(Dr. Kalpana Malasia, ACD) (DIV-K)

NANO MATERIALS

Nanomaterials are materials possessing grain sizes on the order of a billionth of a meter (10^{-9} of a meter).

→ Nanomaterial (nanocrystalline material) has grains on the order of 1-100 nm. The average size of an atom is on the order of 1 to 2 angstroms (Å) in radius.

→ 1 nanometer comprises ~~of~~ 10 Å, and hence in one nm, there may be 3-5 atoms, depending on the ~~ion~~ atomic radii.

→ Particles of metals, semiconductors or ceramics
having diameters in the range 1-50 nm constitute
nanoclusters. The clusters are characterized by a
large surface area to volume ratio which implies
that a large fractions of atoms resides at the
grain boundary. Physical properties of such clusters
correspond neither to those of the free atoms or
molecules making up the particles, nor to those
of bulk solids of the same composition.

→ Nanomaterials are exceptionally strong, hard, ductile at high temperature, corrosion resistant and chemically very active.

→ Nanomaterials are prepared by physical (Evaporation in ~~inert gas~~ inert gas atmosphere, laser pyrolysis sputtering techniques) and chemical methods (Spray technique, precipitation, sol-gel method etc.)

→ Nanophase materials are prepared by compacting
the nanosized clusters generally under high
vacuum. The average grain sizes in these materials
range from 5-25 nm.

- Nanoparticles of oxide materials can be prepared by the oxidation of fine metal particles, by spray techniques, by precipitation or by sol-gel method.
- Cluster of carbon metals and metal ~~oxides~~ carbides (for e.g. M_8C_{12}, M = V, Zr, Hf or Ti) etc. are prepared by laser ablation.
- Nanocomposites as distinct from nanophase (multiphase) solid materials with ~~one~~ at least one dimension in the nanometer range. These composites lead to nanophasic or multiphasic ceramics, glasses or porous materials with tailored and improved properties. They can be derived from sol-gel, intercalation or entrapment.

(Dr Kalpana Maheria, ACD)

APPLICATIONS OF NANOMATERIALS

1. Next generation computer chips
2. Kinetic Energy (KE) penetrators with enhanced lethality
3. Better insulation materials
4. Phosphors for high definition TV
5. Low cost flat panel displays
6. Tougher and harder cutting tools
7. Elimination of pollutants
8. High energy density batteries
9. High power magnets
10. High sensitivity sensors.
11. Automobiles with greater fuel efficiency
12. Aerospace components with enhanced performance characteristics
13. Better and future weapons platforms
14. Longer lasting satellites
15. Longer lasting medical implants
16. Ductile machinable ceramics
17. Large electrochromic display devices

(Dr. Kalpana Maheria, ACD)

Sol-gel Process:

- Solgel process is a widely adopted low temperature process for the preparation of porous as well as some bulk materials of both amorphous and crystalline nature. The major steps involved are,
  (i) The preparation of the sol involving dispersal of the solid or hydrolysis of a precursor.
  (ii) Ageing of the sol & to form a gel
  (iii) Heat treatment.

In the first step, a sol [colloidal suspension of 1-100 nm sized particles] is prepared by dispersing ~~an~~ insoluble solid such as ~~oxide~~ or hydroxide in water at controlled pH, so that the solid particles remain in suspension without precipitating out. Alternatively, the sol may be prepared by the addition of a precursor ~~which~~ which reacts with the solvents to form a colloidal product. ~~the solvent~~ ~~the precursor which reacts with~~

~~For eg. the precursor to form a colloidal~~

For example, the precursor, usually, a metal ~~oxi~~ alkoxide is dissolved in water to yield a sol of metal oxide as the alkoxides undergoes hydrolysis.

$$M(OR)_n + x \cdot nH_2O \rightarrow M(OH)_x(OR)_{n-x} + xROH$$

; where M is metal ion and R is alkyl group.

(Dr-Kalpana Mahajan HOD) (2)

(Polymerization)

- In the second step, the sol is allowed to stand to form a thick gel by ageing or may be heated. The gel is a semi-rigid solid consisting of the solvent in a framework of solid particles, which is either colloidal (potentially a concentrated sol) or polymeric in nature. The gel can be shaped into ~~a~~ fibers, or other required forms by appropriate treatment.
- In the final step, the gel is given a heat treatment to remove the solvent or decompose anions such as ~~alk~~ alkoxides or carbonates to give oxides. The heat treatment also facilitates the rearrangement of the structure of the ~~sol~~ solid and crystallization. The heat treatment may be simple drying to form porous ceramic materials or calcining and sintering (heating to temperatures below the boiling of the solid product and simultaneously applying pressure) to produce compact solids.
- ~~The method has the advantage of~~

For e.g. Lithium niobate, a ferroelectric material used in optical switches, is prepared by mixing the alcoholic solutions of lithium ethoxide (LiOEt) and niobium ethoxide $[Nb_2(OEt)_{10}]$ followed by addition of water to yield the sol of hydroxy ethoxides by partial hydrolysis of the ethoxides. The sol ~~are~~ condenses to form the polymeric gel with metal oxygen links which on heat treatment yield the product lithium niobate.

~~Fig. of sol-gel processing~~.

After drying, ~~step~~ a step is carried out between 670 K and 1070 K to drive off the organic residues and chemically bound water.

Dehydration and dealcoholation are polycondensation reactions that may be represented as follows

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

(Dehydration) ⟶ (2)

$$-M\text{-}OH + RO\text{-}M \rightarrow -M\text{-}O\text{-}M + ROH$$

(Dealcoholation),

<u>Advantage</u>: The solgel method has the advantage of preparing amorphous materials such as glass and crystalline solution at low temperatures.

In the preparation of glass, The mixture of raw materials consisting of metal silicates, phosphates and borates is bought into solution and hydrolyzed at controlled pH to yield the gel ~~cell~~ which is then dehydrated to form the glass.

→ In the preparation of porous high surface area crystalline solids such as silica gel, the precursor isopropoxide is ~~hydrolyze~~ hydrolyzed at controlled pH and dried to dehydrate the gel.

The various steps involved in the solgel process is schematically represented in Fig. 1

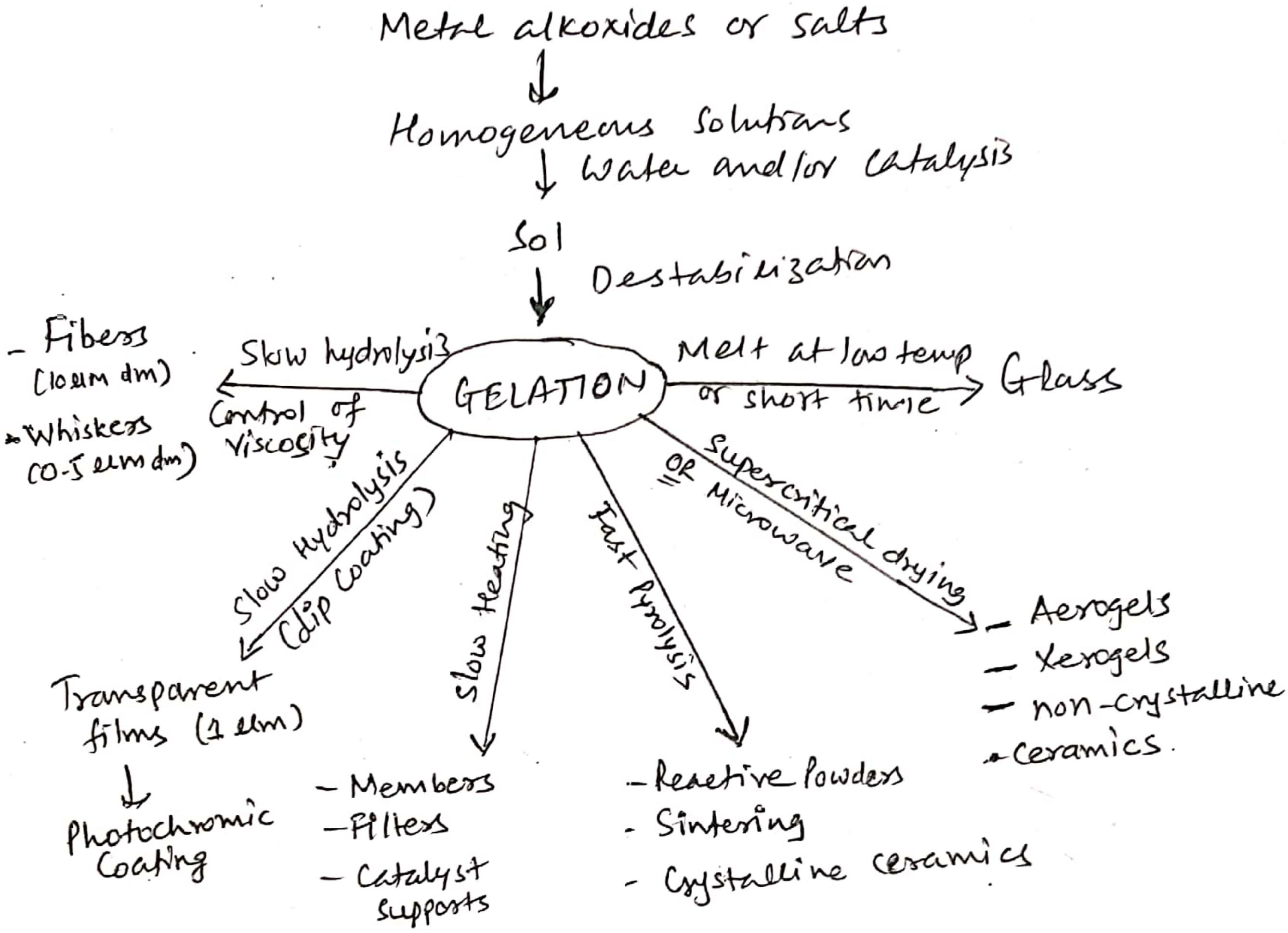

Fig. 1. Sol-gel Process