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APPLIED CHEMISTRY

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Lecture 33

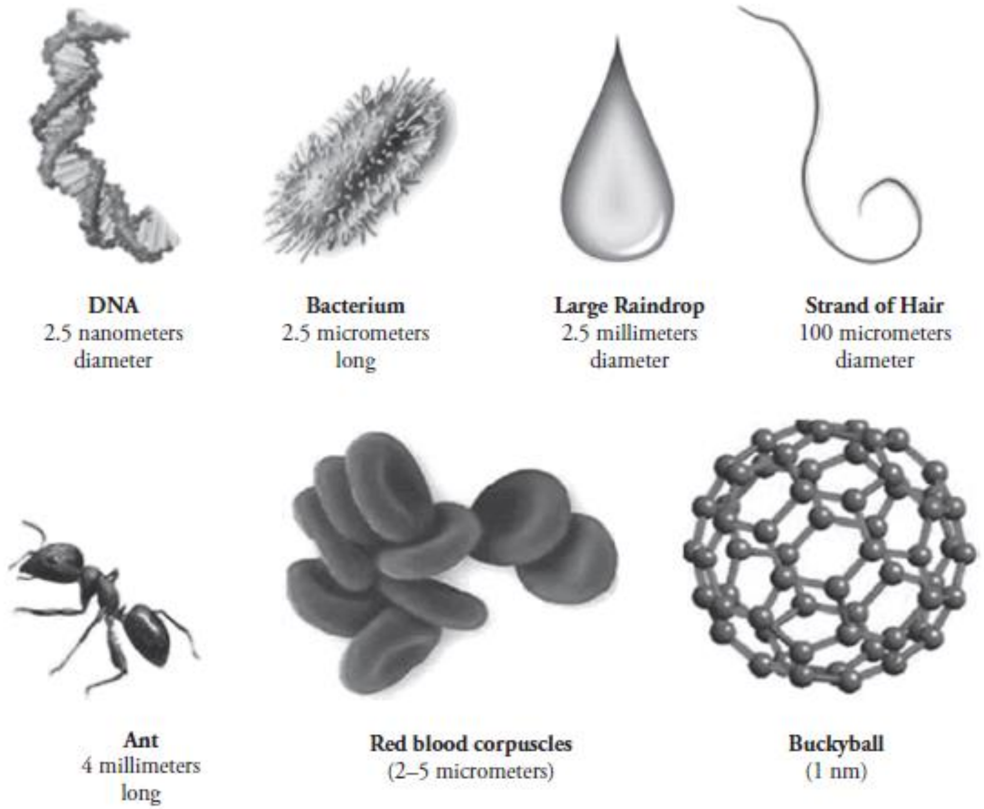
VIPS Technical Campus
योगः कर्मसु कौशलम्
IN PURSUIT OF PERFECTION

SCHOOL OF ENGINEERING AND TECHNOLOGY

Nanomaterials

- Nanoscience is the study of the fundamental principles of molecules and structures with at least one dimension roughly between 1 and 100 nanometers. These structures are known as nanoscale materials.

- One nanometer is equivalent to one billionth (one thousand millionth) of a meter. These particles are not visible to the human eye and can be seen only under a powerful microscope.



Nanogram 10^{-9} g

Nanosecond 10^{-9} s

Nanometer 10^{-9} m.

SYNTHESIS OF NANOMATERIALS

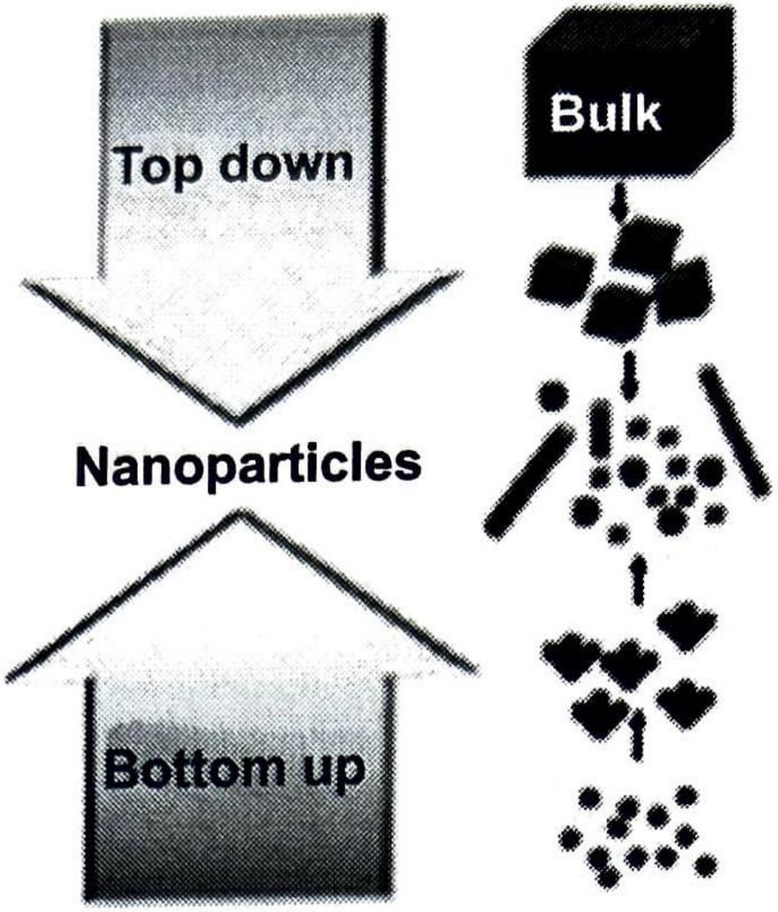
- The two mainstream approaches to synthesise nanomaterials are top -down and bottom-up i.e. either to assemble atoms together or to dis-assemble (break, or dissociate) bulk solids into finer pieces until they are constituted of only a few atoms.

a) <u>Top down approach</u>

- For example, a large block of silicon wafer can be reduced to smaller components by cutting, etching and slicing down to a desired size or shape. This is known as the top-down approach.
- By removing the excess portion of bulk materials by physical, chemical, and mechanical means, the desired nanostructured systems can be constructed.
- Two well-known top-down approaches are milling (or attrition) and thermal cycling
- In the milling method, the nanoparticles are synthesised by the structural decomposition of larger particles by the use of mechanical mills. This method is simple and inexpensive but causes environmental pollution.
- Attrition produces nanoparticles of a wide range of diameter ranging from 20 nm to several hundred manometers.

b) Bottom up approach

- The bottom up approach starts with the individual building units that are the objects of nanometer scale, such as atoms, molecules, polymers, and colloids.
- By assembling these building units with the needed controllability, the desired nanostructured systems can be obtained
- Nanomaterials synthesised from the bottom-up method have novel physiochemical properties that differ from the bulk material.
- There are several bottom up approaches like homogeneous and heterogeneous nucleation processes, microemulsion based synthesis, aerosol synthesis, spray pyrolysis and template-based synthesis.



Top down approach → start with large material and bring it down to nanoscale.
Bottom approach approach → start with individual atoms and build upwards to make a nanostructure.

CLASSIFICATION OF NANOMATERIALS

- Nanostructured materials are classified as Zero dimensional, one dimensional, two dimensional, three dimensional nanostructures.
- Nanomaterials can be nanoscale in one dimension (eg. surface films), two dimensions (eg. strands or fibres), or three dimensions (eg. particles).
- They can exist in single, fused, aggregated or agglomerated forms with spherical, tubular, and irregular shapes.

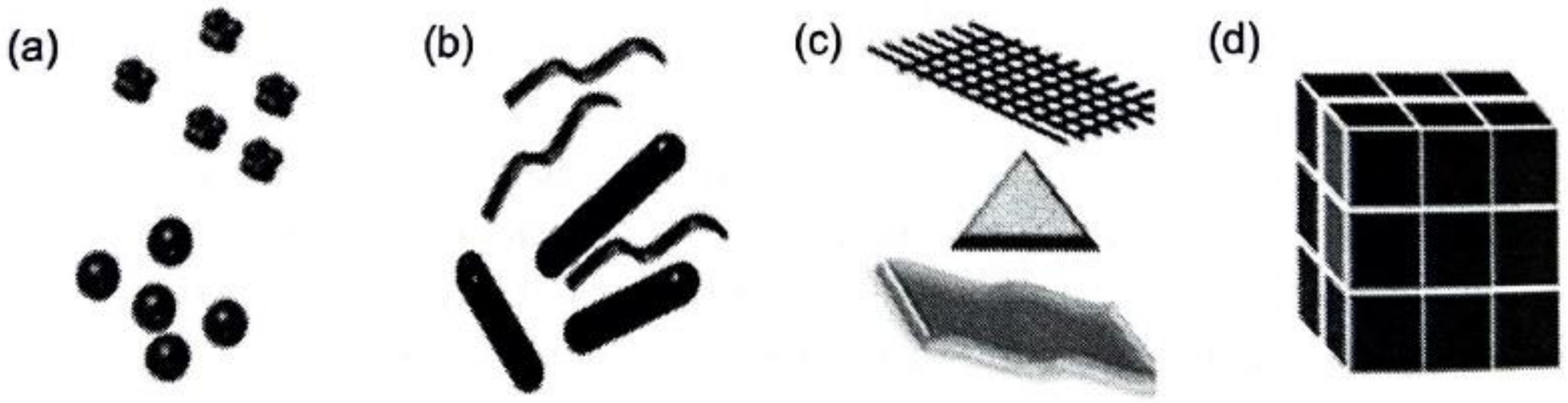


Fig. 11.3 *Classification of Nanomaterials (a) 0D spheres and clusters, (b) 1D nanofibers, wires, and rods, (c) 2D films, plates, and networks, (d) 3D nanomaterials*

NANOPARTICLE PROPERTIES

- **Optical Properties**

- Nanoparticles often possess unexpected optical properties as they are small enough to confine their electrons and produce quantum effects.
- **Example:** gold nanoparticles appear deep-red to black in solution. Nanoparticles of yellow gold and grey silicon are red in color.
- Gold nanoparticles melt at much lower temperatures (-300 °C for 2.5 nm size) than the gold slabs (1064 °C)
- Absorption of solar radiation is much higher in materials composed of nanoparticles than it is in thin films of continuous sheets of material.

- **Mechanical Properties**
- **Tougher and harder cutting tools:** Cutting tools made of nanomaterials, such as tungsten carbide, tantalum carbide, and titanium carbide, are much harder, much more wear resistant
- **Automobiles with greater fuel efficiency:** In automobiles, since nanomaterials are much more stronger, harder, and much more wear-resistant and erosion resistant, they are envisioned to be used in spark plugs
- **Better insulation materials:** Aerogels are nanocrystalline porous and extremely light materials and can withstand 100 times their weight. They are currently being used for insulation in offices, homes, etc

- **Electrical Properties**
- Conductivity is defined in terms of the properties of electrons in the solids. Resistivity is the inverse of conductivity. Metals are characterized by very low resistivity (-10.6 ohms), semiconductors have medium resistivity (few ohm.cm) and insulators have larger resistivity (>103 ohm.cm).
- Resistivity in nanomaterials is in general larger than that in polycrystalline materials. The electrons get scattered at grain boundaries resulting into increase of resistance.

- **Magnetic Properties**
- Magnetism is a very important property of materials as it has diverse applications like information storage, electron circuits, transformers, motors, actuators, sensors and medical field.
- Bulk ferromagnetic materials have spontaneously magnetized domains.
- Small particles are characterized by large surface to volume ratio. Therefore surfaces and interfaces play an Important role their magnetic properties of nanostructures
- Magnets made of nanocrystalline yttrium–samarium–cobalt grains possess exceptional magnetic properties because of their larger grain interface area. These magnets find use in motors, in medical field, in magnetic resonance imaging (MRI) and in microsensors.

APPLICATIONS OF NANOTECHNOLOGY

- **Medicine**

➢ One application of nanotechnology in medicine currently being developed involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells.

➢ Biodegradable nanoparticles are used to carry antibiotics to specific sites.

- **Electronics**

➢ Nanomaterials can improve the display screens on electronics devices and increase the density of memory chips.

➢ Nanotechnology can reduce the size of transistors used ,in integrated circuits.

- **Environment**

➢ **Cleaning up organic chemicals polluting groundwater:** iron nanoparticles can be effective in cleaning up organic solvents that are polluting groundwater. This method can be more effective and cost significantly less than treatment methods that require the water to be pumped out of the ground.

➢ **Generating less pollution during the manufacture of materials:** use of silver nanoclusters as catalysts can significantly reduce the polluting byproducts generated in the process used to manufacture propylene oxide.

➢ **Producing solar cells that generate electricity at a competitive cost:** silicon nanowires embedded in a polymer results in low cost but high-efficiency solar cells

- **Consumer Products**

➢ Silver nanoparticles in fabric that kill bacteria making clothing odor-resistant.

➢ Skin care products that use nanoparticles to deliver vitamins deeper into the skin

➢ Lithium ion batteries that use nanoparticlebased electrodes powering plugin electric cars

Surface Characterisation Techniques

- Bulk properties like shape, size, phase, electronic structure and crystallinity and surface properties like arrangement of surface atoms, surface area, surface composition and surface electronic structure are determined by the various characterization techniques.

- Two important characterization techniques are Brunauer–Emmet–Teller (BET) surface area analysis and transmission electron microscopy (TEM)

- ***BET surface area analysis:*** → This method helps in determining the surface area, pore size and pore size distribution of nanomaterials.

→ This is done by gas sorption method. Prior to determination the adsorbed foreign particles are removed from the surface of the adsorbent by heating and degassing by vacuum force.

→ After cleaning the sample is brought to a constant and very low temperature usually in a dewar flask containing liquid nitrogen (77.4 K).

→Controlled doses of adsorbate gases are admitted into the evacuated sample chamber. They are first adsorbed and then desorbed. Adsorption and desorption isotherms are obtained by subjecting the gas to a wide range of pressures.

→By knowing the area occupied by one adsorbate molecule the total surface area can be determined using the adsorption model.

- ***TEM*: →** This technique is used for the structural information of solid material both by imaging and by electron diffraction.

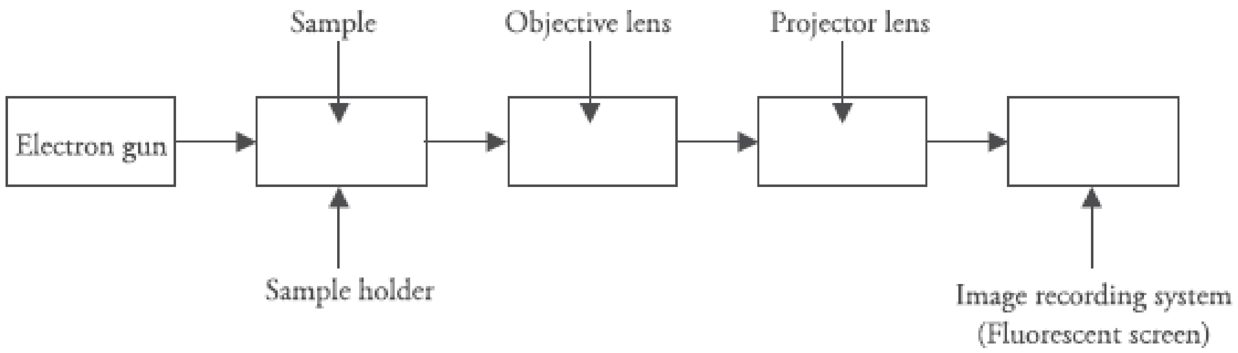
→ In TEM, a thin specimen is irradiated with an electron beam of uniform current density

→The electrons emitted from the electron gun by thermoionic emission from tungsten cathodes or LaB6 rods enter the sample and are scattered as they pass through it.

→They are then focused by the objective lens and amplified by the magnifying projector to produce the desired image

→ Greater spatial resolution can be achieved by high voltage TEM instruments (e.g., with 400 kV). High voltage instruments enable us to work with thicker samples.

→TEM provides information about the particle size, morphology and also provides an insight into the particle aggregation.



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THANK YOU