MODULE 2: NANOTECHNOLOGY AND MEMORY DEVICES

Nanomaterials: Introduction, preparation of nanomaterials by different approaches, size dependent properties of nanomaterials (Surface area, Catalytic, Conducting, Thermal and Electrical). Introduction, properties and applications of Nano-fibres, Nano-photonics and Nano-sensors.

Memory Devices: Introduction, Basic concepts of electronic memory, Organic/polymer electronic memory devices, classification of electronic memory devices, types of organic memory devices (organic molecules, polymeric materials, organic inorganic hybrid materials).

NANOMATERIALS

Nanomaterials have one of its dimensions in the range of 1- 100 nm are known touse for centuries.

For example: Chinese used gold nanoparticles as an inorganic dye into their ceramic porcelains more than thousand years ago.

Nanomaterials are promising because at Nano scale, its physical and chemicalproperties differ significantly from its bulk structured materials.

For Example: For instance, bulk silver is non-toxic whereas silver nanoparticlescan kill viruses upon contact.

Properties like electrical conductivity, color and strength change when theNano scale is reached.

Applications of Nanomaterial's in Real life

- Nanomaterials used in stain-resistant and wrinkle free textiles, cosmetics, sunscreens, electronics, paints and varnishes etc.
- Nano coatings and Nano composites are finding uses in consumer products, such as windows, sports equipment, bicycles and automobiles.
- There are UV- blocking coatings on glass bottles which protect beverages from damage by sunlight, and longer lasting tennis balls using butyl rubber/nano-clay composites.
- Nanoscale titanium dioxide for instance is finding application in cosmetics, sunblock cleans, and self-cleaning windows, and nanoscale silica is being used as filler in a range of products etc.

SIZE DEPENDENT PROPERTIES OF NANOMATERIALS

Material in the nano material scale exhibit physical properties distinctively different from that of the bulk material. Some of the important properties of nano materials are discussed here;

1. Surface area
2. Catalytic
3. Thermal Properties
4. Electrical properties

1. Surface area:

- Bulk material is subdivided into individual nanomaterials, the total volume remains the same but the collective surface area is enormously increased.
- Nano materials have large proportion of atoms existing in the surface.

Ex: Bulk gold is catalytically inactive but gold nanoparticle are catalytically very active for selective redox reactions.

- Certain non-magnetic systems such as Pd and Pt become magnetic when their particle size is reduced to nano range
- Thermal conductivity of nanomaterials is less than that of their macroscopic counterparts

Ex: **Silicon nanowires** have much lower thermal conductivities compared to bulk silicon.

2. Catalytic properties:

- The catalytic properties of materials depends on particle size.
- If the size of the particles reduces form bulk to nanoscale, surface to volume increases drastically, that leads to very high catalytic activity of the same material.
- Nano structural materials have excellent catalytic properties.
  Ex: Gold nano particles deposited on partially reactive oxides such as, Fe_2O_3, NiO, MnO, alumina, titania are found to be more reactive.

3. Thermal properties:

Nanomaterials generally possess **poor thermal stability** compared to their bulk counterparts because of their high specific surface area, quantities of active sites, and large velocity of mass and heat transfer presented at the reaction interface.

- **Thermal properties are those properties of a material which is related to its conductivity of heat.**

- Heat capacity.
- Thermal Expansion.
- Thermal conductivity.
- Thermal stress.

4. Electrical or Conducting properties

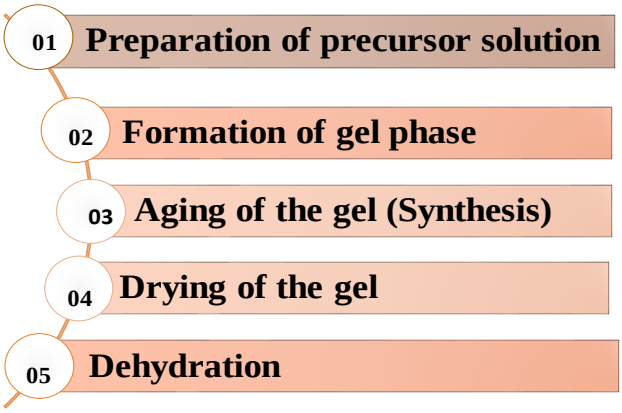
- Some metals which are good conductor in bulk become semiconductor or insulatoras their size is decreased to nano level.
- The reason is that the electronic bands in bulk material are continuous due to overlapping of orbitals of billions of atoms.
- Nanomaterial's very few atoms or molecules are present and so the electronic bonds become separate and separation between different electronic states varies with the size of nanomaterial.

SYNTHESIS OF NANOMATERIALS BY DIFFERENT APPROACHES

SOL GEL PROCESS:

- Metal oxide nanoparticles
- Formation of an oxide network through polycondensation reactions of a molecular precursor in a liquid
- Sol : Is a type of colloid in which solid particles are suspended in a liquid
- Gel: Semi rigid mass which is obtained after polycondensation.

PROCESS:

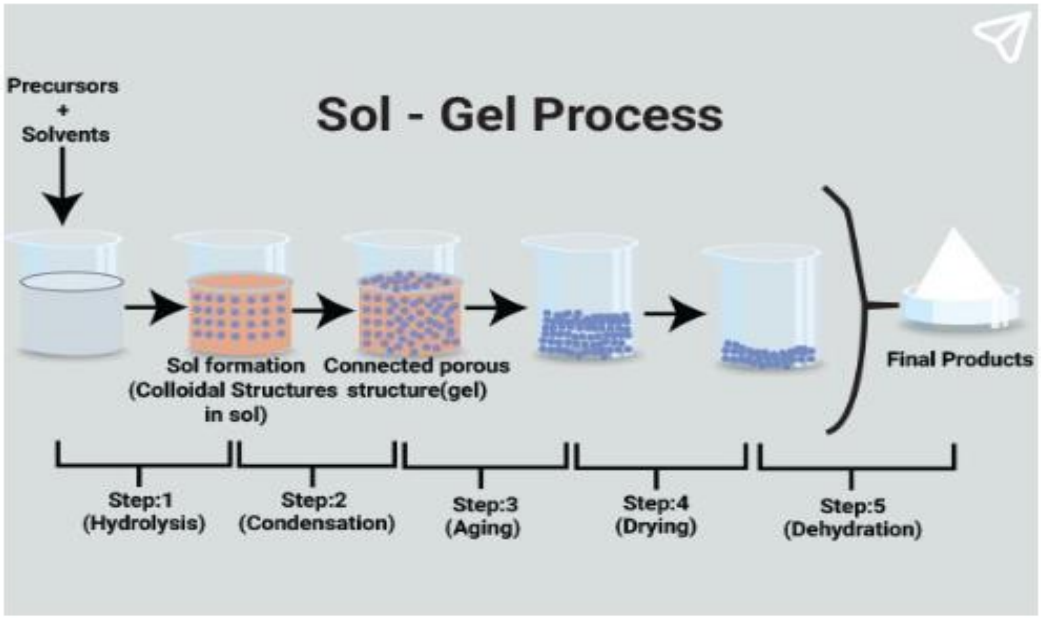


Hydrolysis

$$MOR + H_2O \longrightarrow MOH + ROH$$

Condensation

$$MOH + MOR \longrightarrow M\text{-}O\text{-}M + ROH$$



***Step-1*: Formation of the different stable solution of the alkoxide metal precursor.**

In the first step, metal alkoxide (Precursors) are hydrolyzed in water-alcohol mixed solvent. This step involves the transformation of molecular precursor into a highly cross linked solid

$$M\text{-}O\text{-}R + H_2O \rightarrow M\text{-}OH + R\text{-}OH$$

(Hydrolysis)

***Step-2*: Gelation resulting from the formation of an oxide or alcohol bridged network (gel) by a polycondensation reaction.**

It involves the polycondensation of hydrolysed species with each other. Here gel transforms into a solid mass.

$$M\text{-}OH + OH\text{-}M \rightarrow M\text{-}O\text{-}M + H_2O$$

$$M\text{-}O\text{-}R + M\text{-}OH \rightarrow M\text{-}O\text{-}M + R\text{-}OH$$

Where M= Si, Ti, Al, Zr etc.

Step -3: Aging of the gel – During the period gel transforms into a solid mass

Step 4: Drying of the gel: In this step, water and volatile liquids are removed from the gel network.

Step 5: Dehydration- The material is heated at temperature up to 800 ^{o}C

Advantages:

- Reaction carried out at a lower temperature
- Easy reactions (water) to be carried
- Simple and rapid method

Disadvantages:

- Quite expensive
- Since several steps are involved, close monitoring of the process is needed

PRECIPITATION METHOD

The process is mainly used to prepare metal oxide nano particles.

Steps:

- In this technique, an inorganic metal salt (such as chloride, nitrate, acetate or oxy chloride) is dissolved in water.
- Metal cations in water exist in the form of metal hydrate species such as $[Al(H_2O)]^{3+}$, $[Fe(H_2O)_6]^{3+}$.
- The species are hydrolyzed by adding a base solution, such as NaOH or NH_4OH.
- On increasing the concentration of OH^- ions, the hydrolyzed species condense with each other to form either metal hydroxide or hydrous metal oxide precipitate.
- The precipitate is then washed, filtered and dried.
- The dried powder on subsequent calcination to obtain the final crystalline metal oxide nanoparticles.