Module-4

Nano Materials: The materials having at least one dimension in the nano scale range of 1-100 nm are called as nanomaterials.

Size dependent properties of Nanomaterials

Nanomaterials exhibits several size dependent properties like;

1. Surface Area

Many physical and chemical properties of a material depend on its surface properties. If a bulk material in subdivided into individual nanomaterials, the total volume remains the same, but the collective surface area in greatly increased.
Ex: - The collective surface area of cube (each side of 1m) is 6m2. If this cube in progressively cut into smaller and smaller cubes, the surface area will increased to 6000km2.
Thus, surface area is enormously increased on moving from bulk to nanoscale.
Properties like catalytic activity, gas adsorption, and chemical reactivity depends on the Surface area, therefore, nanomaterials can show specific surface related properties that are not observed in bulk materials.
Ex;- bulk gold in catalytically inactive, but gold nanoparticale are catalytically very active for selective redox reaction.

2. Conducting / Electrical properties

The electrical bands in bulk material are continuous due to overlopping of orbitals of billions of atoms. But, in nanoparticales very few atoms (or) molecules are present so the electric bands become separate (discreate) and the separation between different electric state varies with the size of nanomaterial. Hence, some metals which are good conductor in bulk become semiconductors and insulators as their size in decreased to nanolevels.
Ex: Silicone nanoparticles etc…

3.Catalytic Properties

- The catalytic property of materials depends on particle size.
- If the size of the particles reduces from bulk to nanoscale, surface area increases,that leads to very high catalytic activity of the same material.

Ex: - Bulk gold in catalytically inactive, but gold nanoparticales are catalytically very active for selective redox reaction.

SYNTHESIS OF NANOMATERIALS

SOL – GEL PROCESSES

Sol gel processes principle is conversion of precursor solution into gel via hydrolysis and condensation reactions.
Sol gel processes allow to synthesis of nano materials of high purity.
This process involves five steps
1. **Preparation of sol**: sol is prepared by suspended particles in water during suspension hydrolysis reaction takes place.

$$M\text{-}OR + H_2O \longrightarrow M\text{-}OH + R\text{-}OH$$

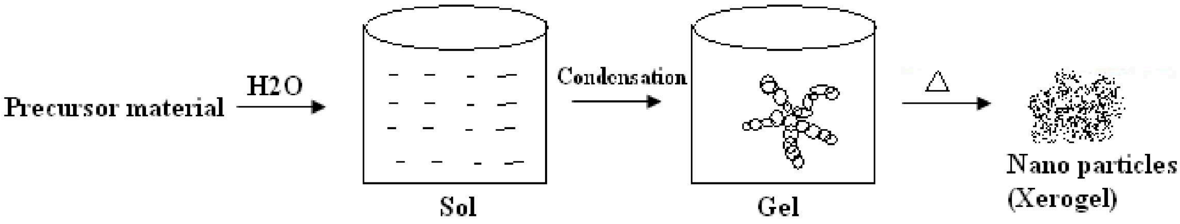
2. **Conversion of sol into gel:** sol is converted into gel by condensation reaction forming network between oxides. When networking takes place, the viscosity of the solution increases.

$$M - OH + M - OH \rightarrow M - O - M + H_2O$$

3. **Aging of gel:** during which poly condensation reaction continue until the gel is transformed into solid mass.

4. **Removal of solvent:** Further the solid mass is isolated from the solvent by thermal evaporation. The product formed is xerogel.

5. **Heat treatment:** solid mass (xerogel) obtained is dried at nearly to 800C to get fine nano particle powder.



Advantages:

- Nano materials of high purity with good homogeneity can be obtained.
- Samples can be prepared at low temperature.
- Easy to control the synthesis parameters like shape and size of resulting material

PRECIPITATION METHOD

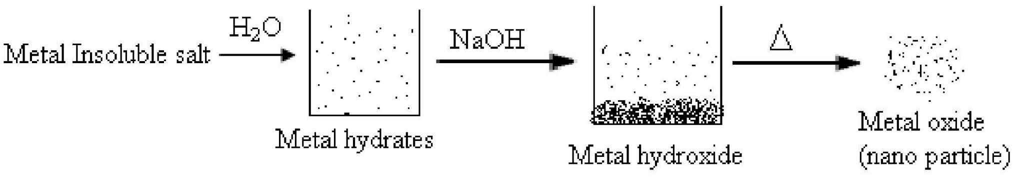
Principle: The principle involved in the precipitation of precursor materials at constant pH via condensation.

Processes: In this method inorganic metal salt such as chloride, sulphate, nitrate ions etc.., are used as precursor. Precursor materials is dissolved in water and undergo hydrolysis where metal ions exist in metal hydrates form. On adding base like NaOH/NH_4OH, pH of the solution changes and reaches super saturation level leading to condensation of precursor to form metal hydroxide precipitate. The precipitate is washed with water, filtered and finally calcinated at higher temperature to convert metal hydroxide into metal oxide by dehydrogenation takes place.

$$MLx + x H2O \longrightarrow M(H_2O)_x + xL^-$$

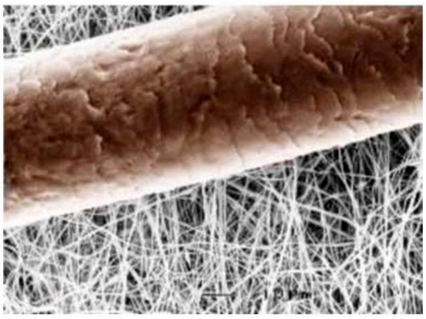
$$M(H_2O)_x \xrightarrow{NaOH} M(OH)x$$

$$M(OH)x \rightarrow MOx + H_2O$$



NANOFIBER

Nano fibers are fibers with diameter in the range of 1 to 100 nanometers.



Properties of Nanofiber

1. Light weight with small diameter.
2. Large Surface to Volume Ratio.
3. Porous Structure.
4. Improved physical, mechanical,
chemical properties. (e.g. stiffness and tensile strength).
5.Flexibility in surface functionalities

Applications of Nanofiber

It can be used in tissue engineering
It can be used in Drug delivery
It can be used in Dry Air Filter
It can be used in High absorbing diapers
It can be used in Molecular filtration
It can be used to remove volatile organic compounds from air
It can be used in Wound healing cont.

NANO PHOTONICS

Nanophotonics is the science and engineering of interaction of light and matter at the nanoscale range.

Applications

Nanophotonics are used to add precession to disease diagnosis.
Biomolecule Sensing
Biomolecule sensing in low concentrations
Used in low power photonic switches which exhibits low power dissipation during operation.
Nanophotonics silicon are power-efficient and exibit high speed, and hence they mainly used in optical communications.
Used in manufacturing thin-film photovoltaic cells.

NANOSENSOR

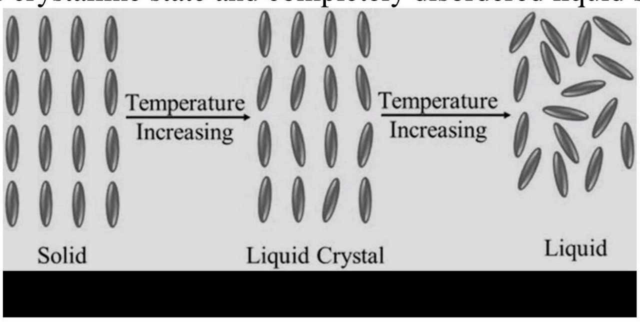
Nanosensor is a nanoscale device that is capable of interacting with a specific chemical or biological analyte, detect it and produce the signal promotional to its quantity which can be measured and analyzed.
They are quick, portable, selective and sensitive.

Applications

1. Nano sensors are used in the defence for the detection of explosives and toxic gases.
2. Used in the detection of different types of environmental pollutants.
3. Plasmonic nanosensors are used in chemical warfare agents.
4. It can be used to detect humidity of the soil, pesticide residues, nutrient requirements and plant pathogens in different environmental setups.
5. Modern nanosensors can be used to understand a person's health status through naninvasive detection of biomarkers in biofluids such as tears, saliva and sweat without sampling.
6. It can be used to detect contaminations in the food like toxins, bacteria, antibiotics, medication and additives.
7. It can be used for the detection of contaminants in water.

LIQUID CRYSTALS

A distinct state of a matter in which degree of molecular ordering is intermediate between the ordered crystalline state and completely disordered liquid state.



Classification of liquid crystals

Liquid crystals is classified as follows,

A. Thermotropic liquid crystals
B. Lyotropic liquid crystals

Thermotropic liquid crystal

The compounds which exhibit liquid crystal behavior with variation of temperature are called thermotropic liquid crystals.

1. Ethyl-*p*-azoxycinnamate (Solid) $\xrightarrow{140°C}$ Ethyl-*p*-azoxycinnamate (liquid crystal)
2. *p*-cholesteryl benzoate (Solid) $\xrightarrow{145°C}$ *p*-cholesteryl benzoate (liquid crystal)

Lyotropic Liquid Crystals:

Some of the compounds transformed into liquid crystal phase when mixed with another substance or solvent by the variation of concentration of the compound are called lyotropic liquid crystals.

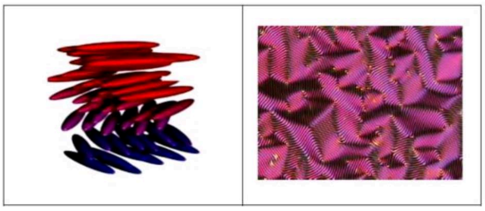
Ex: 1) Soap water mixture
2) Phospholipid water mixture

Thermotropic liquid crystals have been classified into the following types

1) Nematic liquid crystals
2) Cholesteric liquid crystals
3) Smectic liquid crystals
4) Columnar Liquid Crystals or Discotic Liquid Crystals (DLC)

1) Nematic (or thread-like liquid crystals)

i)These are formed by the compounds that are optically inactive.
ii) The molecules have elongated shape and are oriented parallel to the director.
Example: p-azoxyphenetole.



2) Chiral Liquid Crystals or Cholesteric Liquid Crystals

i) These are formed by optically active compounds having chiral Centre.
ii) Hence molecules acquire spontaneous twist about an axis normal to molecular direction.
The director is not fixed in position but rotates throughout the sample in helical pattern.

3) Smectic (or soap-like liquid crystals)

i) The molecules in smectic crystals are oriented parallel to each other as in the nematic phase but in layers.
ii) Based on the orientation of the director there are many types of smectic phases such as A, B, C, etc.
iii). If the director is perpendicular to the plane, it is called smectic A. The molecules are arranged in columns.

4) Columnar Liquid Crystals or Discotic Liquid Crystals (DLC)

i) In these liquid crystals, there is an orientation order but no positional order.
ii) There is a random motion of the molecules perpendicular to the plane.

Properties of liquid crystals

1. They exhibit optical anisotropy.
2. The intermolecular forces are rather weak and can be perturbed by an applied electric field.
3. They interact with an electric field, which causes them to change their orientation slightly.
4. Liquid Crystal can flow like a liquid, due to loss of positional order.

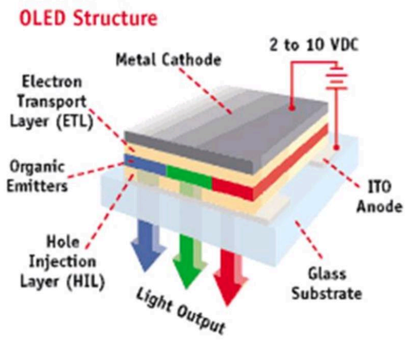
Applications of liquid crystals

1. The liquid crystal layer in LCDs allows for the display of images and text through the use of electrical currents that control the orientation of the crystals.
2. Liquid crystal sensors are used in various applications such as temperature sensing, humidity sensing, and chemical sensing.
3. Liquid crystals are used in various optical devices such as variable optical attenuators, phase shifters, and tunable filters. These devices are used in optical communication systems, spectroscopy, and imaging.

4. Liquid crystals have been used in drug delivery systems, where the drug is encapsulated in the liquid crystal matrix and delivered to specific target cells.
5) Liquid crystals are used in watches, calculators, mobile telephones, laptops. computers etc.
6) These are used in blood pressure instrument, digital thermometers and TV Chanel indicators.
7) These are used in potentiometer, conductometer, Colorimeter etc.

OLED

An OLED is the light emitting diode in which electro - luminiscent layer is a thin film of organic compounds, that emits light in response to electric current applied.



Properties of OLED

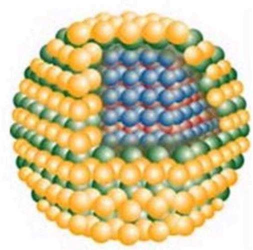
1. OLED devices have solid and planar structure. Therefore, OLED panels are very thin, flat and lightweight.
2. OLED devices have self-emission property and hence their devices have high contrast ratios and wide viewing angles,
3. The response time of OLEDs is as fast as micro or nanosecond order. Therefore, OLED displays can produce sharp moving images.
4. In OLEDS, the emission is from organic materials, Using variety of different organic materials various colors can be generated. Therefore, full-color images can be created.
5. The driving voltage of OLED devices in low, just a few volts. Therefore, OLEDS can be driven by thin film transistors (TFT). Hence, the power consumption of OLED displays is very low.
6. Due to use of TFTs, high information content is possible with OLED displays.

OLED Properties in lighting

1. OLEDs have a solid and planar device structure. Therefore the lighting units of OLEDs are thin, planar and lightweight.
2. The planar shape avoids heat concentration. Hence, temperature elevation in OLEDs is very low.
3. OLEDs are self-emission devices, emission of light from OLED lightings is non- directional.

Applications of OLED

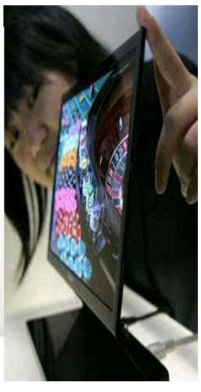
OLEDs are used in TV, Laptop, Mobile phone and Camera display systems.
These are also used in the lightings.



QUANTUM LIGHT EMITTING DIODES (QD-LEDS)

Proerties of QLEDs

QD-LEDs are superior to other display technologies like liquid crystal displays (LCDs), OLEDs, and plasma displays due to ideal blend of features like:
a) high brightness,
b) high efficiency with long lifetime,
c) more flexibility,
d) high-quality lighting with superior color gamut,
e) high color rendering index and
f) low-processing cost.
g) high quantum yields,
h) high molar extinction coefficients,
i) large effective Stokes shifts,

j) broad excitation profiles,
k) narrow symmetric emission spectra.

Applications of QD-LEDS

1. QLED displays are commonly used in televisions, monitors, smartphones, and other electronic devices.
2. QLEDs can also be used as a source of lighting in various applications, including automotive lighting, street lighting, and architectural lighting.
3. QLEDs can be used in medical imaging applications, such as in MRI machines, to produce high-resolution and accurate images.
4. QLED displays can be used in advertising displays, such as digital billboards and signage, to produce high-quality and eye-catching visuals.

PEROVSKITE MATERIALS

Perovskite Material is a three dimensional ABX, type material where A in an organic cation commonly methylammonium cation, B is a metal cation, either Phor Sn", and X is a halide ion, Chloride, Bromide or lodide. This material has cubic structure.

PROPERTIES AND APPLICATIONS IN OPTOELECTRONIC DEVICES

a) long electron-hole diffusion lengths (100 nm)
b) ultra-fast charge transportation
c) high dielectric constant
d) swift charge recombination
e) long carrier lifetimes,
f) direct bandgap for stronger and broader absorption with large absorption coefficients,
g) low-cost production and ease of processing and fabrication.

All these properties have made these materials as the best in thin-film PV technologies.