Unit V -SYNTHESIS AND APPLICATIONS OF NANO MATERIALS	9 Hours
Introduction – Difference between bulk and Nano materials – size dependent properties. Nano scale materials –particles, clusters, rods and tubes. Synthesis of Nanomaterials: Sol-gel process, Electro deposition, Hydrothermal methods. Applications of Nano materials in Electronics, Energy science and medicines. Risk and future perspectives of nano materials.	

Introduction

Nano technology

Nanotechnology is the art and science of manipulating matter at the nanoscale. A nanometer is the one billionth of a meter.

A **meter** is about the distance from the tip of your nose to the end of your hand (1 meter = 3.28 feet).

Millimeter- One *thousandth* of meter. (10^{-3}m)

Micron: a *micron is a millionth of a meter (or) one thousandth of millimeter (10^{-6}m)*

A nanometer is one thousandth of a micron (10^{-9}m)(or) a billionth of a meter. ie.,*one**billion** nanometers in a meter*.

- 1 nm is only three to five ***atoms*** wide.
- ~40,000 times smaller than the width of an average human hair
- Nanometer -One billionth (10^{-9}) of a meter
- The size of Hydrogen atom 0.04 nm
- The size of Proteins ~ 1-20 nm
- Feature size of computer chips 180 nm
- Diameter of human hair ~ 10 µm
- At the nanoscale, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter
- The population of India is one billion or 100 crores. Each Indian like you and me is nano comparison with the total population of India.

Nanotechnology is often divided into two parts:

Nanoscience –Nanoscience is an emerging area of science which involves the study of materials on an ultra-small scale and its novel properties.Materials at 1-100 nm are called nanostructures.

Nanotechnology – It is the science of tools, technologies and methodologies for chemical synthesis, analysis and biochemical diagnostic preferred in nanoscale.

- Nanotechnology involves the manufacturing and application of instruments and materials that have unique properties because of their small size.
- At the nanoscale, properties of materials behave differently and are said to behave under atomic and molecular rules.
- Researchers are using these unique properties of materials at this small scale to create new and exciting tools and products in all areas of science and engineering.

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Comparison of Bulk materials and Nano materials.

S.No.	Property	Bulk material/Microstructure	Nanomaterial/Nanostructure
1	Size	Microns to higher (1micron=10^{-6}m)	Nanometer (1nm=10^{-9}m)
2	Colour	Single colour in bulk form.	Size and shape determines the colour
3	Appearance	Lustrous,shiny surface when polished.	Vary in appearance depending on size and shape
4	Surface to volume ratio	Small	Very large
5	Electron's nature	Particle-like	Wave-like
6	Fabrication	Micro-fabrication	Nano-fabrication
7	Packing	Low	Very high

8	Number of constituting particles	Infinite	2 to several thousands.
9	Method follows	Semi-classical method.	Quantum mechanical method
10	Melting point	High	Low
11	Hardness	Low	5 times greater than bulk materials.
12	Strength	Low	3-10 times higher than bulk materials.
13	Wear resistance	Low	170 times higher than the bulk materials.
14	Corrosion resistance	Low	High
15	Ability to form suspension	Cannot form suspension.	Possible
16	Properties	Possesses constant physical properties.	Possesses size dependent properties.

Science is undergoing yet another change in helping mankind enter a new era, the era of nanotechnology. Nanoparticles are the simplest form of structure with size in the nm range or of structural radius <100nm.

E.g.-Fullerens,metal cluster larger molecule such as protein

<u>"SIZE DOES MATTER-SMALL IS VERY DIFFERENT"</u>

SIZE DEPENDENT PROPERTIES

Why properties of Nano Materials are different?

Two principal factors cause the properties of Nano Materials to differ significantlyfrom other materials

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

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

Let us consider one Cubic volume. Its surface area is $6m^2$ .When it is divided into eight pieces its Surface area becomes $12m^2$, similarlywhen 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

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).

A. Electrical Properties

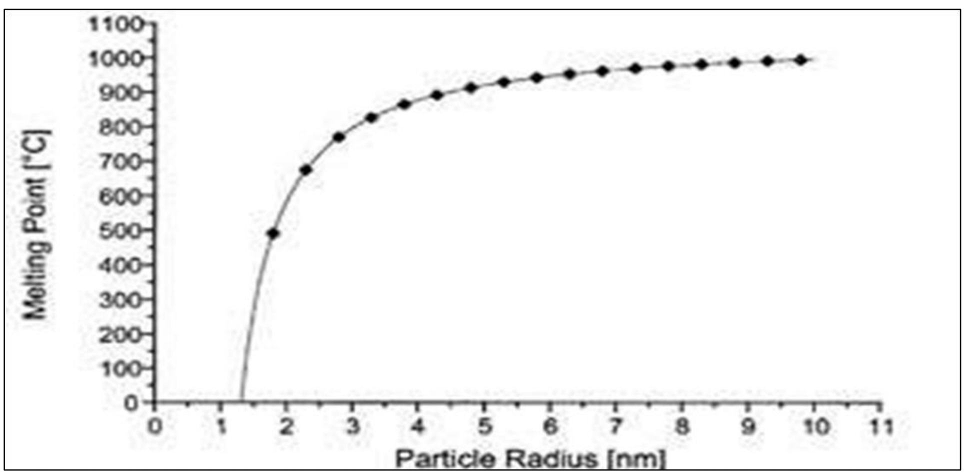
1. Conductivity of a bulk or large material does not depend upon dimensions like diameter or area of cross section and twist in the conducting wire etc. However it is found that in case of carbon nanotubes conductivity changes with change in area of cross section.
2.It is also observed that conductivity also changes when some shear force (in simple terms twist) is given to nanotube.
3.Conductivity of a multiwalled carbon nanotube is different than that of single nanotube of same dimensions.
4.The carbon nanotubes can act as conductor or semiconductor in behaviour but we all know that large carbon (graphite) is good conductor of electricity.
These are the important electrical properties of nanomaterials with their examples.

B. Melting Point

Nanomaterial may have a significantly lower melting point or phase transition temperature.The melting point decreases dramatically as the particle size gets below 5 nm. Melting point of bulk gold is 1063^0C whereas that of nanoparticles is 300^0C. Sintering temperature(Sintering is a heat treatment process in which a large quantity of loose aggregate material is subjected to a sufficiently high temperature and pressure to cause the loose material to become a compact solid piece. The amount of heat and pressure administered during the sintering process is slightly less than the material's melting point.) of refractory material such as tungsten is also reduced from 2200^{0}C in bulk to 1100^{0}C for nanoparticles of size 22 nm. The size effect on lowering of melting point and sintering temperature is also seen in nanoparticles of other materials like Nickel and Indium.

C. Catalytic properties

Nanoparticles shows better catalytic efficiency through higher surface-to- volume ratio.Nanomaterial-based catalysts are usually heterogeneous catalysts broken up into metal nanoparticles in order to enhance the catalytic process. Metal nanoparticles have high surface area, which can increase catalytic activity. Nanoparticle catalysts can be easily separated and recycled.



D. Optical properties/colour

Optical properties at nanoscale arise because of quantum confinement of electrons.

Examples:

1. Bulk gold appears yellow in colour whereas nanosizedgold(12nm) appears red in colour.

Reason:

The particles are so small that electrons are not free to move about as in bulk gold.Because this restricted movement,the particles react differently with light.

2. TraditionalZnO Sunscreen is white whereas nanosized one is clear(transparent).

Reason:

Large ZnO particles scatter visible light whereas nanosizedZnO particles are so small compared to that of visible light that they don't scatter it.

E. Magnetic properties

The magnetic properties of materials undergo a change on reduction of bulk material to nanosize exhibiting increased paramagnetic behaviour.Forexample,Gold(Au),Palladium(Pd) and Platinum(Pt) are non-magnetic(diamagnetic) in bulk but their nanoparticles show magnetic properties(either ferromagnetic or paramagnetic).

Pt and Pdnanoparticles:Ferromagnetic

Au nanoparticles: Paramagnetic

F. Mechanical Properties

The nanomaterials have fewer defects compared to bulk materials,which increases the mechanical strength.

(i) Mechanical properties of polymeric materials can be increased by the addition of nano-fillers.

(ii) As nanomaterials are stronger,harder and more wear resistant and corrosion resistant,they are used in spark plugs.

Example:

Nano crystalline carbides are much stronger,harder and wear resistant and are used in micro drills.

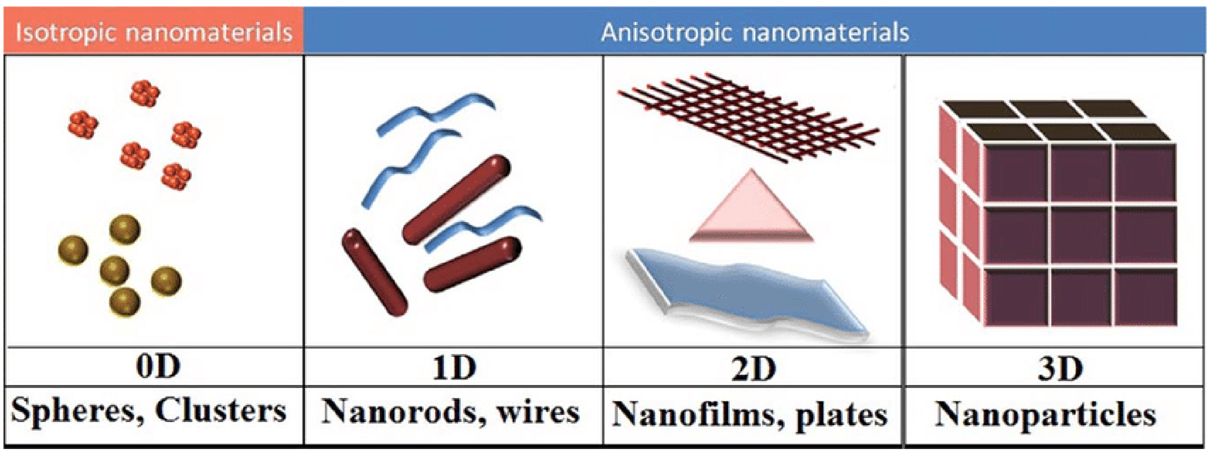
Nanoparticles are the simplest form of structure with size in the nm range or of structural radius <100nm

At the nanoscale, properties of materials behave differently and are said to behave under atomic and molecular rules.

Researchers are using these unique properties of materials at this small scale to create new and exciting tools and products in all areas of science and engineering.

Nanoscale materials are divided into three categories

1. **Zero dimension** – length, breadth and heights are confined at single point. (for example, Nano dots)
2. **One dimension** – It has only one parameter either length (or) breadth (or) height (Example:very thin surface coatings, nanowires)
3. **Two dimensions-** it has only length and breadth (for example, nanotubes)
4. **Three dimensions** -it has all parameter of length, breadth and height. (for example, Nano Particles



Nanoscale materials

- Nanoparticles
- Nanoclusters
- Nanorods
- Nanotubes
- Quantum dots

Nanoparticles

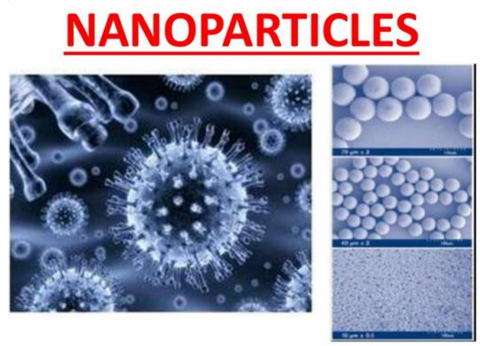
Nanoparticles are the particles, the size of which ranges from 1 to 100 nm. These are tiny aggregates of atoms but smaller than their crystals but bigger than molecules. They have three dimensional structures. Nanoparticles are of interest because of the new properties (such as chemical reactivity and optical behaviour) that they exhibit compared with larger particles of the same materials.

For example, titanium dioxide and zinc oxide become transparent at the nanoscale and have found application in sunscreens.

Nanoparticles have a range of potential applications:

1. In the short-term application such as in **cosmetics, textiles and paints**. In the longer term applications such as **drug delivery** where they could be to used deliver drugs to a specific site in the body.
2. Nano silver particles are used as a catalyst in industries.
3. Nanoparticles are used in medicine
4. Nano silver particles are used in making bone cement, surgical instruments etc.,

Nanoparticles can also be arranged into layers on surfaces, **providing a large surface area and hence enhanced activity, relevant** to a range of potential applications such as catalysts.



Nano clusters

Nanoclusters are fine aggregates of atoms or molecules. The size of which ranges from 0.1 to 10 nm. Of all nanomaterials, nanoclusters are the small sized nanomaterials because of their close packing arrangements of atoms.

E.g., CdS, ZnO, etc

All the atoms, in nanocluster, are bound by forces like metallic, covalent, ionic, hydrogen bond or Vander Waals forces of attraction. Clusters of certain critical size are more stable than others. Nanoclusters consisting of up to a couple of hundred atoms, but larger aggregates, containing 103 or more atoms, are called nanoparticles.

Magic number

Magic number is the number of atoms present in the clusters of critical size with higher stability.

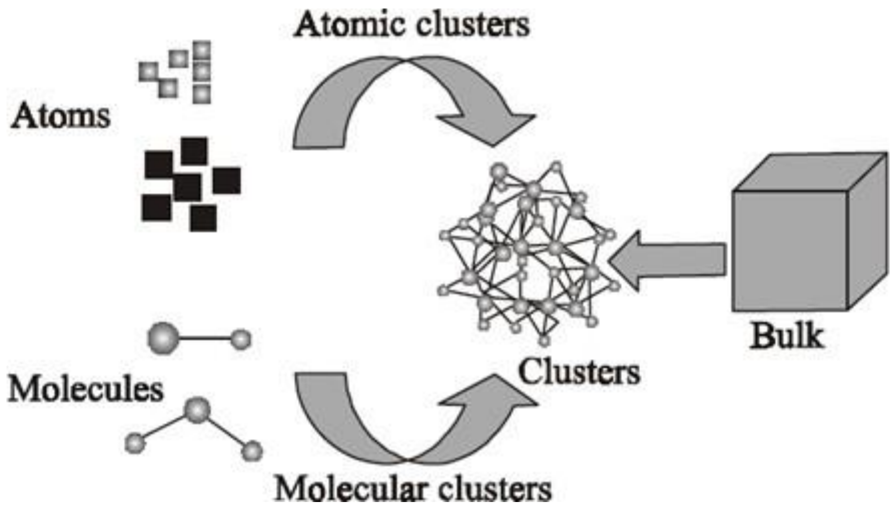
Different type of nanoclusters can be distinguished from the nature of forces present between atoms.

The formation of stable nanoclusters such as Buckminsterfullerene (C_{60}) has been suggested to have occurred during the creation of the universe.

Production

Nanoclusters can be produced from atomic or molecular constituents or from the bulk materials either by bottom up or topdown process.

Atomic and molecular nanoclusters are formed by the nucleation of atoms are molecules respectively.



Properties

1. The reactivity of nanoclusters are decreased due to their decrease in size
2. The melting point of nanoclusters are lower than the bulk materials due to high surface to volume ratio
3. The electronic structure of the nanocluster is more confined than the bulk materials

Applications

1. Nanoclusters are used as a catalysts in many reactions
2. It is used in nano based chemical sensors
3. It is also used as a light emitting diode in quantum computers.

Nanorods

In nanotechnology, **nanorods** are one morphology of nanoscale objects. Nanorod is one dimensional solid material having an aspect tatio i.e., length to width ratio less than 20. Each of their dimensions range from 1–100 nm.

E.g., Zinc oxide, Cadmium sulphide, Gallium nitride nanorods

Synthesis

They may be synthesized from metals or semiconducting materials. Nanorods are produced by direct chemical synthesis. A combination of ligands acts as shape control agents and bond to different facets of the nanorod with different strengths.

This allows different faces of the nanorod to grow at different rates, producing an elongated object.

Characteristics of nanorods

1. Nanorods are two dimensional materials.
2. It also exhibit optical and electrical properties.

Applications of Nanorods

- One potential application of nanorods is in display technologies, because the reflectivity of the rods can be changed by changing their orientation with an applied electric field. Another application is for microelectromechanical systems (MEMS).
- Nanorods, along with other noble metal nanoparticles, also function as theragnostic agents.
- It is also used in the manufacturing of micromechanical switches.
- Nanorods absorb in the near IR, and generate heat when excited with IR light. This property has led to the use of nanorods as cancer therapeutics.
- Nanorods can be conjugated with tumor targeting motifs and ingested. When a patient is exposed to IR light (which passes through body tissue), nanorods selectively taken up by tumor cells are locally heated, destroying only the cancerous tissue while leaving healthy cells intact.
- Nanorods based on semiconducting materials have also been investigated for application as energy harvesting and light emitting devices.

Nanotubes

Nanotubes are tube like structures with diameter of 1-100 nm and length of few nm to microns. Nanotubes consist of tiny carbon and other materials like boron nitride. Nanotubes may be organic or inorganic.

Examples

1. Carbon nanotube
2. Silicon nanotube
3. DNA nanotube
4. Boron nitride nanotube

Carbon nanotubes (CNTs)

- Carbon nanotube is a tubular form of carbon with 1-3 nm diameter and a length of few nm to microns
- Generally carbon in the solid phase exist in different allotropic forms like graphite, diamond, fullerene and nanotubes
- Carbon nanotubes are tubular forms of carbon. When graphite sheets are rolled into a cylinder, theor edges join to each other frrm carbon nanotubes. Each carbon atom in the carbon nanoyubes are linked by covalent bonds. But the number of nanotubes align into ropes and are held together by weak vanderwaals forces

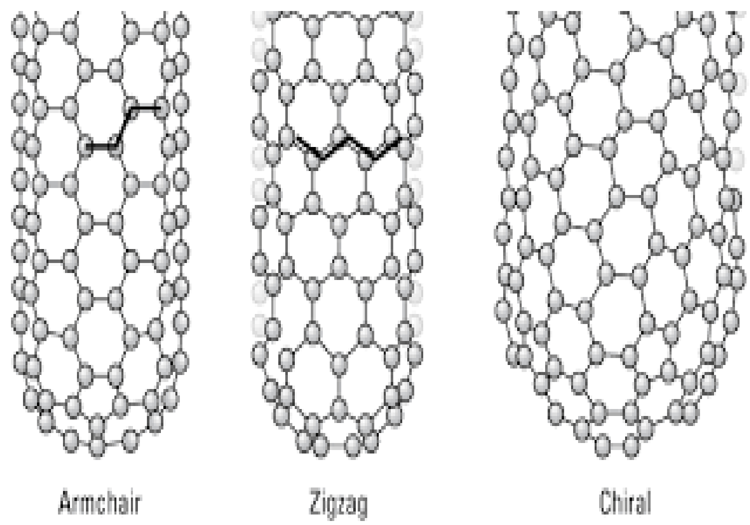
Structure or Types of carbon nanotubes

Depending upon the way in which graphite sheets are rolled, two types of CNTs are formed.

1. Single walled nanotubes (SWNTs)
2. Multi- walled nanotubes (MWNTs)

1. **Single walled nanotubes (SWNTs)**
   - SWNTs consist of one tube of graphite. It is oneatom thick having a diameter of 2 nm and a length of 100 µm.
   - SWNTs are very important, because they exhibit important electrical properties. It is an excellent conductor.
   - Three kinds of nanotubes are resulted, based on the orientation of hexagon lattice.

(a)**Arm-Chair structure:** the lines of hexagons are parallel to the axis of the nanotube.
(b)**Zig-zag structure:** the lines of carbon bonds are down to the centre.
(c)**Chiral nanotubes:** it exhibits twist or spiral around the nanotubes.



It has been confirmed that the arm-chair carbon nanotubes are metallic while zig-zag and chiral nanotubes are semiconducting.

2. **Multi- walled nanotubes (MWNTs)**

MWNTs (nested nanotubes) consist of multiple layers of graphite rolled in on themselves to form a tube shape.It exhibits both metallic and semiconducting. It is used for storing fuels such as hydrogen and methane.

Synthesis of carbon nanotubes

Carbon nanotubes are synthesized by any one of the following methods

1. Pyrolysis of hydrocarbons
2. Laser evaporation
3. Carbon arc method
4. Chemical vapour deposition

1. **Pyrolysis of hydrocarbon**

   Carbon nanotubes are synthesized by the pyrolysis of hydrocarbons such as acetylene at about 700 C in the presence of Fe-Silica or Fe-graphite catalyst under inert conditions

2. **Laser ablation**

   It involves the vapourization of graphite target, containing small amount of carbon or nickel, by exposing it to an intense pulsed beam at higher temperature(1200°C) in a quartz tube reactor. An inert gas such as argon (or) helium is simultaneously allowed to pass into the reactor to sweep the evaporated carbon atoms from the furnace to the colder part ie., copper collector, on which they condense as carbon nanotubes.

3. **Carbon arc method**

   It is carried out by applying direct current (60-100 and 20-25 V) arc betweengraphite electrodes of 10-20 μm diameter.

4. **Chemical vapour deposition**

   It involves the decomposition of vapour of hydrocarbons such as acetylene, ethylene etc., at high temperatures (1100C) in presence of metal nanoparticles catalysts like nickel, cobalt, iron supported on MgO or Al_2O_3. Carbon atoms produced by the decomposition on a cooler surface of the catalyst.

Properties of CNTs

1. CNTs are very strong; withstand extreme strain in tension and poses elastic flexibility
2. The atoms in a nano-tube are continuously vibrating back and forth.
3. it is highly conducting and behaves like metallic or semiconducting materials
4. it has very high thermal conductivity and kinetic properties

Applications

1. It is used in battery technology and in industries as catalyst
2. It is also used as light weight shielding materials for protecting electronic equipments
3. CNTs are used effectively inside the body for drug delivery.
4. It is used in composites, ICs.
5. It also acts as an efficient catalysts for some chemical reactions
6. It acts as a very good biosensor. Due to its chemical inertness carbon nanotubes are used to detect many molecules present in the blood.
7. It is also used in water softening process as a filter.
8. It finds applications in nanoelectronics.
9. Carbon nanotubes may be used to improve the efficiency of ultracapacitors.

Quantum well

- It is a two dimensional system
- The electron can move in two directions and restricted in one direction.

Quantum Wire

- It is a one-dimensional system
- The electron can move in one direction and restricted in two directions.

Quantum dot

- It is a zero dimensional system
- The electron movement was restricted in entire three dimensions
- The extreme case of this process of size reduction in which all three dimensions reach the low nanometer range
- A quantum dot is a semiconductor nanostructure the confines the motion of conduction band eleltrons, valance band holes in all three spatial directions.

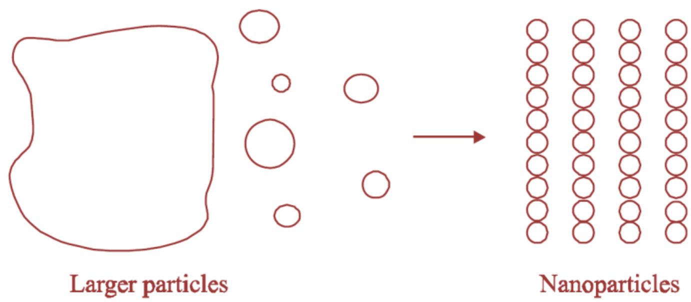
Synthesis of Nanomaterials

Synthesis of nanosize materials is of great importance, as particles built up from a few hundred atoms possess properties different from bulk. There are two possible routes for the synthesis of nanomaterials – "bottom up" and "top down". In the bottom up approach nanostructures are built up from individual atoms or molecules (small to big).

In the top down approach the nanostructures are built up from breaking up bulk materials (big to small). In this method a bulk material is broken up into nanoparticles using grinder, lasers etc.

Top-down process

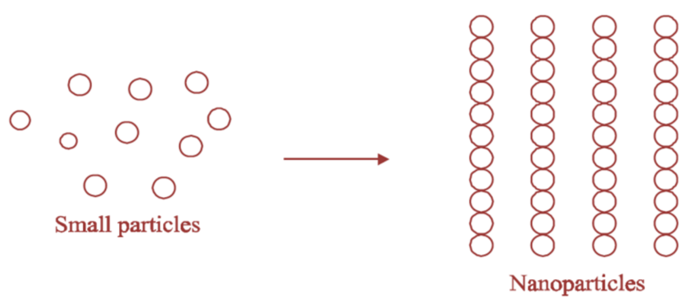
Top-down process involves the conversion of bulk materials into smaller particles of nano scale structure.



Top-down process

Bottom-up process

Bottom-up process involves building up of materials from the bottom by atom by atoms, molecule by molecule or cluster to the nanomaterials.



Bottom up process

Nanoscale Approaches and Fabrication

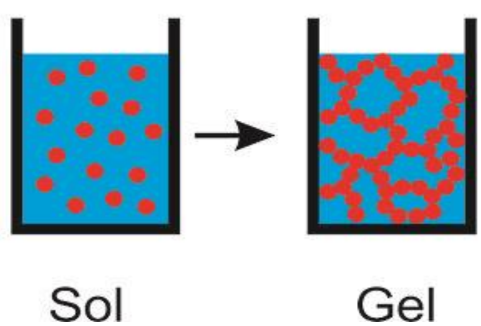
Top-down Approaches	Bottom-up Approaches
Create smaller objects using larger	They arrange smaller components in to more

objects	complex
Uses principles of molecular recognition	Layer-by-layer self assembly

Sol-gel process

- SOL: Colloidal solution of solid particles(a few hundred nm in dia) suspended in a liquid phase. If a solid is dispersed in a liquid,the colloid is termed as SOL.
- GEL: 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.If a liquid is dispersed in a solid,the colloid is termed as GEL.

S.No.	Sol	Gel
1.	Definition: The liquid state of a colloidal solution is called sol	Definition: The solid or semi-solid (Jelly like) stage of a colloidal solution is called gel.
2.	The sol does not have a definite structure.	The gel possesses honeycomb like structure.
3.	The dispersion medium of the sol may be water (hydrosol) or alcohol (alcosol)	The dispersion medium of gel will be hydrated colloid particles.
4.	The sol can be converted to gel by cooling	The gel can be converted to sol by heating.
5.	The sol can be easily hydrated	The gel cannot be dehydrated.
6.	The viscosity of the sol is very low	The viscosity of the sol is very high.
7.	Sol can be categorized into lyophobic and lyophilic sols	There is no such classification of gel.



The sol-gel process, involves the evolution of inorganic networks through the formation of a colloidal suspension (*sol*) and gelation of the sol to form a network in a continuous liquid phase (*gel*). The precursors for synthesizing these colloids consist usually of a metal or metalloid element surrounded by various reactive ligands. The starting material is processed to form a dispersible oxide and forms a sol in contact with water or dilute acid.

Removal of the liquid from the sol yields the gel, and the sol/gel transition controls the particle size and shape. Calcination of the gel produces the oxide.

The precusors for synthesizing these colloids consist:

- Metal alkoxides

e.g: tetramethixysilane (TMOS) and tetraethoxysilane (TEOS)

- Metal chlorides

They readily react with water

Reactions involved in the sol-gel process are as follows:

- **Hydrolysis**
- **Polycondensation**

Sol-gel processing refers to the hydrolysis and condensation of alkoxide-based precursors such as $Si(OEt)_4$. The reactions involved in the sol-gel chemistry based on the hydrolysis and condensation of metal alkoxides can be described as follows:

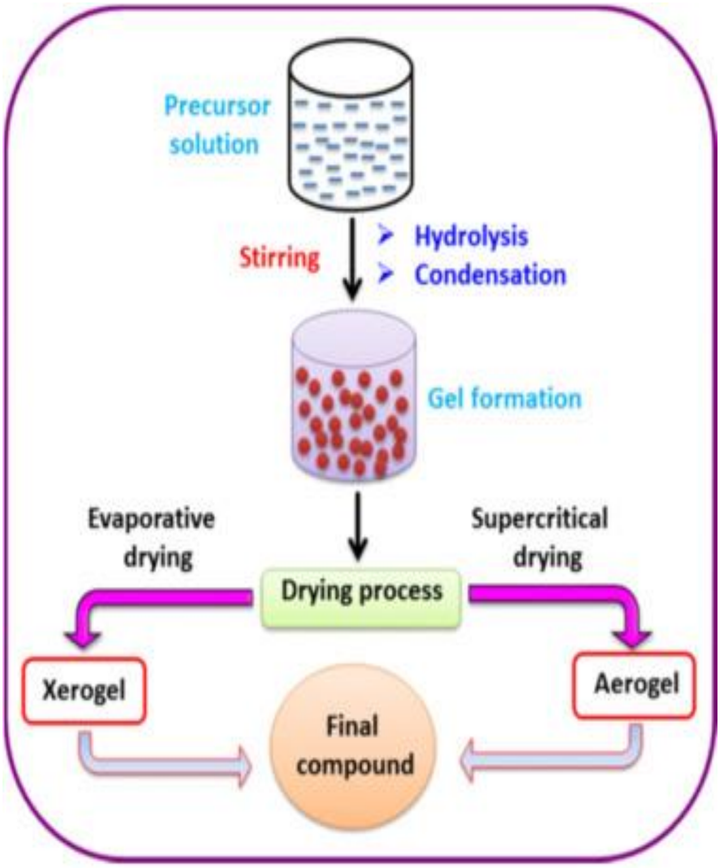
$$MOR + H_2O \rightarrow MOH + ROH \text{ (hydrolysis)}$$

$$MOH + ROM \rightarrow M\text{-}O\text{-}M + ROH \text{ (condensation)}$$

Sol-gel method of synthesizing nanomaterials is very popular and is widely employed to prepare oxide materials.

Sol – gel processing

- The sol-gel process is awet-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 alkaloids 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 inorganic continuous network containing a liquid phase (gel) was formed from the sol.
- 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 polycondenstion and enhance mechanical properties.



Chemical reactions

Hydrolysis

M-OR (metal alkoxide) + H_2O → M-OH (Sol) + R-OH

Condensation

M-OR (metal alkoxide) + M-OH (Sol) →M-O-M (gel) + R-O

Drying

Drying may be done by two methods.

- Evaporative drying
- Supercritical drying

S. No.	Evaporative drying	Supercritical drying
1.	This type takes place at the room temperature itself, we can convert the gel into nanoparticle	Here the Nanomaterial is subjected to Temperature and pressure is maintained above its critical point.
2.	Evaporation of the solvent at low pressure.	Involves steam drying of products containing water.
3.	Xerogels are formed	Aerogels are formed.
4.	It is an economical method.	It is not an economical method. Hence it is not used frequently.

Advantages:

1.The size, shape and chemical composition of the nanomaterials can easily be controlled.

2.Substances formed are of high purity.

3.The reaction mechanism is easily controllable.

Disadvantages:

1. It takes long period for deposition.

2. High temperature (nearly 500^{o}C) required to form nanocrystals.

Electrodeposition

Electrodeposition is a well-known conventional surface modification method to improve the surface characteristics, decorative and functional, of a wide variety of materials. Now, electrodeposition is emerging as an accepted versatile technique for the preparation of nanomaterials.

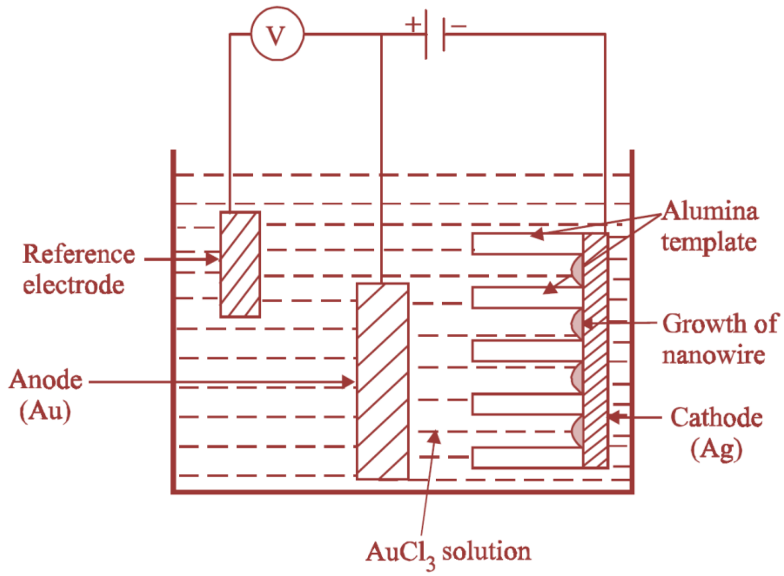
Principle

The principle of electrodeposition is inducing chemical reactions in an aqueous electrolyte solution with the help of applied voltage. E.g. this is the process of using electrical current to coat an electrically conductive object with a relatively thin layer of metal.

It is anelectrochemical method in which ions from the solution are deposited at the surface of cathode. Template assisted electro-deposition is an important technique for synthesizing metallic nanomaterials with controlled shape and size. Array of nano-structured materials with specific arrangements can be prepared by this method using an active template as a cathode.

Process of electro-deposition

- The cell consists of a reference electrode, specially designed cathode and anode. All these electrodes are connected with the battery through a voltmeter and dipped in an electrolytic solution of a soluble metal as shown in the figure.
- When the current is passed through the electrodes of template, the metal ions from the solution enter into the pores and get reduced at the cathode, resulting in the growth of nanowire inside the pores of the template.



Electrodeposition of Gold on silver

Nanostructured gold can be prepared by the electrodeposition technique using gold sheets as an anode and silver plate as a cathode. An array of alumina template is kept over the cathode as shown in the figure and the $AuCl_3$ is used as an electrolyte.

When the current of requited strength is applied through the electrodes, Au^+ ions diffuse into the pores of alumina templates and get reduced at the cathode resulting in the growth of nanowires (or) nanorodes inside the pores of the alumina templates.

<u>**Advantages of Electro-deposition**</u>

- The ability to create highly conductive nanowires. Because electrodeposition relies on electron transfer, which is the fastest along the highest conductive path.
- Electrodeposited nanowires tend to be dense, continuous and highly crystalline in contrast to other deposition methods.

- The ability to control the aspect ratio of the metal nanowires by monitoring he total amount of passed charge.
- This method is relatively cheap and fast.
- Complex shaped objects can be coated.
- The film or wire obtained is uniform.
- Metal nanowires including Ni, Co, Cu and Au can be fabricated by this method.

Hydrothermal method:

Hydrothermal synthesis can be defined as a method of ***synthesis of single crystals that depends on the solubility of minerals in hot water under high pressure***.

Principle:

• Liquid water cannot be heated above 100^{o}C in an open vessel since it boils at that temperature.

• However,when water is heated in a sealed vessel,pressure increases which in turn increases the boiling point of water(>100^{o}C).

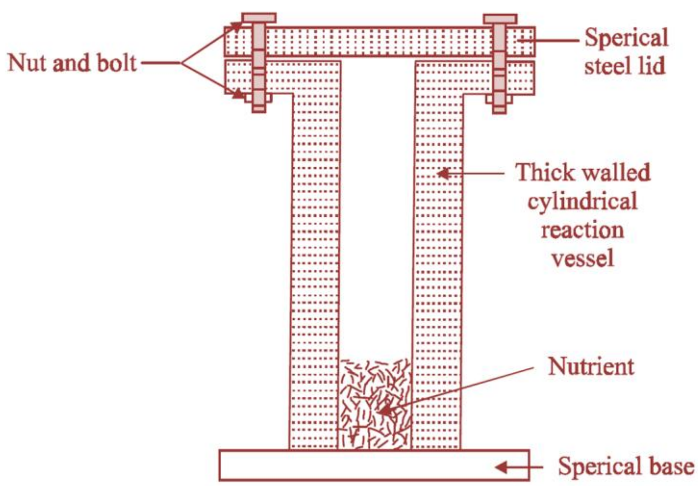
• When autoclave is heated,pressure increases and water remains in liquid above its normal boiling point(100^{o}C)which is called Super-heated water.

• These conditions in which pressure is raised above atmospheric pressure and temperature above boiling temperature are known as **Hydrothermal Condition.**

Process:

The crystal growth is performed in an apparatus consisting of a steel pressure vessel called an autoclave, in which a nutrient is supplied along with water. A temperature gradient is maintained between the opposite ends of the growth chamber.

At the hotter end, the nutrient solute dissolves, while at the cooler end it is deposited on a seed crystal, growing the desired crystal.



Autoclave

Advantages:
1. Materials which have a high vapour pressure near their melting points can be grown by the hydrothermal method.
2. The method is also particularly suitable for the growth of large good-quality crystals while maintaining control over their composition.

Disadvantages:
1. Need of expensive autoclaves.
2. It is not possibleto observethe progress of crystal growth

Applications
- It is used in the preparation of Zeolites.
- Metal oxides like TiO_2 and CrO_2 can be prepared.
- ZnS nanoparticles.
- Nanowires and Nanorods.
- Carbonaceous material.

<u>Application of nano materials in electronics</u>

1. Quantum wires are found to have high electrical conductivity
2. Integrated memory circuits have been found to be effective devices
3. A transistor, called NOMFET (Nanoparticle Organic Memory Field Effect Transistor) is created bycombining gold particles with organic molecules
4. MOSFET(Metal Oxide Semiconductor Field Effect Transistor) performs both as switches and amplifiers
5. Nanowires are used to build transistor without p-n junction
6. Nano radios are other important device prepared by using carbon Nanotube
7. Light weight Nano emissive display panel uses CNTs
8. Memory chips with density of one terabyte per square inch is in use.
9. Silver nanoparticle ink was used to form the conductive lines needed in circuit boards
10. Nano magnets are used in switches, transistors for lower energy consumption
11. Today's solar cells utilize only 40% solar energy. Nanotechnology could help to increase the efficiency of light conversion using nanostructures.
12. The efficiency of internal combustion engine is about 30-40% Nano technology could improve combustion by designing catalysts with maximized surface area.
13. The use of batteries with higher energy content is possible with nano materials.
14. Nanotechnology has already introduced integrated circuits in nanoscale (50nm) in CPU's and DRAM devices.
15. Carbon nano-tubes based cross bar memory called Nano-RAM gives high density memory for computers has been developed.
16. The data storage density of hard discs is increased by using the nanoparticle

Application of nanomaterials in Energy Sciences.

- **Generating steam from sunlight.**
  Researchers have demonstrated that sunlight, concentrated on nano particles, can produce steam with high energy efficiency. The "solar steam device" is intended to be used in areas of developing countries without electricity for applications such as purifying water or disinfecting dental instruments

- **Producing high efficiency light bulbs.**

  A nano-engineered polymer matrix is used in one style of high efficiency light bulbs. The new bulbs have the advantage of being shatterproof and twice the efficiency of compact fluorescence light bulbs.

- **Increasing the electricity generated by windmills.**

  An epoxy containing carbon nanotubes is being used to make windmill blades. Stronger and lower weight blades are made possible by the use of nano tube-filled epoxy.

- **Generating electricity from waste heat.**

  Researchers have used sheets of nanotubes to build thermo cells that generate electricity when the sides of the cell are at different temperatures.

- **Nanotechnology used for storing hydrogen for fuel cell powered cars**.

- **Clothing that generates electricity**.

  Researchers have developed piezoelectric nano fibers that are flexible enough to be woven into clothing. The fibers can turn normal motion into electricity to power your cell phone and other mobile electronic devices

Application of nanoparticle technology in medicine

The biological and medical research communities have exploited theproperties of nano particles for various applications. Integration of nano materials with biology led to the development ofdiagnostic devices and drug delivery vehicles.

1. Fluorescent biological labels
2. Drug and gene delivery
3. Bio detection of pathogens
4. Detection of proteins
5. Probing of DNA structure
6. Tissue engineering
7. Tumour destruction via heating (hyperthermia)
8. Separation and purification of biological molecules and cells
9. MRI contrast enhancement

Diagnostics:

- Gold nano particles tagged with DNA can be used for the detection ofgenetic sequence.

- Manganese oxide nanoparticles have been used as contrast agent formagnetic resonance imaging (MRI).The results of an MRI scan can beused to help diagnose conditions, plan treatments and assess how effectiveprevious treatment has been.
- Nanoparticles are used for early and specific cancer detection andtherapy.

Drug Delivery: Drug can be delivered for specific cell using nano particles.

Tissue Engineering

1.This may replace today's conventional treatment like organ transplants/artificial implants.
2.Advanced forms in tissue engineering may lead to life extension.
3.It can repair the targeted damaged tissue.
4.Lipid based nanoparticles are used in cosmetics and Creams.
5.The zinc oxide nanoparticles block the UV rays; hence it is used in Sunscreen lotion.

Risk or challenges

For the fabrication and processing of nanomaterials and nanostructures, the following challenges must be met:

- Overcome the huge surface energy, a result of enormous surface area or large surface area to volume ratio.
- Ensure all nanomaterials with desired size, uniform size distribution, morphology, crystallinity, chemical composition, and micro structure, that all together result in desired physical properties.
- Prevent nanomaterials and nanostructure from coarsening through either Ostwald ripening or agglomeration as time evolutes.

Future perspectives

1. Development and demonstration of novel tools to study at the nanometer level what is being manifested at the macro level.
2. New innovative measurement techniques need to be developed at the nanometer scale.
3. The mathematical models available for macro materials are not applicable to nanoscale materials. They must be developed to predict the behavior of nanomaterials.
4. Create integrated circuits using three dimensional carbon nanotubes contributing to the growth of computer power.
5. Design solar panel with greater efficiency using nano crystalline materials.
6. Fabricate lighter and stronger military equipmentusing nanomaterial composites.
7. Revolunizedisplay technologies allowing bright images, light weight with less power consumption.
8. Protect humanity from ill health with reformulated & targeted pharmaceutical products
9. Product smart materials with nanotechnology surfaces which are resistant to bacteria, dirt and scratches.
10. Protect environment from degradation by designing nanomembranes to capture CO_2 in exhaust.

11. Contribute to more efficient, energy saving manufacturing process with reduced waste by-products using nanocrytalline catalyst.
12. Make safe drinking water.
13. Nanotechnology is expected to continue the ever increasing miniaturization of cessing and memory devices.