super conductor exhibit perfect diamagnetism

We know that mathematical the magnetic induction is given as

$$B = \mu_0 (H+M) \rightarrow (1)$$

where

M - Magnetization, H - External magnetic field

μ_0 - Absolute permeability, B →

For super conductor

$B = 0$

$0 = \mu_0 (H+M)$

$H + M = 0 \Rightarrow H = -M \Rightarrow 1 = -\frac{M}{H} \quad [\because \chi = \frac{M}{H}]$

$\chi = -1$

And magnetic susceptibility is -ve for dia magnetism.

Effect of pressure

Q3) What are Cooper Pairs?

Cooper pairs are pairs of electrons bound together at low temperatures in a superconductor.

- They move without resistance due to an attractive interaction via lattice vibrations (phonons).
- Cooper pairs have opposite spin and momentum and form the basis for superconductivity.

Super conductor.

4) Meissner Effect

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$T < T_c$ $H < H_c$

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Prove that Super Conductor exhibit ...

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Q6) List out applications of superconductors.

1. MRI machines
2. Maglev trains
3. Particle accelerators
4. Quantum computers
5. Power transmission cables
6. SMES (energy storage)
7. Fault current limiters
8. SQUIDs (magnetic field sensors)

Q7) Discuss the characterisation technique of XRD.

X-ray Diffraction (XRD) is used to determine the **crystal structure** of materials.

- X-rays are diffracted by crystal planes at specific angles.
- Using **Bragg's Law**, the **interplanar spacing (d-spacing)** is calculated.
- XRD gives information on **phase identification, crystallinity, and lattice parameters.**

Q8) Confer the characterisation technique of EDS.

Energy Dispersive X-ray Spectroscopy (EDS) is used to determine the **elemental composition** of materials.

- It is often attached to a **SEM** (**Scanning Electron Microscope**).
- When a material is hit by an electron beam, it emits characteristic X-rays.
- These are detected to identify the **elements present and their quantities**.

Q9) Write the application of nanomaterials.

1. Drug delivery systems
2. Sunscreens and cosmetics
3. Nano-sensors for detection
4. High-efficiency batteries
5. Catalysts in chemical reactions
6. Lightweight materials in aerospace
7. Water purification systems
8. Nano-coatings for protection and durability