

MSE - II Chemistry Question Paper Pattern

Unit - I - Sensors, PCB, Nanomaterials.

Unit - II - Memory devices, Display system.

MCQ - PART-A

1. } Unit I

2.

3.

4. }

Unit II

PART - B

1. a) Sensors

b) PCB

2. a) Sensors

b) Nanomaterials

3. a) Memory devices

b) Display system

4. a) Memory devices

b) Display system.

MSE - II - Question Bank - Chemistry :-

→ SENSORS:

- ★★ 1. Explain the principle, construction, working and application of electrochemical sensors. - V. Imp
- ★ 2. Explain the principle, working and optical sensors.
3. Explain the electrochemical sensor for the determination of dissolved oxygen. (Rarely Asked)
- ★★ 4. Explain the application of electrochemical sensor ^{for sensing} i) NO_x ii) SO_2
 ↳ Any one

→ PCB

1. Describe the electroless plating of copper on PCB - V. Imp
2. Application of electroless plating.

→ Nanomaterials:

1. Classification of nanomaterial with example - Imp
2. Preparation of Nanomaterials using Sol-gel method
3. Preparation using Co-precipitation method - (Rarely Asked)
4. Synthesis of carbon nanotubes by Chemical Vapour deposition (CVD) method - Imp

Unit I ↑

UNIT - II

→ Memory devices

1. Explain the classification of memory devices based on their volatility - **Imp**
2. Mention the classification of electronic memory devices
(Any two)

→ Display Systems:

1. Explain the working principle of light emitting electrochemical cell. → **Imp**
- ★ 2. Explain Electro-optic effect of liquid crystals
(2 Marks - Effect of electric field, 2 Marks - Effect of Magnetic field)
3. Applications of liquid crystal display (LCD)
4. Explain the classification of liquid crystals - **Imp**

ELECTROCHEMICAL SENSOR

Principle:

Electrochemical reactions take place at electrode-electrolyte interfaces and provide a switch for electricity to flow between two phases of different conductivity, i.e. the electrode (electrons or holes are the charge carriers) and solid or liquid electrolyte (ions are the main charge carriers). The reactions which occur at the interface of the surface of an electrode between the recognition element, and the target/binding analyte generate an electrical double layer and thus this potential is measured after transforming these chemical reactions into this measurable electrochemical signal by a recognition element, and a transducer of the sensor.

Construction and Working:

The fundamental concept in the detection of analytes by electrochemical sensors involves the measurement of electric current generated by chemical reactions in the electrochemical system. Electrochemical sensors are made up of three essential components: a receptor that binds the sample, the sample or analyte, and a transducer to convert the reaction into a measurable electrical signal. In the case of electrochemical sensors, the electrode acts as the transducer. Electrochemical sensing always requires a closed circuit. Current must flow to make a measurement. In most electrochemical sensors. An electrode surface is used as the site of the reaction. The electrode will either oxidize or reduce the analyte of interest. The current that is produced from the reaction is monitored and used to calculate important data such as concentrations from the sample. Electrochemical sensor's working mechanism involves the interaction of the target analyte material with the electrode surface and bringing the desired change as a consequence to a redox reaction, which generates an electrical signal that can be transformed to explore the nature of the analyte species.

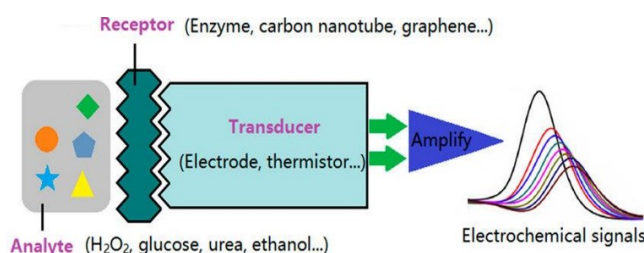


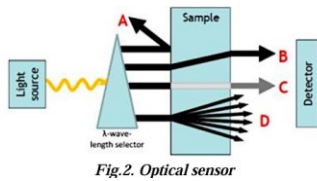
Fig. 1. Electrochemical Sensor

Applications of Electrochemical sensors:

- Detection of important molecules or biomarkers that are used for the diagnosis of diseases and disorders.
- They are used for the monitoring toxic levels of different substances in food quality and environmental control.
- The biosensor application areas of these sensors extend to medical and biomedical applications, process control, bioreactors, quality control, agriculture, bacterial and viral diagnosis, industrial wastewater control.

2. OPTICAL SENSORS:

Optical sensors are electronic components designed to detect and convert incident light rays into electrical signals. Eg: Colorimetric Sensors. Optical sensors are divided into several subclasses such as resonance, dispersion, reflection, refraction, phosphorescence, infrared absorption, Raman scattering, fluorescence, and chemiluminescence.



Principle and working

- When a sample solution is interacted with a light of suitable wavelength, certain quantity of light is absorbed by the analyte solution and it is observed by a sensor. The transducer converts intensity of absorbed light into electrical signal. The change in intensity at certain wavelength within visible (400–800nm) range can be determined using special instrumentation.
- The relationship between the incident light intensity and the transmitted radiation is given by the Beer-Lambert law:

$$A(\lambda) = \log \frac{I_0}{I} = \epsilon(\lambda) \cdot d \cdot c$$

where $A(\lambda) = \log \frac{I_0}{I}$ is the absorbance at a given wavelength λ , (I_0 and I are the incident and transmitted light intensities); ϵ is the molar absorptivity; d is the optical path through the absorbing sample and c is the molar concentration of absorbing analyte.

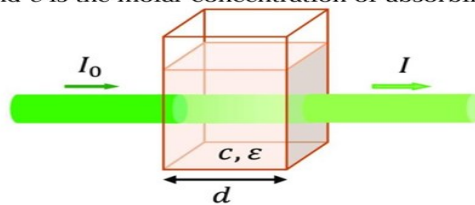


Fig. 3. Beer-Lambert's law

- What the detector monitors varies by technique (e.g., refractive index, scattering, diffraction, absorbance, reflectance, photoluminescence, chemiluminescence, etc.), can cover different regions of the electromagnetic spectrum, and can allow measurement of multiple properties.

Eg: Colorimetry, a quantitative optical technique, measures absorbance or reflectance within the visible range (400-800nm) using a light source, wavelength selector, photodetector, and read-out device. Monochromatic light passes through an analyte solution, where absorption, proportional to analyte concentration, is measured. The photodetector senses the change in light intensity, governed by Beer-Lambert's law.

Applications of Optical Sensors

- Computers
- motion detectors.
- copy machines (xerox machines)
- light fixtures that turn on automatically in the dark.
- alarm systems
- synchro for photographic flashes
- systems that can detect the presence of objects.

DISSOLVED OXYGEN SENSOR

The two methods for estimation of DO are optical method and electrochemical method.

(a) Electrochemical method:

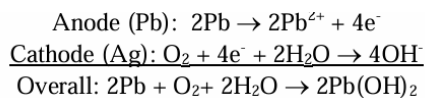
Electrochemical DO sensors, also known as amperometric or Clark-type sensors, measures dissolved oxygen concentration in water based on electrical current produced. Galvanic Sensor is a Electrochemical sensor, which is used to measure DO

The following are the components:

- Cathode: Working electrode-Ag
- Anode: Zn, Pb or any other active metal
- Electrolyte: KOH, NaOH or any other inert electrolyte
- Membrane: Teflon

Working principle

The difference in potential between the anode and the cathode should be at least 0.5V. DO sensor is immersed in water sample. Oxygen molecule diffuses across the oxygen permeable membrane (Teflon) and the rate of diffusion is proportional to the pressure of oxygen in the water. Molecular Oxygen reduces to OH⁻ at cathode. This reaction produces an electrical current that is directly related to the oxygen concentration. This current is carried by the ions in the electrolyte and runs from the cathode to the anode.



(b) Optical method:

Optical DO sensors are made of two parts, a sensor spot and a fibre optic reader. The sensor spot is attached to the interior of a cell culture vessel and contains a fluorescent dye suspended in a hydrogel. The sensor spot is the only part of the system that comes in contact with cells or media. The external reader is connected to a computer or data hub and is responsible for sending and receiving optical signals to the sensor spot. Optical DO sensors measure the DO concentration of liquid media or air based on the quenching of luminescence in the presence of oxygen. Since oxygen affects both the intensity and the lifetime of the luminescence, either may be used to measure DO. Optical DO sensor technology was developed from the principle that DO quenches the luminescence associated with chemical dyes in the sensor. The fluorescent dye exhibits an excitation maximum around 455nm, and an emission wavelength of approximately 613nm.

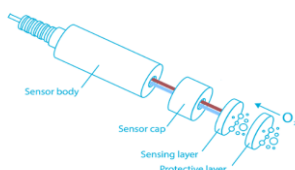


Figure 4. DO sensor

ELECTROCHEMICAL GAS SENSORS:

(a) Detection of SO_x

Sulphur dioxide is one of the main substances that pollute the air. Sulfur oxides, SO₂ released from thermal power stations and other industrial plants, are gases harmful to the environment. It is very important to detect and control the concentrations of SO_x in industrial processes. The attempt to detect sulphur dioxide in the air is a regular task of air inspection.

Gas sensors detect chemicals in the gas phase. The gas sensors operate by reacting with the gas of interest and producing an electrical signal proportional to the gas concentration. A typical electrochemical sensor consists of: a sensing electrode (or working electrode), counter electrode separated by a thin layer of electrolyte and a reference electrode. Gases diffuse through a membrane to be reduced or oxidized at an electrode. Initially the gas passes through a small capillary-type opening and then diffuses through a hydrophobic barrier, and eventually reaches the electrode surface. SO_x sensors utilizing a solid electrolyte such as K₂SO₄, Na₂SO₄, Li₂SO₄, Ag₂SO₄, Nasicon, Na-Al₂O₃ and Ag Al₂O₃ have been widely studied, because this type of sensor has its own advantages like continuous quantitative measurement; high selectivity and sensitivity; easy operation and fast response; simple construction and low price.

Anode reaction: $2\text{Ag} \rightarrow 2\text{Ag}^+ + 2\text{e}^-$

Cathode reaction: $2\text{Ag}^+ + \text{SO}_3 + \frac{1}{2}\text{O}_2 + 2\text{e}^- \rightarrow \text{Ag}_2\text{SO}_4$

Overall reaction: $2\text{Ag} + \text{SO}_3 + \frac{1}{2}\text{O}_2 \rightarrow \text{Ag}_2\text{SO}_4$

SO₃ was produced by the reaction can be checked by sensor.

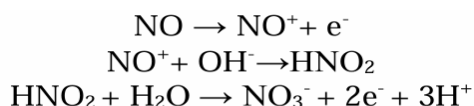
(b) Detection of NO_x:

Nitrogen oxide is the general term for a gas mixture composed of various oxides of nitrogen, often referred as NO_x. The normal air is nitric oxide and nitrogen dioxide. In environmental analysis, nitrogen oxide generally refers to NO and NO₂. NO is an important vasodilator, and monitoring its levels becomes crucial in the diagnostics of cardiovascular complications.

Electrochemical sensors are made up of three essential components: a receptor that binds the sample, the sample or analyte, and a transducer to convert the reaction into a measurable electrical signal. In the case of electrochemical sensors, the electrode acts as the transducer.

The electrode surface is used as the site of the reaction. The electrode will either oxidize or reduce the analyte of interest. The current that is produced from the reaction is monitored and used to calculate important data such as concentrations from the sample. The NO_x sensor monitors the oxidation of NO as it occurs on the electrode surface. In many instances of electrochemical sensors, the electrode surface can be modified with catalysts, membranes, or other metals to make the electrode more sensitive and/or more selective toward the analyte (in the instance below, the Glassy Carbon (GC) electrode is modified with Cobalt (IV) Oxide and Platinum).

The direct electro oxidation of NO in solutions follows the following 3 step reaction.



The ΔE for the overall process is +0.5V vs. a Ag/AgCl reference electrode. The reaction for the Ag/AgCl reference electrode is the following: $\text{AgCl} + \text{e}^- \leftrightarrow \text{Ag} + \text{Cl}^-$; $E^0 = +0.222\text{V}$.

Electroless plating of Copper (on PCB):

Pretreatment and activation of the surface:

The PCB is degreased and etched in acid. It is activated by dipping in stannous chloride solution containing HCl at 25C followed by dipping in palladium chloride. The surface is dried to get a layer of palladium.

Sl. No.	Particulars	Electroless plating of copper
1.	Plating bath solution	A solution of copper sulphate (12 g/dm ³)
2.	Reducing agent	Formaldehyde (8 g/dm ³)
3.	Complexing agent and exaltant	EDTA (20 g/dm ³)
4.	Buffer	Sodium hydroxide (15 g/dm ³) + rochelle salt (14 g/dm ³)
5.	pH	11
6.	Temperature	25°C
7.	Reactions: Cathode: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ Anode: $2\text{HCHO} + 4\text{OH}^- \rightarrow 2\text{HCOO}^- + 2\text{H}_2\text{O} + \text{H}_2 + 2\text{e}^-$ Overall reaction: $\text{Cu}^{2+} + 2\text{HCHO} + 4\text{OH}^- \xrightarrow{\text{catalyst surface}} \text{Cu} + 2\text{HCOO}^- + 2\text{H}_2\text{O} + \text{H}_2$	
8.	Rate of plating	1 to 5 $\mu\text{m h}^{-1}$

Applications:

- ✓ An important application of electroless copper plating is printed circuit boards (PCB).
- ✓ In double side and multilayer boards where plating-through-holes is required, electroless technique is the best since the holes cannot be electroplated. The technique used to manufacture printed circuit boards is the substrative method.
- ✓ The base object in PCB is a plastic material such as glass fibre reinforced plastic (GRP), epoxy or phenolic polymer over which a layer (5 to 100 μm) of copper is electroplated.
- ✓ Selected areas are then protected by a photo-resist or electroplated image and the rest of the copper is etched away to produce the circuit pattern or the track.

- ✓ Usually, double sided tracks are made in order to pack more number components in a small space. Finally, the connection between the two sides of PCB is made by drilling holes, followed by electroless copper through holes.

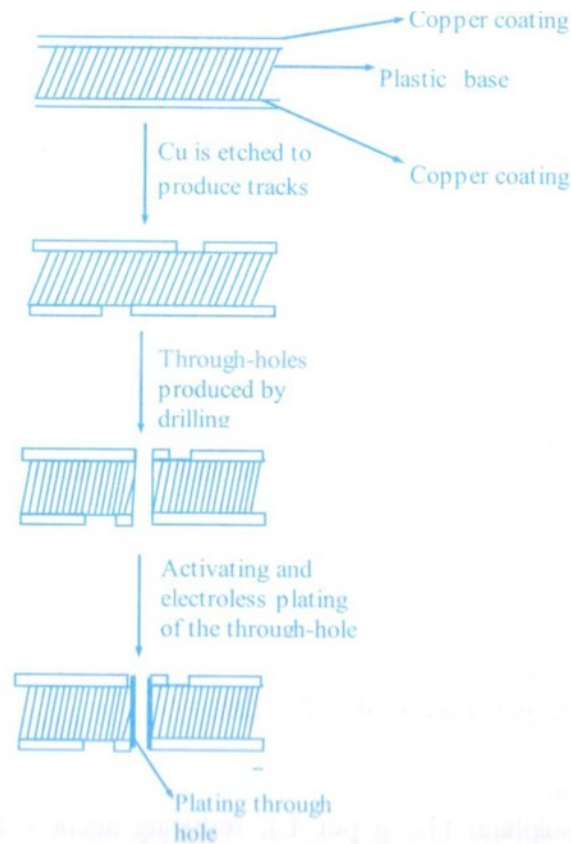


Fig.5. Steps in subtractive technique of plating-through in the manufacture of double sided PCB. Copper clad tracks on each side of the plastic board are connected through-hole.

ADVANTAGES OF ELECTROLESS PLATING

- ✓ Use of electrical power and electrical contacts are eliminated.
 - ✓ Semiconductors and insulators like plastics can also be plated.
 - ✓ Electroless baths have better throwing power. Intricate parts with irregular shapes, inside parts of tubes, recesses can be uniformly coated.
 - ✓ Hydrogen gas liberated is not trapped in blind holes.
 - ✓ Electroless coating are harder than that produced by conventional electroplating.
 - ✓ No levelers are required.
 - ✓ Deposits have unique chemical, mechanical and magnetic properties.
-

CLASSIFICATION OF NANOMATERIALS WITH ONE EXAMPLE EACH:

The classification is based on the number of dimensions which are not confined to the nanoscale range (< 100 nm).

- (i) **Zero dimensional:** Materials wherein all the dimensions are within the nanoscale range are called as 0-D nanomaterials. The most common representation of 0-D nanomaterials are nanoparticles.
- (ii) **One dimensional:** Here two dimensions are at nanoscale range, another dimension is not. This leads to needle like-shaped nanomaterials. Eg. Nanotubes, nanorods, nanowires.
- (iii) **Two dimensional:** One dimension is at nanoscale range, other two dimensions are not. They exhibit plate-like shapes. Eg. Nano coatings, nanofilms.
- (iv) **Three dimensional:** These materials are not confined to the nanoscale in any dimension. Thus, these materials are characterized by having three arbitrarily dimensions above 100nm. They are also called as bulk nanomaterials. Bulk nanomaterials can form a nanocrystalline structure by multiple arrangements of nano size crystals, most typically in different orientations. 3-D nanomaterials can contain dispersions of nanoparticles, bundles of nanowires/nanotubes as well as multi nanolayers.

SOL GEL METHOD

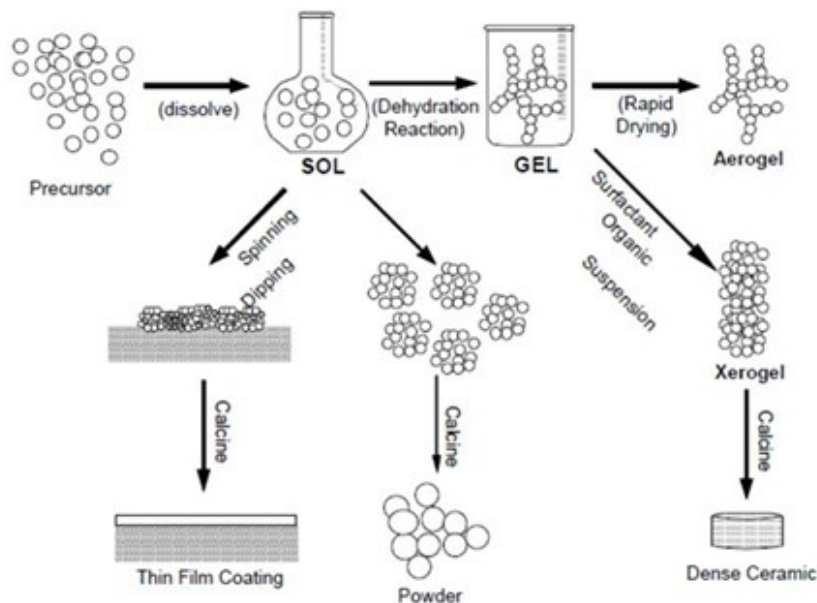


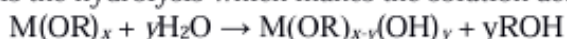
Fig.1. Sol-gel process.

(i) Sol-gel method:

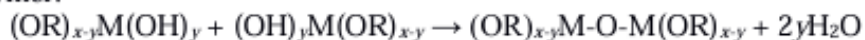
Sol-gel approach is most widely used for nanocomposite fabrication due to its simple processing steps, the flexibility of solution chemistry, the low temperature treatments and small investment in equipment.

A sol is a stable suspension of colloidal solid particles in a liquid. A gel is a porous, three-dimensional, continuous solid network surrounding a liquid phase. The sol-gel process usually consists of following steps:

(a) Preparation of a precursor solution: The desired colloidal particles are dispersed in a liquid to form a sol. The precursors generally used for the formation of sol are metal alkoxides (say silica, alumina and others). This is mainly because alkoxides readily react with water. A catalyst may be used to start the reaction as well as to control the pH. The first reaction to occur is the hydrolysis which makes the solution active.



(b) Formation of gel: The particles in the sol are polymerized through the removal of the stabilizing components. This can be done by either heating the sol at a low temperature or allowing it to stand for certain duration. This results in the formation 1, 2, or 3-dimensional continuous network [M-O-M] bonds (Gel) by condensation polymerization accompanied by the liberation of water molecules. These reactions increase the molecular weight of the oxide polymer.



(c) Aging of gel (syneresis): The reaction mixture is allowed to continue polycondensation reactions until the gel transforms into a solid mass, accompanied by contraction of the gel network and expulsion of solvent from gel pores. Ostwald ripening (is the phenomenon by which smaller particles are consumed by larger particles during the growth process) and phase transformations may occur concurrently with syneresis.

(d) Drying of the gel: Water and other volatile liquids are removed from the gel network. If isolated by thermal evaporation, the resulting nanomaterial is called **xerogel**. If the solvent is extracted under supercritical or near supercritical conditions, the product is an **aerogel**.

(e) Dehydration: During dehydration, surface bound M-OH groups are removed, thereby stabilizing the gel against dehydration. This is normally achieved by calcining at temperatures up to 800°C.

(f) Densification and decomposition of gels at high temperatures ($T > 800^\circ\text{C}$). The pores of the gel network are collapsed, and remaining organic contaminants are volatilized.

The typical steps that are involved in sol-gel processing are shown in the Fig.

Synthesis of carbon nano tubes by Chemical vapour deposition (CVD) method:

In 1993, Chemical vapor deposition (CVD) technique was first reported to produce MWNTs (Multi walled nano tubes) by Endo and his research group. Schematic diagram of the chemical vapor deposition apparatus is shown in Fig. 5.

In this method, CNTs are synthesized by thermal CVD method by using hydrocarbon gas as carbon source. A quartz tube is placed inside a furnace maintained at high temperature (500–900°C) heated by resistivity heated coil or plasma. A crucible containing the substrate coated with catalyst nanoparticles

such as Fe, Co or Ni is placed inside quartz tube filled with inert gas such as argon gas. The hydrocarbon gas (carbon source) is pumped into the quartz tube which undergoes pyrolysis reaction and forms vapor carbon atoms. These carbon atoms bind to the substrate and join to each other by Vanderwaal force of attraction and grow as multi-walled carbon nanotubes (MWCNTs) on the substrate. To synthesize single walled carbon nanotubes catalyst nanoparticles of Fe, Co, Ni are used. The obtained CNTs are further purified to get the pure form of CNTs.

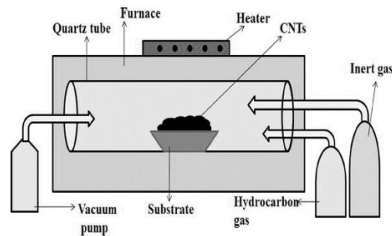
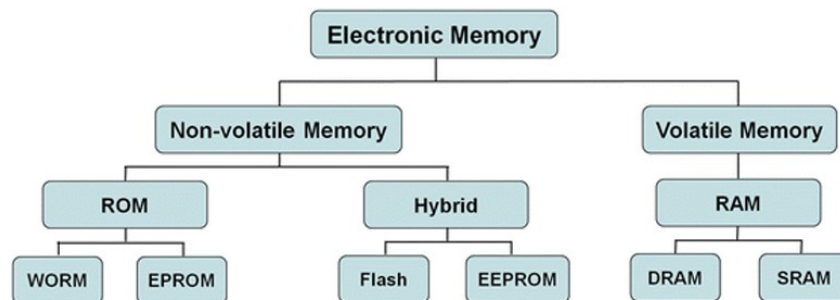


Fig. 5. Schematic diagram of the chemical vapor deposition apparatus

Classification of memory based on volatility:



1) Volatile Memory: Volatile memory eventually loses the stored information unless it is provided with a constant power supply or refreshed periodically with a pulse.

2) ROM (Read-only memory): It is a type of computer storage containing non volatile, permanent data that, normally, can only be read, not written to.

3) WORM (Write once – read many times) : It can record data once and then the data becomes permanent on the disc. Eg: CD-R (Compact Disc-Recordable).

4) EPROM (Erasable programmable read only memory): Here the content can be erased by exposing it to UV light. It allows users to write new data on it after erasing. Eg: basic input/output system chips (BIOS chips)

5) Hybrid memory: Hybrid memory allows data to be read and re-written at any time.

6) EEPROM (Electrically erasable programmable read only memory): The content on EEPROM can be programmed and erased electrically. It is byte-wise erasable. Eg: Products such as real-time clocks, digital potentiometers, digital temperature sensors, among others, may have small amounts of EEPROM to store calibration information or other data that needs to be available in the event of power loss.

7) Flash: Flash memory is a distinct type of EEPROM, which is programmed and erased in large blocks.
Eg: Solid state drive (SSD), USB Flash drive, Secure digital card (SD Card)

8) Non Volatile Memory: Nonvolatile memory does not loses the stored information even in the event of power failure.

9) RAM (Random-access memory): It is a read/write memory used to store data of currently running programs.

10) DRAM (Dynamic random-access memory): It stores information with the help of transistors and capacitors. Due to the discharge of capacitors, they need to be periodically refreshed with electricity otherwise there will be data loss. They are used as main memory in computer systems.

11) SRAM (Static random-access memory): It stores information with the help of transistors. It does not need to be periodically refreshed. They are used as cache memory in computer and other computing devices.

CLASSIFICATION OF ELECTRONIC MEMORY DEVICES (ANY 2)

According to the device structure, electronic memory devices can be divided into four primary categories: transistor-type, capacitor-type, resistor-type and charge transfer- type.

1. TRANSISTOR-TYPE

- It uses transistors to store information.
- A transistor type semiconducting electronic memory device contains a electronic circuit, including a complementary metal oxide semiconductor(CMOS)transistor and capacitor (C).
- In a transistor-type memory device, each transistor represents one bit of information
- In the electronic circuit, "0" or "ON" and "1" or "OFF" corresponds to the "discharged" and "charged" respectively.
- An organic transistor memory device stores data based on two conductivity states. In the organic transistor memory device, the organic material itself is the memory element.
- But a semiconducting memory device generally consists of a minute and complicated electric circuit.
- Therefore, organic transistor memory device structure can be simplified and the device can be fabricated in simple steps.

2. CAPACITOR- TYPE

- It uses capacitors to store information.
- Capacitors have two parallel plate electrodes and charges are stored in these electrodes under an applied electric field.
- Each capacitor represents one bit of information, which is a 0 or a 1.
- When a capacitor is charged, it represents a 1, and when it's discharged, it represents a 0.

➤ One popular type of capacitor-type memory is Ferroelectric Random Access Memory or FeRAM which is used in some specialized applications.

3. RESISTOR-TYPE

- It uses resistors to store information.
- Resistors are electronic components that resist the flow of electrical current.
- It is based on the change of the electrical resistivity of materials in response to an applied voltage (electric field).
- Each resistor represents one bit of information, which is a 0 or a 1.
- The resistors are arranged in a particular pattern to store the information.
- One popular type of resistor-type memory is Programmable Read-Only Memory or PROM.

4. CHARGE TRANSFER TYPE

- It is based on the Charge Transfer effects of a charge transfer complex.
- A charge transfer (CT) complex consists of two parts, one electron donor and other an electron acceptor. It is also called as a donor-acceptor (D-A) complex.
- The conductivity of a CT complex is dependent on the ionic binding between the D-A components. In CT complex, a partial transfer of charges occurs from donor part to the acceptor part. This results in difference in conductivity.
- CT complexes exhibit bistable states due to difference in conductivity. This behaviour is used to design molecular electronic devices.
- Many organic CT systems, including organometallic complexes, carbon allotrope (fullerene, carbon nanotubes and graphene)-based polymer complexes, gold nanoparticle-polymer complexes, and single polymers with intra-molecular D-A structures are used for memory applications.

CLASSIFICATION OF LIQUID CRYSTALS:

Liquid crystals are classified into two main categories, namely,

1. Thermotropic liquid crystals
2. Lyotropic liquid crystals
1. Thermotropic liquid crystals:

The class of compounds that exhibit liquid crystalline behaviour on variation of temperature alone are referred to as thermotropic liquid crystals. The temperature range at which some liquid crystal are stable are given below:

	Solid		Liquid crystal		Liquid
Cholesteryl Benzoate		145 ⁰		178 ⁰	
p-Azoxyphenetole		137 ⁰		167 ⁰	
p-Azoxyanisole		116 ⁰		135 ⁰	

2. Lyotropic liquid crystals:

Some compounds transform to a liquid crystal phase when mixed with a solvent. They have a lyophilic and a lyophobic end that is they are amphiphilic compounds. They are usually obtained by mixing the compound in a solvent and increasing the concentration of compound till liquid crystal phase is observed. Such liquid crystals are called lyotropic liquid crystals. The formation of lyotropic mesophases is dependent on the concentration of either the component or the solvent. Variation of temperature also affects the formation of these mesogens. Examples: (i) soap (soap-water mixture) molecules

Thermotropic liquid crystals have been classified into the following types:

- 1) Nematic liquid crystals;
- 2) Cholesteric liquid crystals
- 3) Smectic liquid crystals; and
- 4) Columnar or discotic liquid crystals

(1) Nematic phase:

Nematic (Greek; nematos = thread like) liquid crystals are formed by compounds that are optically inactive. The molecules have elongated shape and are approximately parallel to one another (Fig.1). Nematic phase is characterized by the total loss of positional order and a near normal flow behaviour similar to its liquid phase.

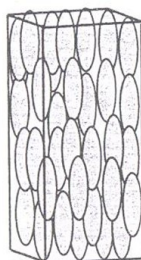


Fig.1 Nematic liquid crystal

Examples: (i) p-Azoxy anisole (116-135⁰); (ii) p-Azoxy phenetole (137-167⁰C); (iii) p-Anisaldehyde (165-180⁰C).

(2) Chiral (Twisted) Nematic Phase (Fig.2):

The chiral nematic phase, also known as the twisted nematic or cholesteric phase, is formed from optically active compounds possessing chiral centres. Unlike the nematic phase, molecules in this phase arrange into a helical structure, where the director rotates, creating a screw-like pattern. The distance required for a 360° director turn is termed the pitch. This twisted structure gives rise to strong optical activity and selective light reflection. Notably, the pitch is temperature-dependent, making these materials useful in thermography and as thermochromic materials.

Examples: (i) Cholesteryl benzoate; (ii) Cholesteryl myristate and (iii) Cholesteryl formate etc.

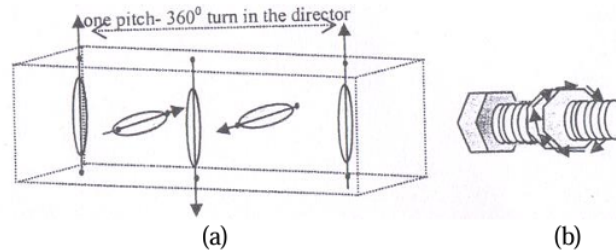


Fig. 2(a) Illustration of the twisted structure in a chiral nematic phase of a liquid crystal as shown by the change in the direction of the director. Arrows show the orientation of the molecules. (b) A nut moves a certain distance when it makes a full turn (one pitch) and comes back to its original direction as shown by the arrows.

3) Smectic mesophase:

Smectic phases, named for their soap-like nature, exhibit both orientational and positional order, forming layered structures. Molecules align along a director and reside predominantly within regularly spaced planes, with some molecules between layers. Smectic A phases feature directors perpendicular to the layers, while Smectic C phases have directors at an angle. Smectic B phases also have perpendicular directors, but with molecules arranged hexagonally within the layers, demonstrating varied organizational patterns within the smectic classification.

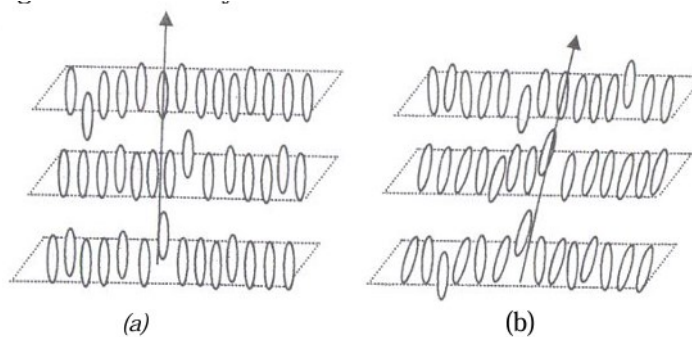


Fig.3 Schematic representation of smectic mesophase where molecules lie on regularly spaced planes (in the form of layers). (a) Smectic A where molecules is perpendicular to the layer planes. (b) Smectic C where the molecules are tilted with respect to the layer planes.

Examples: (i) 4-n-Butyloxybenzylidene aminopropiophenone (smectic-A); (ii) 4,4'-di-n-Heptyloxyazobenzene (smectic-C); (iii) Terephthalidene-bis-4-n-butylaniline (smectic-B).

4) Discotic or Columnar Liquid crystalline Phase:

Discotic liquid crystals, formed by disk-shaped molecules, exhibit two main phases. The discotic nematic phase shows orientational order, with molecular axes aligning along a director, but lacks positional order. In the columnar phase, molecules additionally arrange into columns, forming a hexagonal lattice, though the stacking within columns is random, unlike perfectly ordered coin stacks.

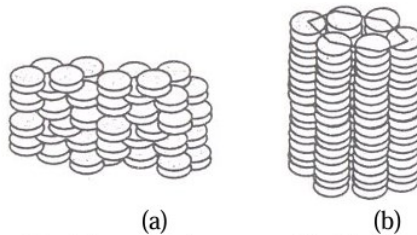


Fig.4. Schematic representation of disc like molecules arranged in (a) Discotic nematic (b) discotic columnar liquid crystal phases

Example: Benzene-hexa-n-alkanoate

ELECTRO-OPTIC EFFECT OF LIQUID CRYSTALS:

Effect of electric field:

The director in a liquid crystal is free to point in any direction. But when a film of liquid crystal is placed between two plates of certain materials, director is forced to point along a particular direction when an electric field is applied. For example, when a film of liquid is placed between two specially treated glass sheets (such as rubbing with a velvet cloth, or applying a thin coat of a polyamide followed by unidirectional rubbing with a roller), the molecules close to the glass surfaces are forced to orient themselves parallel to the surfaces of the glass sheets.

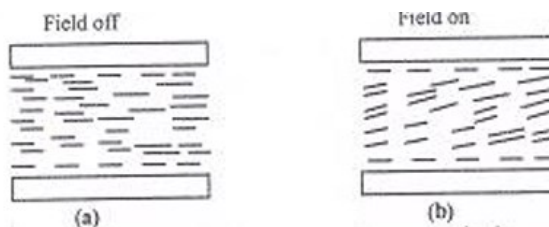


Fig.5 Liquid crystal film kept between two treated glass plates (a) in the field off state all molecules and the director orient parallel to the surface (b) in the field on state the molecules near the surface orient parallel to the surface whereas in others it is deformed

In the absence of an electric field, (below a threshold value) the molecules at other layers are also aligned parallel to the surfaces giving a homogeneous arrangement. But when an electric field is applied perpendicular to the glass surface, molecules near the surface are aligned parallel to the surface (perpendicular to the applied field). The molecules near the centre of the liquid crystal layer (away from the surface) are free to orient themselves along the applied field. The crystal undergoes deformity (Fig. 8). This transition (deformity) is important in the operation of liquid crystal displays (LCD) because the transition brings about a significant change in the optical characteristics of the liquid crystal.

Effect of light:

When light is incident on two crossed polarizers, no light emerges because the light emerging from the first polarizer is completely absorbed by the second polarizer and hence appears dark. When a film of a liquid crystal is placed between two polarizers, only a part of the light from

first polarizer is absorbed by the second polarizer some light emerges giving bright appearance. A cell is assembled such that the direction of alignment at the top surface is perpendicular to that at the lower surface of the cell. Then it filled with a twisted nematic liquid crystal (TNLC) having a positive dielectric anisotropy (dielectric constant parallel to the director is higher). Twisted structure acts like a wave-guide and gradually rotates the plane of polarization of light by 90°. Hence a linearly polarized light incident on the cell emerges linearly polarized but in an orthogonal direction resulting in a bright appearance (Fig. 6).

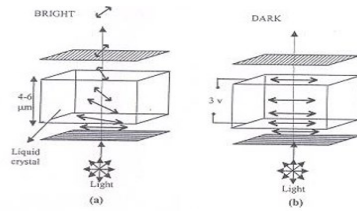


Fig.6 Bright and dark appearance when light is passed through twisted nematic liquid crystal placed between two crossed polarizers (a) appearance is bright in the absence of electric field (b) appearance is dark in the presence of electric field.

The 90° twist in the cell is lost when a sufficiently strong electric field (2-5V) is applied to the cell. Hence the cell appears dark between two crossed polarizers (Fig. 6b). The following conditions, however should be met to see the electro-optic effect.

- (i) The plane of polarization of incident light should be parallel or perpendicular at the surface of the cell.
- (ii) The product of optical anisotropy, Δn , (the difference in refractive indices parallel and perpendicular to the director) and pitch P should be greater the wavelength of the incident light. $\Delta n \times P > \lambda$.

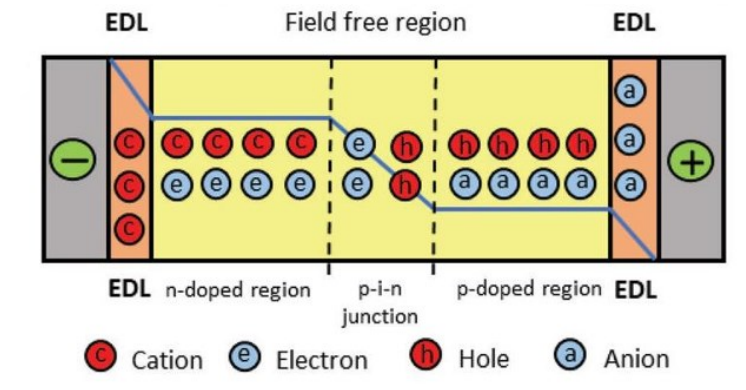
LIGHT-EMITTING ELECTROCHEMICAL CELLS (LECS):

These are solid-state lighting devices that convert electric current to light within electroluminescent organic semiconductors.

Working:

- 1) The active layer of LECs comprises of electroactive compounds and mobile ions and are sandwiched between cathode and anode.
- 2) When dc current is passed, mobile ions in the active layer drift toward the respective electrodes, and an injection of electrons and holes takes place at the electrode interface.
- 3) Injected charge carriers attract mobile ions through electrostatic force of attraction.
- 4) The charges on injected charge carriers are compensated by charges on mobile ions.
- 5) It results in the formation of n- and p-type doped regions at the respective electrodes.
- 6) These regions extend towards each other and meet at the p-n junction.
- 7) At the p-n junction, the electrons and holes recombine to form excitons.

8) The excitons subsequently decay to emit photons, resulting in electroluminescence emission.



APPLICATIONS IN LIQUID CRYSTAL DISPLAYS (LCD'S):

A liquid crystal display (LCD) is a flat panel display technology that uses liquid crystals to produce images. The light is passed or blocked by changing the polarization.

1. The working principle of an LCD is based on the optical properties of liquid crystals.
2. An LCD consists of a layer of liquid crystal material sandwiched between two transparent electrodes.
3. The molecules adjacent to the glass will align to the polarizer, resulting in a helical structure between the two glass plates.
4. As light strikes the first plate, it gets polarized.
5. The molecules in each layer then guide the light through the display, changing the angle of polarization.
6. When light reaches the final layer of the crystal material its plane of polarization will have rotated 90 degrees, and now matches the plane of the top polarizing film hence comes out through it appearing bright.
7. When electric field is applied across the plates, the liquid crystal molecules untwist and lose their property of rotating the light.
8. Hence the plane of the light no longer matches the angle of the top polarizable plate. Consequently, no light can pass through that area of the LCD, which makes that area look dark.

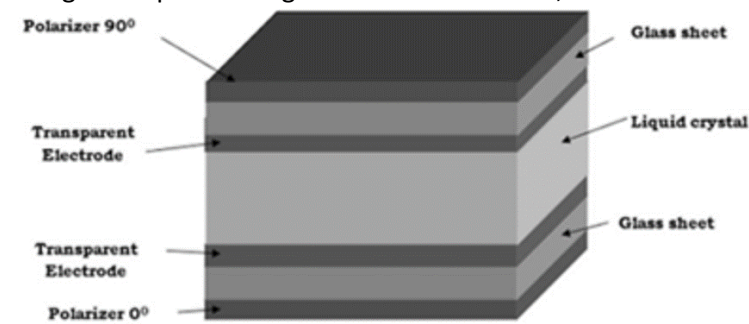


Fig.7. Constitution of liquid crystal display