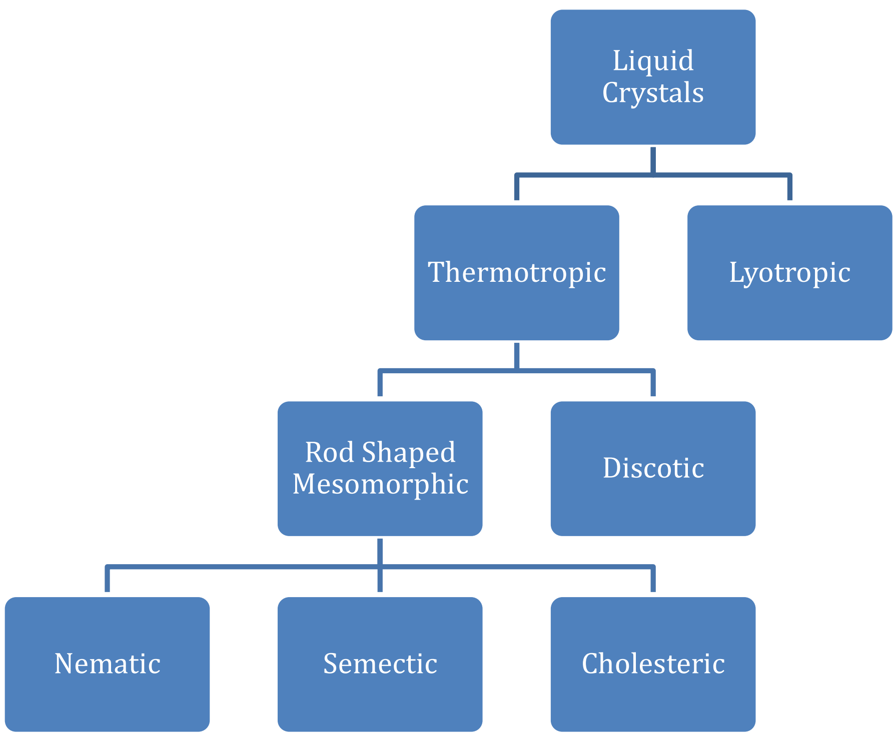
<u>ENGINEERING MATERIALS</u>

Q1. Enlist different Liquid Crystal Phases.

Liquid crystal (LC) Phases can be classified into **Thermotropic** and **Lycotropic** based on the method of production. If material in solid state is heated to produce LC, such LC are thermotropic. If the concentration of liquid solution is increased by dissolved some suitable solute in it to make it reach a LC phase then such liquid crystals are called as Lyotropic. **Thermotropic** liquid crystals are further classified into **Mesomorphic (Rod shaped)** and **Discotic** crystals based on the shape. The **Rod-shaped** Liquid crystals are further classified as, **Nematic**, **Semectic** and **Cholesteric** based on the arrangement and orientation of the rod-like crystals.



Q2. Explain Liquid Crystal Phases.

(M.U. May 2012, 2013, 2014; Dec 2013)[2-5 Marks]

Liquid crystal (LC) is a state of matter which has properties between those of conventional liquids and those of crystalline solids. For instance, a liquid crystal may flow like a liquid, but its molecules may be oriented in a crystal-like way.

The tendency of an ordered arrangement of molecules like a crystalline solid is to pass through an intermediate stage known as **liquid crystal** rather than melting directly into liquid state.

The important property of LC is that a small electric field can disturb the alignment of molecules, this property of LC is used in displays.

a. **Semectic liquid crystals:**

A crystalline state where the orientation and periodicity characteristics from a crystal are retained is called semectic liquid crystal. In other words, we can say the liquid crystals which have ordered position as well as orientation. *Figure 2a* shows the schematic of a Semectic liquid crystal.

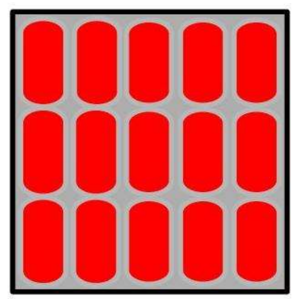


Figure 2a: Semectic LC

b. **Nematic liquid crystals:**

A crystalline state where the orientation is retained but the periodicity characteristics are lost is called nematic liquid crystal. In other words, we can say the liquid crystals which have ordered orientation but disordered position. *Figure 2b* shows the schematic of a Nematic liquid crystal.

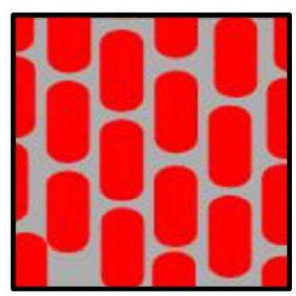


Figure 2b: Nematic LC

c. Cholesteric liquid crystals:

The liquid crystals that have the same arrangement of molecules as that of Nematic type. The cholesteric phase of liquid crystals has molecules parallel to each other but the direction of alignment layer by layer twists gradually and results in a helical structure as shown in *Figure 2c*.

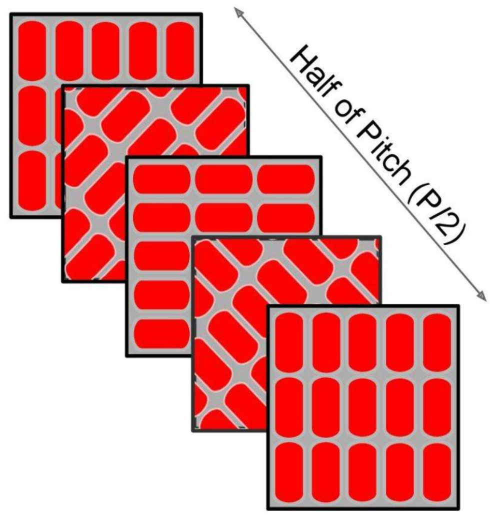


Figure 1c: Cholesteric liquid crystals

Q3. Enlist different applications of Liquid Crystals.

Liquid crystals have a wide range of applications, some of them are:

1. Liquid crystals are used in Liquid Crystal Displays (LCD) of several devices like digital watches, pocket calculators, cell phones, pagers, e-book readers etc.
2. Liquid crystals are also used in high speed computing, due to the ease of change in orientation that is made by application of very small disturbance.
3. Gas-liquid chromatography makes use of liquid crystals for their electrical properties that lie between crystalline solids and isotropic liquid.

Q4. Explain properties of Ferroics.

Ferroics is a generic name given to the study of Ferromagnetism, Ferroelectricity and Ferro elasticity. These three are sometimes called as the properties of ferroics, which we define as follows:

1. Ferromagnetism: The tendency of magnetic materials having permanent magnetic moment to get strongly influenced by application of magnetic field is called ferromagnetism. It is the strongest type of magnetism. This magnetism that is also responsible for creation of permanent magnets. In other words, it is a magnetism that can be controlled by application of another magnetic field.
2. Ferroelectricity: The tendency of materials with inherent electrical polarization to get influenced by external electric field is called ferroelectricity. In other words, it is an electric polarization that is switchable by applied electric field.
3. Ferro elasticity: The tendency of a material to have a phase change due to application of stress is called Ferro elasticity. In other words, a deformation or phase that is switchable by applied stress.

Q5. Explain Multiferroics and its type.

(M.U. Dec 2019)[5 Marks]

Ferroics is a generic name given to the study of primary properties like Ferromagnetism, Ferroelectricity and Ferro elasticity. Multiferroics are materials that exhibit more than one of the above primary properties of the Ferroics materials. There are two types of Multiferroics which are also called as Type-I and Type-II multiferroics. The difference between them is described briefly below:

Type I and Type II Multiferroics:

1. **Type I:** These materials are the ones in which the ferroelectricity and ferromagnetism occur at different temperatures and arise from different mechanisms. Thus, ferroelectricity and ferromagnetism in such materials is largely independent of one another. E.g. $YMnO_3$.
2. **Type II:** In these materials magnetism causes ferroelectricity implying strong coupling between the two. Thus, ferroelectricity and ferromagnetism in such materials is largely dependent on one another. E.g. $TbMnO_3$.

Applications of Multiferroics:

1. Electric field control of magnetism
2. Spintronic devices
3. Microelectronic devices MOSFET
4. Information storage devices
5. Quantum electromagnets in Particle physics
6. Sensors
7. Radio and high frequency devices

Q6. What is Magnetoresistance? Give one application.

(M.U. Dec 2019)[3 Marks]

The materials that exhibit the tendency to change the value of their electrical resistance in an externally applied magnetic field are called **magneto resistive materials.** In other words, the tendency of certain materials to undergo change in their resistance whilst being subjected to an external magnetic field is known as **magnetoresistance.** It is used in making several sensors and data drives and drivers, read heads etc.

Q7. Explain Giant Magnetoresistance (GMR).

Introduction:

Magneto resistive effect is observed in materials which have alternating ferromagnetic and non- magnetic layers. The magnetic moments of the magnetic layers sandwiched between the non-magnetic layers can be aligned in antiparallel or parallel fashion as shown in *Figure 7a*. The antiparallel layers can get re-aligned as parallel when subjected to high

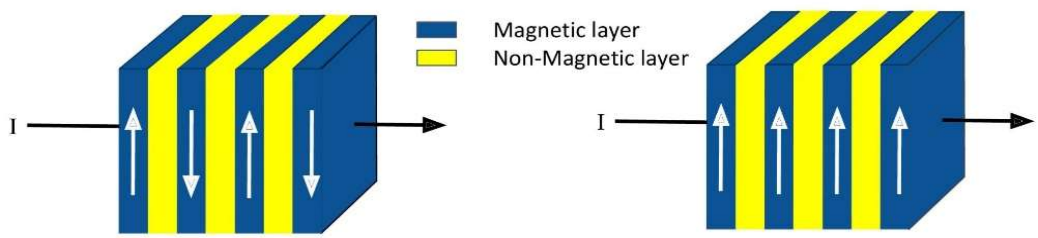


Figure 7a: Alternating magnetic and non-magnetic layers for GMR

magnetic field. This is due to the fact that the multilayer system becomes saturated.

Explanation:

We know that electrons have a spin value (intrinsic angular momentum), according to Quantum Mechanics. Due to this, they have a tendency to start behaving like small magnets. Hence, electrons scattering is spin dependent. As shown in *Figure 7b* a spin up electron will scatter only if it comes in contact with a spin down layer and vice versa.

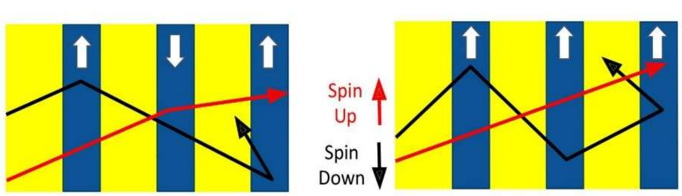


Figure 7b: Spin Dependent scattering of electrons

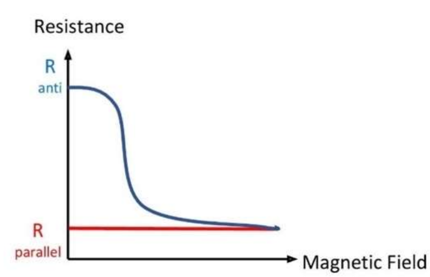


Figure 7c: Variation in Resistance with Field

Therefore, scattering in system of layers with parallel magnetic moments is comparatively much lesser than the system that has layers with antiparallel magnetic moments. More scattering implies more resistance and less current. Thus, the system with parallel moments has much less resistance as compared to the anti-parallel system. The variation of resistance with magnetic field is shown in *Figure 7c* for both the systems.

Giant Magnetoresistance (GMR):

The tendency of a system of alternating magnetic and non-magnetic conductive materials to undergo enormous changes in their resistance when placed in an external magnetic field as shown in *Figure 7c* is known as Giant Magnetoresistance or GMR.

This effect is used in MRAMs (Magnetoresistive Random access memory), spintronics, magnetic field sensors and data drives and drivers, read heads, biosensor, spin valve sensor etc.

Q6. Explain Colossal Magnetoresistance(CMR).

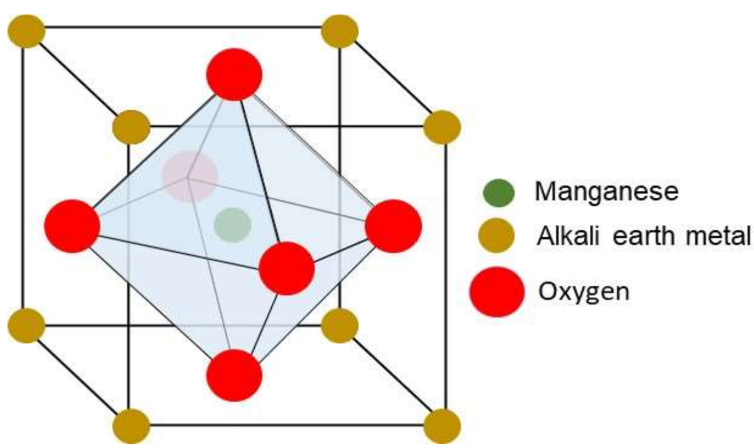


Figure 6: CMR materials

Magneto resistive effect of very high magnitude was observed in some manganese-based perovskite oxide materials as shown in *Figure 6*. Simplest example of CMR material is $LaMnO_3$. **Colossal Magnetoresistance (CMR):**

The tendency of a material to demonstrate drastic change in their electrical resistance by an enormous magnitude, in the presence of a strong, external magnetic field is called Colossal Magnetoresistance. This effect is used in redhead devices, bolometers, spintronics, magnetic field sensors.

Q7. Explain the working principle of Liquid crystal display.

Principle: Liquid crystal display works on the principle of polarization and cholesteric characteristics of liquid crystal that has the ability to rotate light vibrations by 90^0.

Construction:

The Liquid Crystal Display does not produce light, but depends on the ambient light for creating a display of information. The cholesteric properties of Liquid crystal are used in creating a display. A cell filled with Liquid crystal is placed in between two glass sheets. Thin Indium Tin oxide layers are coated over the glass plates which act as electrodes as shown in *Figure 7a*. The top and bottom of the liquid crystal are covered with two polaroids, one is zero degree and the other one is 90 degree as shown in *Figure 7a*. Such a Liquid crystal cell is placed on a reflecting mirror on the back side for achieving a good contrast as shown in *Figure 7c*. Such seven cells together make up the seven-segment display shown in *Figure 7b*.

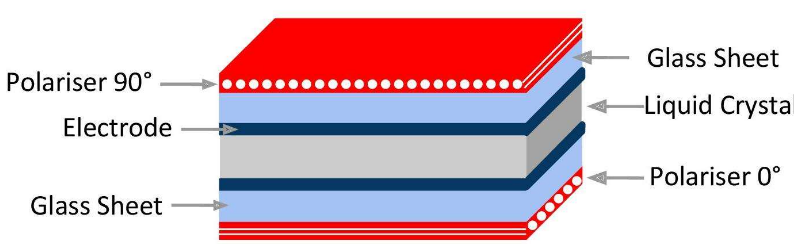


Figure 7a: A liquid crystal cell in a display

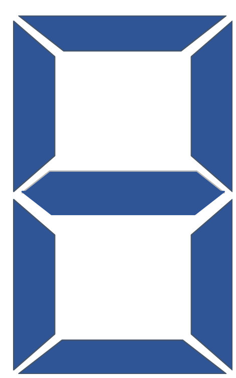


Figure 7b: Seven segment display

Working of a cell:

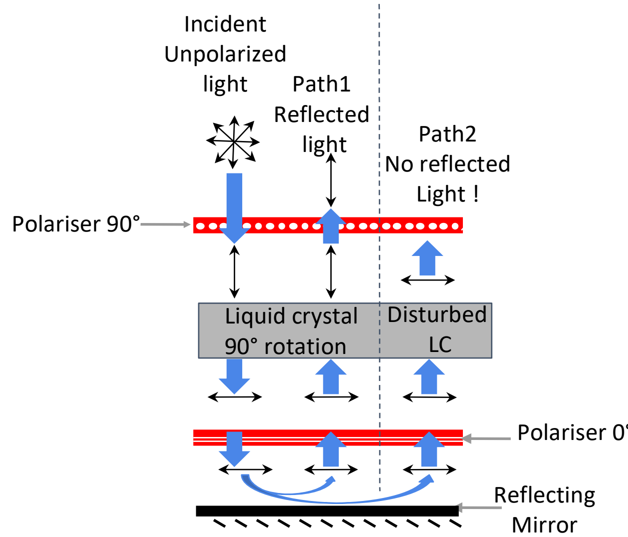


Figure 7c: Working of a cell in LCD

All ambient light is mostly unpolarized (Vibrations in all planes) and polarizers are capable of polarizing it (restricting its vibration to one plane only). When ambient light is incident on an undisturbed liquid crystal via polarizers 90^0 it gets polarized in the perpendicular direction. When this polarized light is made to pass through the liquid crystal capable of 90^0 rotation it rotates the plane of vibration from perpendicular to parallel. Due to this rotation light polarized at 0^0 is now able to pass through the 0^0 polarizer. After passing the polarizer the light gets reflected via path1 because liquid crystal is not yet disturbed by repeating same set of steps. Thus, reflected light is observed creating well-lit screen which has no data display.

When one wants to create a display the desired cell in the seven-segment display is disturbed by applying a very small voltage. Due to application of this small voltage liquid crystal loses the ability of 90^0 rotation. Thus the reflected light follows path2 as shown in *Figure 7c* and the light gets trapped inside that cell and that cell appears dark on the display segment. Similarly, by making desired segments/cells appear dark one can create a display of data/information using several seven-segment displays.

Merits: LCD requires very little power in microwatts

Demerit: LCD is activated by AC and DC destroy display.

Application: Calculator, computer and TV etc.