UNIT-5(INTRODUCTION TO NANO MATERIALS)

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INTRODUCTION TO NANO METERS -PROPERTIES OF NANO MATERIALS

61. INTRODUCTION TO NANOMATERIALS

What are Nanomaterials?

- Nanomaterials are materials that have **structures sized between 1 and 100 nanometers (nm)**.
- At this scale, materials show **unique physical, chemical, and biological properties** different from their bulk counterparts.
- The properties change because a large fraction of atoms are on the **surface** and **quantum effects** become important.

Why Nanomaterials are Important?

- They have applications in **electronics, medicine, energy, and materials science**.
- Nanotechnology helps develop **stronger, lighter, and more reactive materials**.

62. PROPERTIES OF NANOMATERIALS

1. Size-Dependent Properties

- Properties like melting point, electrical conductivity, and optical behavior change with size.

2. High Surface Area to Volume Ratio

- A large number of atoms are on the surface → **higher reactivity** and **catalytic activity**.

3. Quantum Effects

- At nanoscale, electrons and photons behave differently → leads to **quantum confinement** and **discrete energy levels**.

4. Mechanical Properties

- Nanomaterials can be **stronger and harder** than bulk materials due to reduced defects.

5. Optical Properties

- Show unique color changes (like gold nanoparticles appear red or purple) because of interaction with light (surface plasmon resonance).

6. Electrical Properties

- Can act as conductors, semiconductors, or insulators depending on size and shape.

7. Magnetic Properties

- May show **superparamagnetism** or enhanced magnetic behavior different from bulk.

63. SYNTHESIS OF NANOMATERIALS BY BALL MILLING

What is Ball Milling?

- Ball milling is a **mechanical method** to produce nanomaterials by grinding bulk materials into nanosized particles.
- It involves **high-energy collisions** between balls and the material inside a rotating container.

Process:

- Bulk powder and hard balls (steel, ceramic) are placed in a rotating container.
- As the container rotates, balls collide with the powder particles, causing **fracture and cold welding** repeatedly.
- After prolonged milling, the powder particles become **nanometer-sized** due to continuous impact and grinding.

Advantages:

- Simple and cost-effective.
- Can produce large quantities of nanomaterials.
- Suitable for many materials including metals, alloys, and ceramics.

Limitations:

- Possible contamination from milling balls and container.

- Long milling times may be required.
- Control over size and shape can be difficult.

64. SYNTHESIS OF NANOMATERIALS BY PULSED LASER DEPOSITION (PLD)

What is Pulsed Laser Deposition?

- PLD is a **physical vapor deposition technique** where a high-power laser pulse **vaporizes material from a target** to form a plasma plume that deposits onto a substrate as a thin film or nanomaterial.

Process:

- A pulsed laser beam is focused on the surface of a target material inside a vacuum chamber.
- The laser ablates material from the target, creating a **plasma plume** of atoms, ions, and clusters.
- These particles travel and **deposit on a heated substrate**, forming a thin film or nanostructured layer.

Advantages:

- Precise control over film thickness and composition.
- Can produce high-quality, uniform nanomaterials.
- Suitable for complex materials and multilayers.

Limitations:

- Requires expensive laser equipment.
- Limited scalability for large-area production.
- Process parameters need careful optimization.

65. CHARACTERIZATION TECHNIQUES OF NANOMATERIALS

1. X-Ray Diffraction (XRD)

- **Purpose**: To identify the **crystal structure, phase, and size** of nanomaterials.
- **How it works**: X-rays are directed at the material and diffracted by the crystal lattice.
- The diffraction pattern is recorded and analyzed to determine crystal structure and particle size using **Bragg's Law**.
- **Uses**: Confirming crystallinity, detecting phases, estimating average particle size.

2. Energy Dispersive X-ray Spectroscopy (EDS or EDX)

- **Purpose**: To determine the **elemental composition** of nanomaterials.
- **How it works**: Sample is bombarded with an electron beam in an electron microscope, causing emission of characteristic X-rays from elements.
- The X-rays are detected and analyzed to identify which elements are present and their relative amounts.
- **Uses**: Elemental mapping, purity analysis, detecting contaminants.

66. APPLICATIONS OF NANOMATERIALS

- **Electronics**: Used in semiconductors, transistors, and nanoscale circuits.
- **Medicine**: Targeted drug delivery, imaging agents, biosensors.
- **Energy**: Solar cells, batteries, supercapacitors, and fuel cells.
- **Catalysis**: Nanoparticles as catalysts for chemical reactions.
- **Environmental**: Water purification, pollutant removal.
- **Materials**: Stronger, lighter composites and coatings.

67. HEALTH HAZARDS OF NANOMATERIALS

- **Toxicity**: Nanoparticles can penetrate cells and tissues, causing **oxidative stress**, inflammation, and DNA damage.

- **Respiratory risks**: Inhalation of nanoparticles may lead to lung damage and diseases.
- **Unknown long-term effects**: Due to their small size, nanoparticles might cross the blood-brain barrier or accumulate in organs.
- **Environmental impact**: Nanoparticles can affect aquatic life and soil organisms.
- **Precautions**: Use protective equipment, proper handling, and disposal to minimize exposure.