

Nanotechnology - Complete Study Notes

1. What is Nanotechnology?

Nanotechnology is the branch of science and engineering that studies, designs and uses materials, devices and systems at the nanoscale (1–100 nanometers). At this scale, materials often behave differently because of quantum effects and their very high surface area.

2. What is a Nanometer?

- 1 nanometer (nm) = 10^{-9} meter (one billionth of a meter).
- Human hair diameter $\approx$ 80,000–100,000 nm.
- DNA diameter $\approx$ 2 nm.
- Many viruses are 20–300 nm.

3. Unique Properties of Nanomaterials

- High surface-area-to-volume ratio.
- Greater strength and hardness.
- Improved electrical and thermal conductivity.
- Unique optical and magnetic properties.
- Higher chemical reactivity.

4. Types of Nanomaterials

- Nanoparticles
- Carbon Nanotubes (CNTs)
- Graphene
- Quantum Dots
- Nanowires
- Nanocomposites

5. Manufacturing Approaches

- Top-down approach: Break larger materials into nanoscale structures.
- Bottom-up approach: Build materials atom-by-atom or molecule-by-molecule.

6. Instruments Used

- Scanning Tunneling Microscope (STM)
- Atomic Force Microscope (AFM)
- Scanning Electron Microscope (SEM)
- Transmission Electron Microscope (TEM)

7. Applications

- Medicine: Drug delivery, cancer treatment, tissue engineering.
- Electronics: Smaller, faster and energy-efficient chips.
- Energy: Better batteries, solar cells and fuel cells.
- Environment: Water purification and pollution control.
- Agriculture: Smart fertilizers and pesticides.
- Food: Smart packaging and freshness sensors.
- Textiles: Stain-resistant and antibacterial fabrics.

8. Advantages

- Lightweight and stronger materials.
- Improved healthcare.
- Lower energy consumption.
- Miniaturization of electronic devices.
- Better environmental protection.

9. Challenges

- High production cost.
- Health and toxicity concerns.
- Environmental impact.
- Ethical and privacy issues.
- Need for regulations and standards.

10. Future Scope

- Nanorobots for targeted surgery.
- Advanced AI hardware.
- Quantum computing materials.
- Self-healing materials.
- Next-generation clean energy technologies.

11. Frequently Asked Exam Questions

- Define nanotechnology.
- What is the nanoscale?
- Differentiate Top-down and Bottom-up approaches.
- Write four applications of nanotechnology.
- State advantages and disadvantages of nanotechnology.
- Name four instruments used in nanotechnology.

12. Quick Revision

- Size range: 1–100 nm.
- 1 nm = 10^{-9} m.
- Key tools: STM, AFM, SEM, TEM.
- Main applications: Medicine, Electronics, Energy, Environment.
- Important materials: CNTs, Graphene, Quantum Dots.