# Introduction to Liquid Crystal – An Overview

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## 1. Introduction

Liquid crystals are the state of matter to facilitate properties between those of the completely disorder isotropic liquid and three dimensionally ordered solid crystal [1]. A solid molecular crystal has a long range positional order at the centre of mass as well as long range orientational order. The study of liquid crystals began in 1888 by Friedrich Reinitzer [2], Austrian botanist, of a material known as cholesteryl benzoate. Experimentally he observed two distinct melting points when the temperature of a solid sample increased. At first he suggests that, the crystal exhibit into a hazy liquid with increases of temperature. As he increased the temperature further, the material changed again into a clear, transparent liquid. At the same time Otto Lehmann [3] gave the name of Liquid crystal because of the anisotropic properties of the substances. The molecules in the liquid phase have no intrinsic order but in the solid state phase molecules are highly ordered and have little translational order. The fluidity and anisotropic properties of LCs serve as the basis of many functional applications in modern devices, such as sensor [4], flat panel displays [5] and light modulators [6]. Nowadays liquid crystal research has made huge contributions to nano science and nanotechnology and a new field i.e. liquid crystal nano science has gained growing interest. LC compounds are very sensitive to external perturbations and their physical properties can be suitably tuned by preparing binary mixtures or embedding nanoparticles into the liquid crystalline matrix. Development of such hybrid systems having mixtures of liquid crystalline compounds with nanoparticles at different concentrations [7, 8] proved to be an useful technique to enhance the optical as well as some other physical properties of the host LC materials. Study of the different thermal parameters of nano doped liquid crystals has attracted a new interest owing to their consequence for several application devices based on the electro-optical properties of the same.

## 2. Classification of Liquid Crystals

There are mainly two types of liquid crystal, viz, thermotropic liquid crystal and Lyotropic liquid crystal. The thermotropic liquid crystal which arises due to the change of temperatures and the lyotropic liquid crystal was solvent dependent. Friedel [9] from his detailed optical and x-ray studies have classified thermotropic into three main types: nematic, cholesteric and smectic. Classification of smectic liquid crystals are based mainly on the optical and miscibility studies.

### 2.1 Lyotropic Liquid Crystals

Appear both as a function of concentration and temperature. Lyotropic liquid crystals have relevance to biological systems as bio-membranes consist of lipids and water and usually also proteins, which have liquid crystalline Lyotropic liquid crystals, belong to a class of substances called amphiphilic compounds (surfactant). One end of the molecule is polar and attracted to water (hydrophilic), while the other end is nonpolar and attracted to hydrocarbons, or lipophilic. In solution, the molecules arrange themselves such that either the polar ends are dissolved in a polar solvent or the nonpolar ends are dissolved in a nonpolar solvent. The opposite end is kept isolated from the unlike solvent. As the concentration of the molecules in solution increases, they take on different arrangements or phases–lamellar, cubic and columnar (*Figure 1.1*). The amount of solvent is the controlling parameter for forming such mesophases. Solution of soap and water are typical examples of lyotropics and their mesomorphic properties.

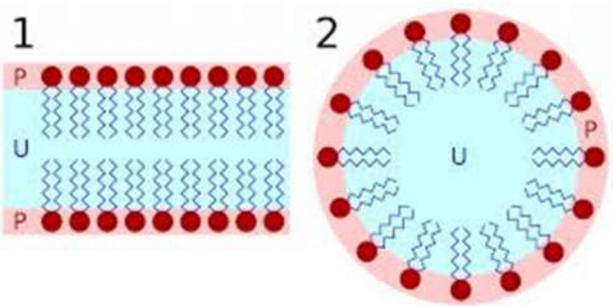

**Figure 1.1. Different Kinds of Lyotropic Liquid Crystals.**

## 2.2 Thermotropic Liquid Crystals

In thermotropic liquid crystals are temperature dependent, mesophase behaviour is induced due to change in temperature (*Figure 1.2*). The thermotropic liquid crystals are composed of rod-like molecules which exhibit reversibility of phase transition are called ‘enantiotropic’, and in certain cases mesophase is observed only during cooling or heating and these transitions are called ‘monotropic’ transitions.

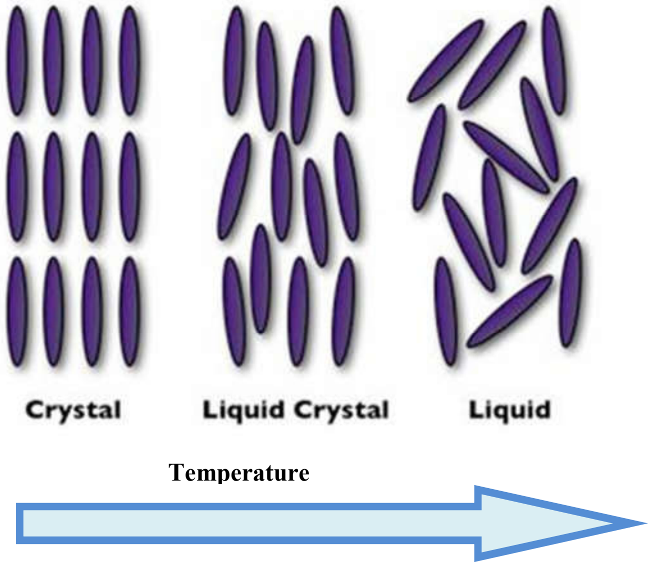

Figure 1.2. Phase Transitions of a Typical Rod Like Liquid Crystal Material.

### 2.3 Nematic Liquid Crystals

Nematics are classified mainly according to the fact that there is no positional order of the centers of mass of the rod-like molecules. In nematics, there is no correlation between the molecular centers of gravity, but the directions of molecular long axis do statistically have a preferred direction called director denoted by $\hat{n}$. Since there is no restriction regarding the positions of the centre of mass, the molecules in this phase have a high degree of mobility. Deformation in alignment of the nematic molecules can be translated by even small external influences of electrical, magnetic and mechanical into visible optical effects for which they are extremely useful in various display devices. The ordinary nematics show an optically positive uniaxial behaviour, but a biaxial modification has also been discovered. Another characteristic property of this phase is that the mirror images are indistinguishable, i.e., achiral, indicating the system to be a racemic mixture or right- and left-handed molecules. X-ray studies indicate that fluctuation of smectic like order parameter manifest itself in certain nematic phases, the so – called “cybotactic nematics”. There is no long-range order in the positions of the centers of mass of the molecules of a nematic, but a certain amount of short-range order may exist as in ordinary liquids. The molecules appear to be able to rotate about their long axes and also there seems to be no preferential arrangement of the two ends of the molecules if they differ. Hence the sign of the director is of no physical significance, $\hat{n} = -\hat{n}$. Optically, a nematic behaves as a uniaxial material with a center of symmetry. A simplified picture of the relative arrangement of the molecules in the nematic phase is shown in *Figure.1.3.*The long planar molecules are symbolized by ellipses.

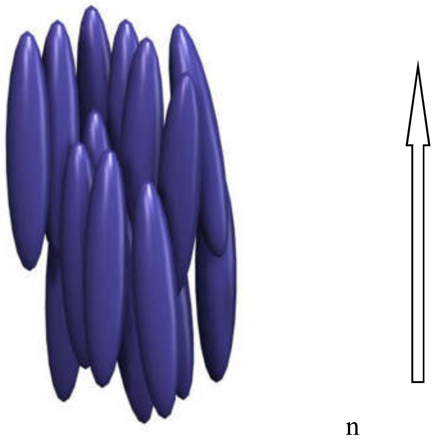

Figure 1.3. Schematic Diagram of Nematic (N) Phase.

### 2.4 Smectic Liquid Crystals

The smectic phase is characterized by the existence of a one-dimensional density wave. The molecular centers of mass on the average are arranged in equidistant planes. Within the layers the molecular centers lie in a single plane, while their long axes are either perpendicular or tilted relative to this plane. In both cases the arrangement of the centers of the molecules within each layer corresponds to a two dimensional liquid.

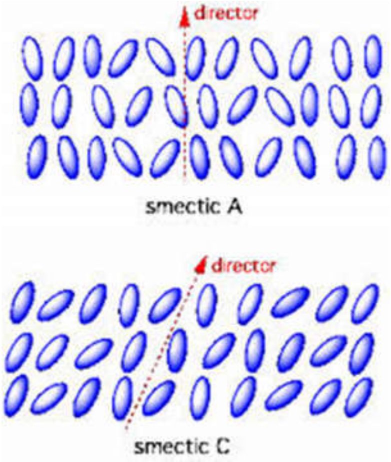

Figure 1.4. Schematic Diagram Of Smectic Phase.

The smectic liquid crystals are generally more viscous than nematics. The interlayer attractions are weaker than the lateral forces between the molecules and the layers can slide over each other, thus showing fluid like behaviour. In some smectic phases a periodicity characteristic of a two – dimensional solid is observed with respect to the position of the centers of mass of the molecules within each layer, while the molecular long axes remain either perpendicular or inclined to the plane of the layer. A large number of smectic phases [10, 11] are identified, some of them are listed below in the order of their possible appearance SmA, SmC, SmB, SmD, SmE, SmF, SmG, SmH.

## 2.5 Cholesteric Liquid Crystals

A cholesteric liquid crystal contains a liquid crystal with a helical structure and which is therefore chiral. Cholesteric liquid crystals are also known as chiral nematic liquid crystals. They organize in layers with no positional ordering within layers, but a director axis which varies with layers. The variation of the director axis tends to be periodic in nature. The period of this variation (the distance over which a full rotation of 360° is completed) is known as the pitch, p. This pitch determines the wavelength of light which is reflected.

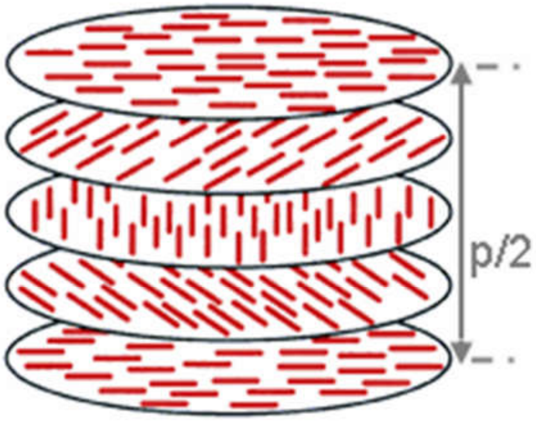

Figure 1.5. Schematic Diagram Of Cholesteric Phase.

## References

[1] P. G. de Gennes and J. Prost, “The Physics of Liquid Crystals’’, 2nd ed., Oxford University Press., New York, **(1993)**.

[2] F. Reinitzer, “Zur Kenntnis des Cholesterins‘‘, Monatxh Chemistry., vol. 9, **(1888)**, pp. 421.

[3] O, Lehmann, “Zeitschrift für Physikalische Chemie”, vol. 4, **(1889)**, pp. 462–472.

[4] A.D. Price, D.K. Schwartz, Journal of Americal Chemical Society, vol. 130, **(2008)**, pp. 8188.

[5] Y. Ishii, Journal of display technology, vol. 3, **(2007)**, pp. 35.

[6] H.K. Hong, M. Lim, Liquid Crystal, vol. 36, **(2009)**, pp. 109.

[7] B. Kinkead, T.J. Hegmann, Material Chemistry. vol. 20, **(2010)**, pp. 448..

[8] R. Basu, G.S. Iannacchione, Physical Review E, vol. 80, **(2009)**, pp. 010701.

[9] G. Friedel, Annales de Physique, vol. 18, **(1922)**, pp. 273, 1922.

[10] H. Kelker und R. Hatz. Verlag Chemie, Weinheim. “Handbook of Liquid Crystals’’, Deerfiel Beach, Florida, Basel, vol. 1, **(1980)**, pp. 6.

[11] D. Damus, S. Diele, M. Klapperstuck, V.Link and H. Zaschke, Molecular Crystal Liquid Crystal, vol. 15, **(1971)**, pp. 161.