Introduction of Nanomaterials

Introduction

A material with

- any external dimension in the nanoscale (size range from approximately $1–100\ \mathrm{nm}$).
- having internal structure or surface structure in the nanoscale.

At nanoscale, materials exhibit very unusual and very interesting properties. Examples: Graphene has very high young’s modulus and very high carrier mobility.

Nano object

An object with any external dimension is in the nanoscale.

Examples: carbon nanotube, bucky ball.

Nano structured material

A material where its internal or surface structure is in the nano scale.

Examples: $\mathrm{TiO_2}$ nanotube films.

Nano in nature

- Lotus leaves being superhydrophobic
- Gecko adhesive system

Nanoscience

Study of structures and materials on the nanoscale.

Nanotechnology

Development of materials and devices by exploiting the characteristics of particles on the nanoscale.

Applications

- Nanoscale transistors
    - Higher-performance
    - Improved energy efficiency
- Magnetic data storage
    - High data density and data capacity
    - Ultra compact
- Nanomedicine and drug delivery
- Energy storage

Preparation of nanomaterials

Top-down approach

Nanoscale dimensions are created using larger components, by externally controlled devices.

Examples: Lithography, Etching techniques.

Photolithography

Can be used to create nanoscale patterns in thin films or bulk substrates.

The steps:

1. Coat Si wafer with a photosensitive material.
   A material which changes its properties when exposed to electromagnetic radiation
2. Allow the radiation to pass through the mask on to photosensitive material.
3. Developer solution removes either reacted or unreacted material.
4. The silicon wafer is etched to transfer the pattern onto silicon wafer.
5. Photosensitive material is removed.

Bottom-up approach

Molecular components arrange themselves into more complex nano materials/objects.

Examples: Molecular self-assembly, Chemical vapour deposition

Graphene

Carbons arranged to a hexagonal network. 2D crystal based.

Unit Cell

- A rhombus with 120° .
- Lattice parameter is $2d\cos 30^\circ$ where d is the $\mathrm{C}-\mathrm{C}$ bond length.
- 2 atoms per unit cell.

> **Note**
> Single layer of graphene was discovered using scotch tape method and the discovery won a Nobel prize in 2010.

Synthesis

- Top-down approaches
  - Exfoliation (eg: Scotch tape method)
- Bottom-up approaches
  - Chemical vapor deposition

> **Note**
> Graphene has a band gap of 0.

Carbon Nanotubes

A rolled up sheet of graphene.

Properties:

- Extraordinary electrical and heat conductivity
- High mechanical strength

Classifications

Based on _____:

- Single wall carbon nanotubes (SWNT)
- Multi wall carbon nanotubes (MWNT)

Based on Chirality