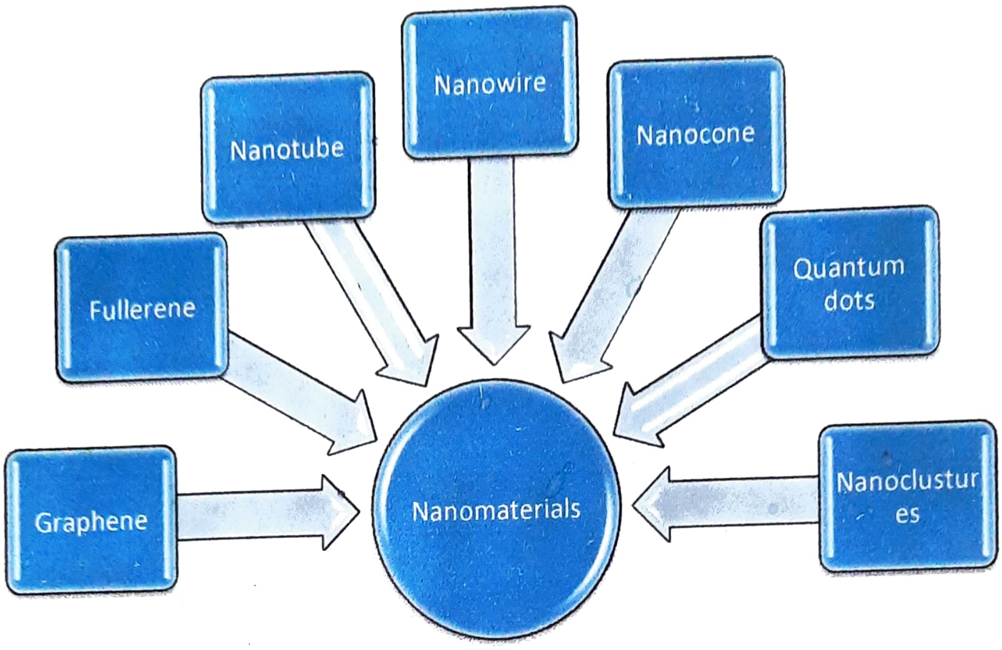
NANOMATERIALS



INTRODUCTION

The concept of nanotechnology was first given by renowned physicist Richard Feynman in 1959 and earned Nobel Prize. The term was also popularized by the invention of scanning tunneling microscope and fullerene. Nanotechnology involves designing and producing objects at nanoscale size (~1 to 100 nm). One nanometer is one billionth (10–9) of a metre. Nanomaterials are one of the main products of nanotechnology as nanoparticles, nanotubes, nanorods, etc. It is also explained as nanoparticles have a high surface to volume ratio. Nanoparticles can display properties significantly different from the bulk material because at this level quantum effects may be significant. Simply we can say the mechanical, electrical, optical, electronic, catalytic, magnetic, etc. properties of solids are significantly altered with great reduction in particle size. For example:

- Silver foil does not react with dilute HCl but silver nanoparticles rapidly react with dilute HCl.
- Gold and silver both are chemically inert but their nanoparticles showcatalytic property.
- Gold nanoparticles are deep red but its bulk material (gold pieces) is gold-coloured.

CLASSIFICATION OF NANOMATERIALS

The classification of nanomaterials is based on the number of dimensions as shown in Fig. 1. According to Siegel, nanostructured materials are classified as: zero- dimensional (0D), one-dimensional (1D), two-dimensional (2D) and three- dimensional (3D) nanomaterials.

(i) Zero-dimensional nanomaterials: Here, all dimensions (x, y, z) are at nanoscale, i.e., no dimensions are greater than 100 nm. It includes nanospheres andnanoclusters.

(ii) One-dimensional nanomaterials: Here, two dimensions (x, y) are at nanoscaleand the other is outside the nanoscale. This leads to needle shaped nanomaterials. Itincludes nanofibres, nanotubes, nanorods, and nanowires.

(iii) Two-dimensional nanomaterials: Here, one dimension (x) is at nanoscale and the other two are outside the nanoscale. The 2D nanomaterials exhibit plate- like shapes. It includes nanofilms, nanolayers and nanocoatings with nanometre thickness.

(iv) Three-dimensional nanomaterials: These are the nanomaterials that are not confined to the nanoscale in any dimension. These materials have three arbitrary dimensions above 100 nm. The bulk (3D) nanomaterials are composed of a multiple arrangement of nanosize crystals in different orientations. It includesdispersions of nanoparticles, bundles of nanowires and nanotubes as well as multi- nanolayers (polycrystals) in which the 0D, 1D and 2D structural elements are in close contact with each other and form interfaces.

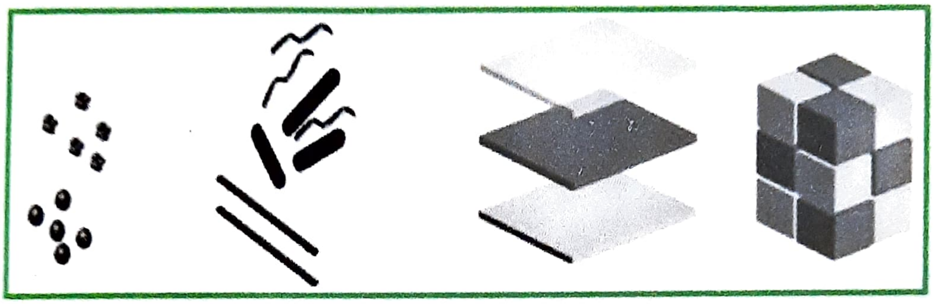


Fig. 1: Classification of nanomaterials.

For the better understanding, nanomaterials are again organized into four types as follows. Some types of nanomaterials are shown in Fig. 2.

(i) Carbon based materials

(ii) Metal based materials

(iii) Dendrimers

(iv) Composites

(i) Carbon based materials: These are composed of carbon, taking the form of hollow spheres, ellipsoids or tubes. The spherical and ellipsoidal forms are referredas fullerenes, while cylindrical forms are called nanotubes.

(ii) Metal based materials: These include quantum dots, nanogold, nanosilver andmetal oxides like TiO2. A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, whose size is on the order of a few nanometers to a few hundred nanometers.

(iii) Dendrimers: Dendrimers are repetitively branched molecules. The name comes from the Greek word 'dendron' (tree). These nanomaterials are nanosized polymers built from branched units. The surface of a dendrimer has numerous chain ends, which can perform specific chemical functions. Dendrimers are used inmolecular recognition, nanosensing, light harvesting, and opto-electrochemical devices. They may be useful for drug delivery.

(iv) Composites: Composites are combination of nanoparticles with other nanoparticles or with larger, bulk-type materials. Nanoparticles like nanosizedclays are added to products (auto parts, packaging materials, etc.) to enhance mechanical, thermal, and flame-retardant properties.

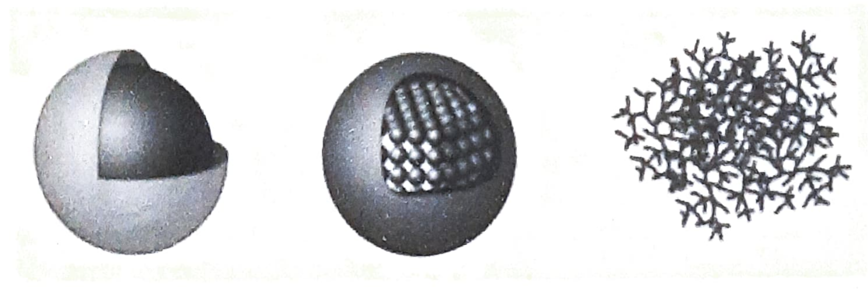


Fig. 2 Some types of nanomaterials

*1. **Basic properties of nano materials***

When the material size of the object is reduced to nanoscale, then it exhibits different properties than the same material in bulk form. The factors that differentiatethe nanomaterials form bulk material is

1. Increase in surface area to volume ratio
2. Quantum confinement effect

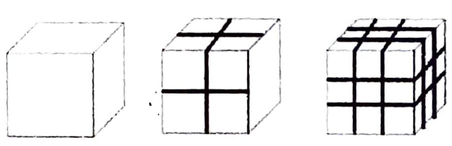
Increase in surface area to volume ratio:

The ratio of surface area to volume ratio is large for nano materials.

Example 1: To understand this let us consider a spherical material of radius 'r'. Then its surface area to volume ratio is ^{3}.Due to decrease of r, the ratio increases r predominantly.

Example 2: For one cubic volume, the surface ratio is $6m^2$. When it is divided into eightcubes its surface area becomes $12m^2$. When it is divided into 27 cubes its surface areabecomes $18m^2$. Thus, when the given volume is divided into smaller pieces the surfacearea increases.

Due to increase of surface of surface area, more number of atoms will appear at the



surface of compared to those inside. For example, a nano material of size 10nm has 20% of its atoms on its surface and 3nm has 50% of its atoms. This makes the nanomaterials more chemically reactive and affects the properties of nano materials.

Quantum confinement effect:

According to band theory, the solid atoms have energy bands and isolated atoms possess discrete energy levels. Nano materials are the intermediate state to solids andatoms. When the material size is reduced to nanoscale, the energy levels of electrons change. This effect is called quantum confinement effect. This affects the optical, electrical and magnetic properties of nanomaterials.

Physical properties

Inter atomic distance:

When the material size is reduced to nanoscale, surface area tovolume ratio increases. Due to increase of surface of surface area, more number of atoms will appear at the surface of compared to those inside. So Interatomic spacingdecreases with size.

Thermal properties

Thermal properties nano materials are different from that of bulk materials. The Debye Temperature and ferroelectric phase transition temperature are lower for nano materials. The melting point of nano gold decreases from 1200 K to 800K as the size of particle decreasesform 300A^0 to 200A^0.

Optical properties:

Different sized nano particles scatters different of light incident on it and hence they appear with different colours. For example nanogold does not act as bulk gold. The nano particles of gold appear as orange, purple, red or greenish in colour depending on their grain size. The bulk copper is opaque where as nanoparticle copper is transparent.

Magnetic properties:

The magnetic properties of nano materials are different from that of bulk materials. In explaining the magnetic behavior of nanomaterials, we use single domains unlike largenumber of domains in bulk materials. The coercivity values of single domain is vary large. For example, Fe,Co, and Ni are ferromagnetic in bulk but they exhibit super paramagnetism. Na, K, and Rh are paramagnetic in bulk but they exhibit ferro-magnetic. Cr is anti ferromagnetic in bulk but they exhibit super paramagnetic.

1. Fabrication methods of nanomaterials

The nanomaterials can be synthesized in two ways,
namelyBottom –up approach and
Top-down approach

Bottom-up approach:

In this method, the nanomaterials are synthesized by assembling the atoms andmolecules together.

Examples: Ball milling and Sol-gel method.

Top-down approach:

In this method, the nanomaterials are synthesized by dis-assembling the solids into finer pieces until the particles are in the order of nanometers.

Examples: plasma arching, chemical vapour deposition method