- Top-Down Approaches: Involve the breaking down of bulk materials into nanosized structures. Example: Lithography, ball milling
- Bottom-Up Approaches: Involve assembling atoms or molecules to form nanostructures. Example: Chemical vapor deposition (CVD), sol-gel process.

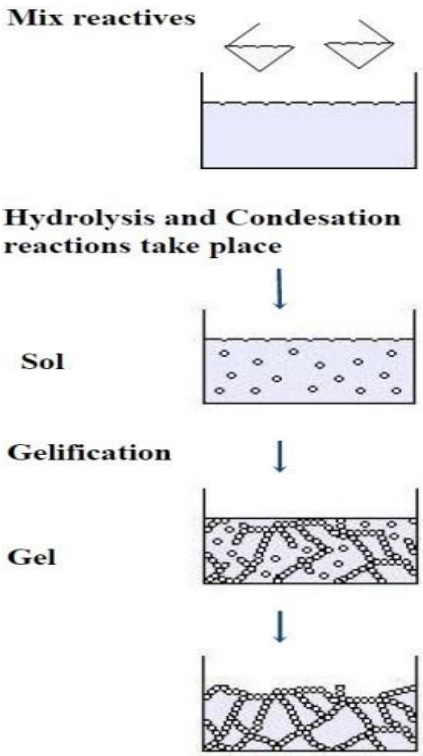
Sol gel method

The sol-gel process is a wet chemical technique also known as chemical solution deposition. It is the method for producing solid materials from small molecules. This method is used for the fabrication of metal oxides. It involves conversion of monomers into a colloidal solution (sol), that acts as the precursor. This colloidal solution gradually evolves towards the formation of a gel-like system.

- Sol-gel is a chemical solution process used to make ceramic and glass materials in the form of thin films, fibers or powders.
- A sol is (a colloidal or molecular suspension) obtained from (starting materials).
- A gel is a semi-rigid mass that forms when the solvent from the sol begins to evaporate and the particles or ions left behind begin to join together in a continuous network
- The sol-gel process is a wet-chemical technique that uses either a chemical solution (sol short for solution) or colloidal particles (sol for nanoscale particle) to produce an integrated network (gel).
- Metal alkoxides and metal chlorides are typical precursors. They undergo hydrolysis and polycondensation reactions to form a colloid, a system composed of nanoparticles dispersed in a solvent. The sol evolves then towards the formation of an inorganic continuous network containing a liquid phase (gel)

- Formation of a metal oxide involves connecting the metal centers with oxo (M-O-M) or hydroxo (M-OH-M) bridges, therefore generating **metal-oxo or metal-hydroxo polymers** in solution.
- After a drying process, the liquid phase is removed from the gel. Then, a thermal treatment **(calcination)** may be performed in order to favor further poly condensation and enhance mechanical properties

Reactions involved in sol gel process



Hydrolysis

$$Si - OR + HOH \longrightarrow Si - OH + ROH$$

Condensation

$$Si - OH + HO - Si \longrightarrow Si - O - Si + H_2O$$

$$Si - OR + HO - Si \longrightarrow Si - O - Si + ROH$$

Pictorial representation of sol gel process

Advantages

- It is cheap and low temperature technique
- Provides a thick coating for corrosion prevention
- It is a versatile method for synthesizing ceramic nanostructures