Science and Technology of Nano Materials

Introduction

Matter and Energy are manifestations of the universe they exist in a variety of forms and interact with each other in many ways.

Nano means 10^{-9}. (Nanometer is one thousand Millionth of a Meter)

To understand how small one nm is let us see few comparisons

1. A **Red blood cell** is approximately **7000nm** wide.
2. Water Molecule is almost **0.3nm** across.
3. Human hair which is about **80,000nm** wide.

Nano Material

1. Nano Materials could be defined as the materials with at least one of its dimensions in the range of a Nano meter.

2. Thus the material need not be so small that it cannot be seen, it can be a large surface or a long wire whose thickness is in the scale of Nanometers.

3. Materials that are Nano scale in one dimension are layers, such as a Thin films or Surface coatings.

4. Materials that are Nano Scale in two dimensions include Nano wires and Nano tubes.

5. Materials that are Nano scale in three dimensions are particles for example precipitates, colloids and quantum dots (Small particles of Semiconductor Materials)

Nano Science

Nano Science can be defined as the study of phenomena and manipulation of materials at Atomic, Molecular and Macromolecular scales where properties differ significantly from those at a larger scale.

Nano Science is the study and understanding of properties of Nano Particles.

Nano Technology

Nanotechnology can be defined as the design, characterization, production and application of structures devices and systems by controlling shape and size at a Nano meter Scale.

Why properties of Nano Materials are different ?

The properties of Nano Materials are very much different from those at a larger scale.
Two principal factors cause the properties of Nano Materials to differ significantly from other materials.

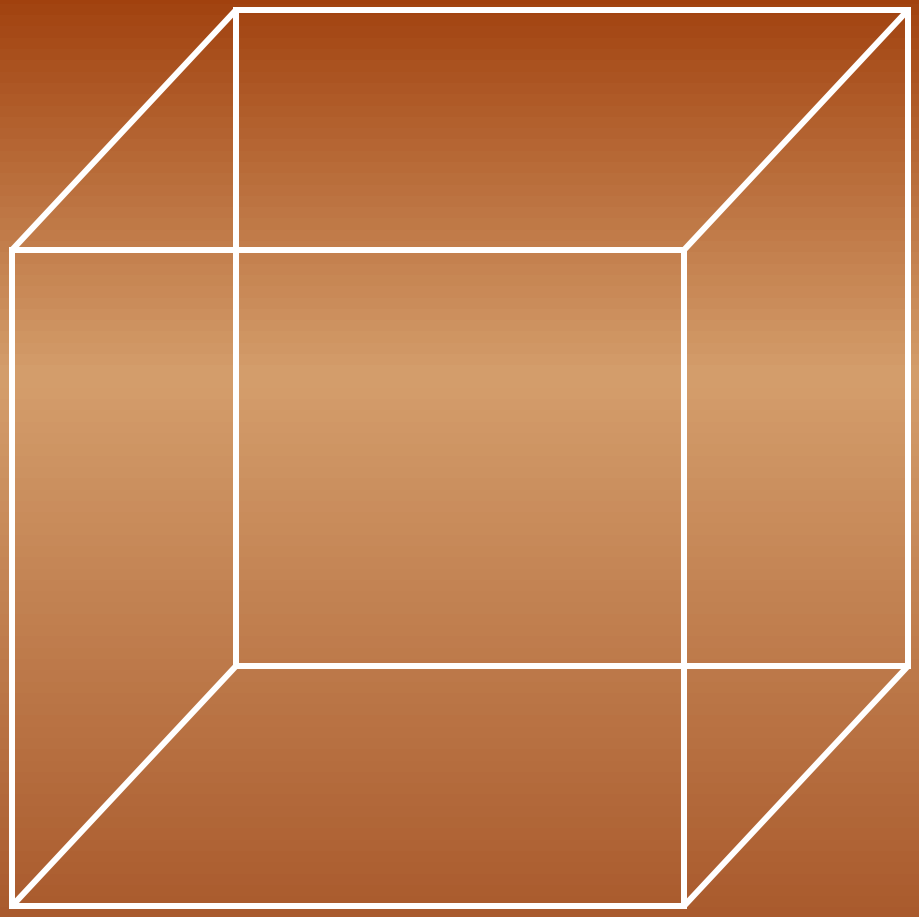
1. Increased relative surface area.
2. Quantum confinement effect.

These factors can charge or enhance properties such as reactivity , strength and electrical characteristics.

Increase in a Surface Area to Volume ratio

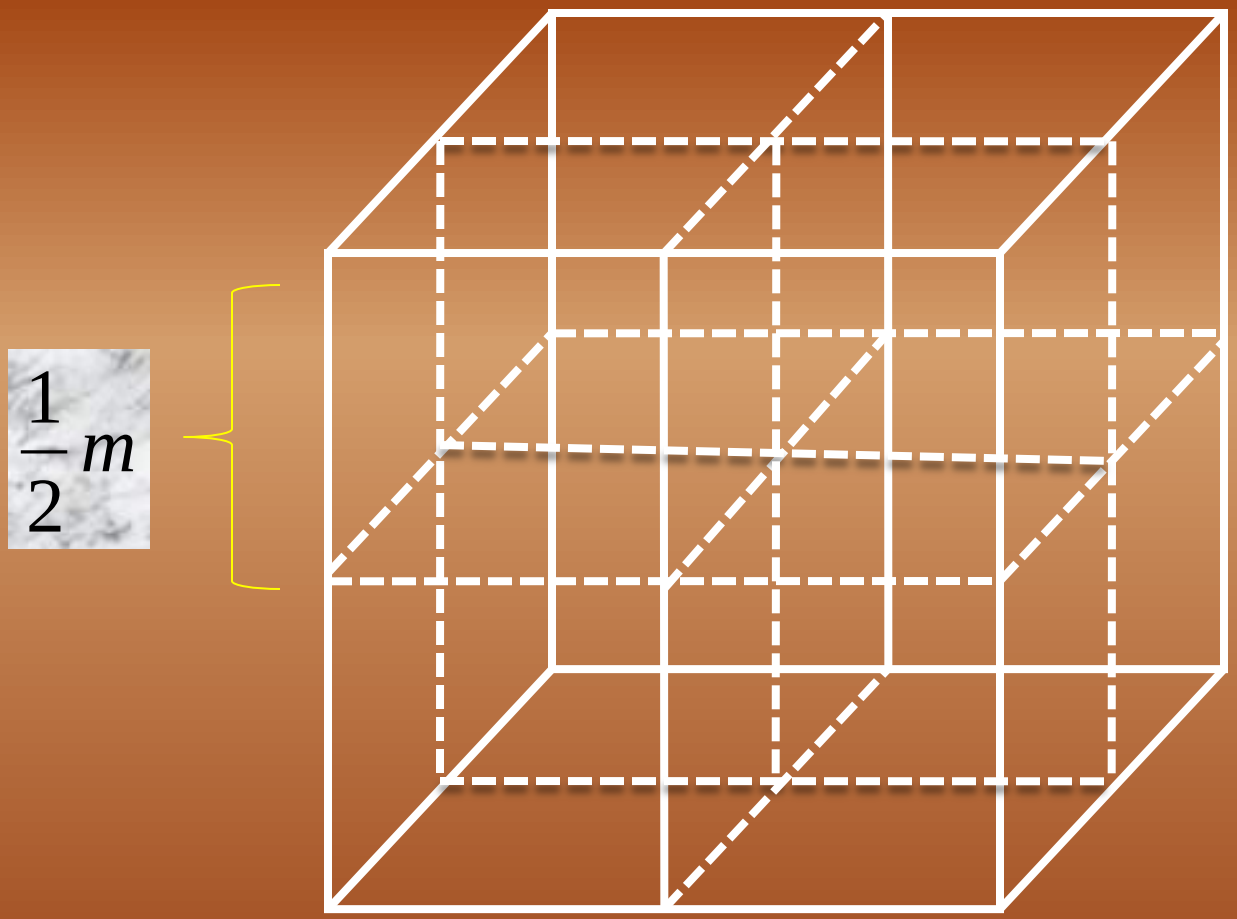
Nano Materials have a relatively larger Surface area when compared to the same volume or mass of the material produced in a larger form.

Let us consider a Sphere of radius “r”.
Its Surface Area $=4\pi r^{2.}$
Its volume= $4/3\pi r^{3}$
Surface Area to Volume Ratio= 3/r.
Thus when the radius of the Sphere decreases , its Surface to Volume ratio increases.



$$surface\ \ area = 6 \times 1m^2 \Rightarrow 6m^2$$

- Let us consider one Cubic Volume shown in figure its the Surface Area is $6m^2$.
- When it is divided into eight pieces its Surface Area becomes $12m^2$, similarly When the same volume is divided into 27 pieces its Surface Area becomes $18m^2$.
- Thus we find that when the given volume is divided into smaller pieces the Surface Area increases.
- Hence as particle size decreases a greater proportion of atoms are found at the surface compared to those inside.
- Nano particles have a much greater surface area per given volume compared with larger particles. It makes materials more Chemically reactive.



$$surface\ \ area = 6 \times (\frac{1}{2}m)^2 \times 8 = 12m^2$$

Quantum Confinement

In Nano Crystals, the Electronic energy levels are not continuous as in the bulk but are discrete (finite density of states), because of the confinement of the electronic Wave function to the physical dimensions of the particles. This phenomenon is called Quantum confinement and therefore Nano Crystals are also referred to as quantum dots (QDs).

Properties of Nano Materials

Nano Materials have properties that are different from those of bulk materials.
Most Nano structure materials are Crystalline in nature and they posses unique properties.

Physical Properties of Nano Particles

- Crystal structure of Nano particles is same as bulk structure with different lattice parameters.
- The inter atomic spacing decreases with size and this is due to long range electrostatic forces and the short range core-core repulsion.
- The Melting point of Nanoparticles decreases with size.

Chemical Properties

- The Electronic structure of Nanoparticles is dependent on its size and the ability of Nano cluster to react, depends on cluster size.

- The large Surface area to volume ratio the variations in geometry and the electronic structure of Nano particles have a strong effect on catalytic properties.

Electrical properties

- The electronic structure of Nano materials is different from its bulk material.
- The density of the energy states in the conduction band changes.
- When the energy spacing between two energy levels is more than $K_B T$, energy gap is created.
- Nano clusters of different sizes will have different electronic structures and different energy level separations.
- The Ionization potential at Nano sizes are higher than that for the bulk materials

Magnetic Properties

- The Magnetic Moment of Nano particles is found to be very less when compared them with its bulk size.
- Nanoparticles made of semiconducting materials Germanium , Silicon and Cadmium are not Semiconductors.

Applications of Nanomaterials

Chemical Industry:

- Fillers for point systems
- Coating Systems based on Nano composites.
- Magnetic fluids.

Automotive Industry:

- Light weight construction
- Painting
- Catalysts
- Sensors

Medicine

- Drug delivery systems
- Active agents
- Medical rapid tests
- Antimicrobial agents and coatings.
- Agents in cancer therapy.

Electronic Industry:

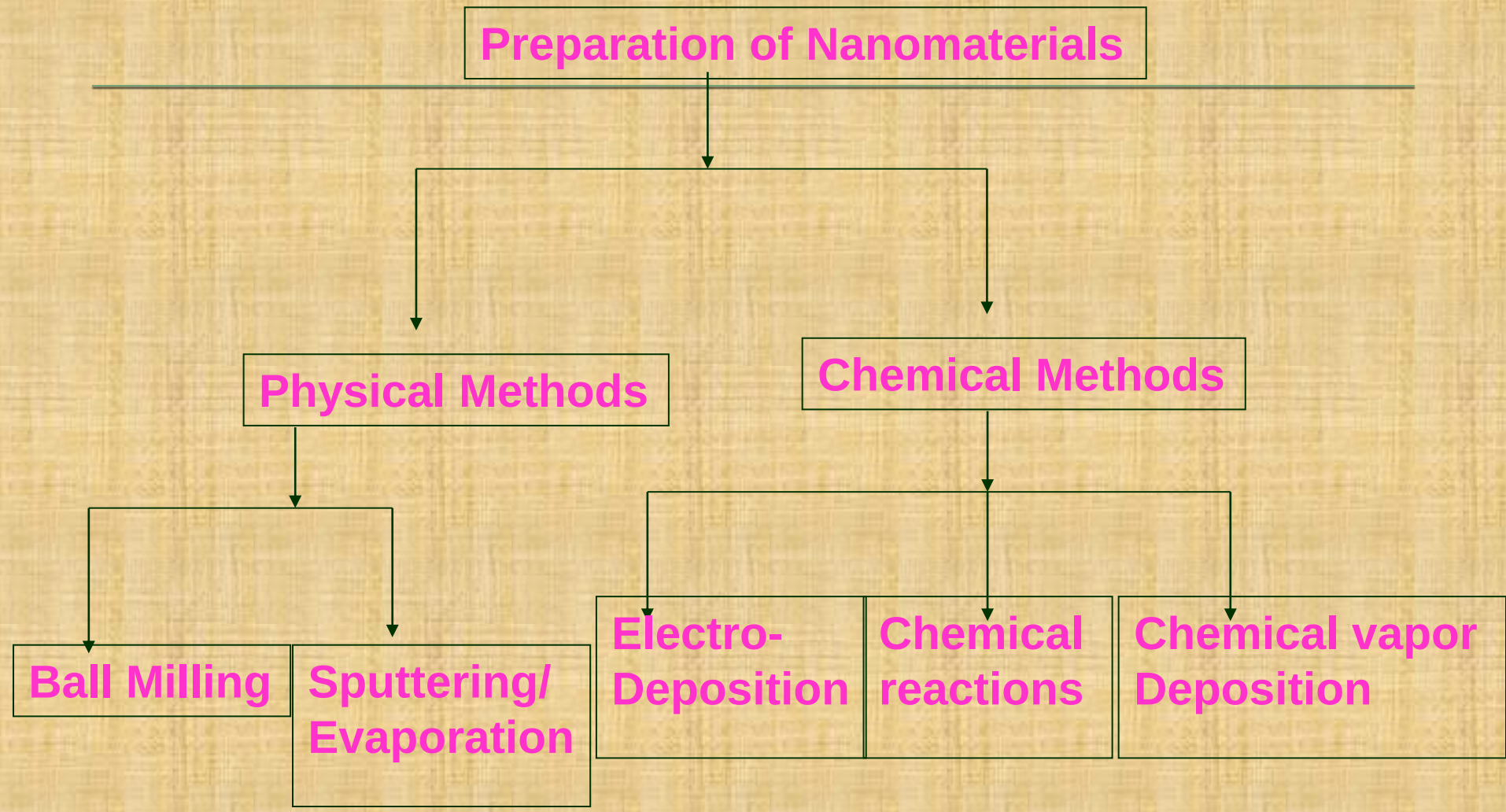
- Data memory
- Displays
- Laser diodes
- Glass fibers
- Filters
- Conductive, antistatic coatings.

Energy Sources

- Fuel cells
- Solar cells
- Batteries
- capacitors.

Cosmetics

- Sun protection creams
- Tooth paste


Preparation of Nanomaterials
Physical Methods
Chemical Methods
Ball Milling
Sputtering/ Evaporation
Electro-Deposition
Chemical reactions
Chemical vapor Deposition