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Liquid Crystals - The 'Fourth' Phase of Matter (Review)

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Abstract— **It is an intermediate state of a matter, in between the liquid and the crystal. It must possess some typical properties of a liquid (e. g. fluidity, inability to support shear, formation and coalescence of droplets) as well as some crystalline properties (anisotropy in optical, electrical, and magnetic properties, periodic arrangement of molecules in one spatial direction, etc.). Liquid crystals can be divided into thermotropic, lyotropic and metallotropic phases. Thermotropic and lyotropic liquid crystals consist of organic molecules. Thermotropic LCs exhibit a phase transition into the liquid-crystal phase as temperature is changed. Lyotropic LCs exhibit phase transitions as a function of both temperature and concentration of the liquid-crystal molecules in a solvent (typically water). Metallotropic LCs are composed of both organic and inorganic molecules; their liquid-crystal transition depends not only on temperature and concentration, but also on the inorganic-organic composition ratio. Liquid crystals find wide use in liquid crystal displays, which rely on the optical properties of certain liquid crystalline substances in the presence or absence of an electric field. Liquid crystal tunable filters are used as electrooptical devices, e.g., in hyperspectral imaging.**

Keywords— **orientation, optical, polarizer, transition, alignment, isotropic etc**.

I. INTRODUCTION

The term 'liquid crystal' is both intriguing and confusing; while it appears self-contradictory, the designation really is an attempt to describe a particular state of matter of great importance today, both scientifically and technologically. Liquid-crystal physics, although a field in itself, is often included in the larger area called 'soft matter', including polymers, colloids, and surfactant solutions, all of which are highly deformable materials. This property leads to many unique and exciting phenomena not seen in ordinary condensed phases, and possibilities of novel technological applications. Liquid crystalline materials have been observed for over a century but were not recognized as such until the 1880s. The most significant breakthrough came in 1888 when an Austrian botanist named Friedrich Reinitzer (credited for the first systematic report of the phenomenon) observed that a material known as cholesteryl benzoate had two distinct melting points. In his experiments, Reinitzer increased the temperature of a solid sample and watched the crystal change into a hazy liquid at l45.5oC. As he increased the temperature further, the material changed into a clear, transparent liquid at l78.5oC.

II. CLASSIFICATION OF LIQUID CRYSTALS

The distinguishing characteristsics of phases of condensed matter are:

• Positional order

• Orientational order.

Positional order refers to the extent to which molecules or groups of molecules, on average, show translational symmetry. Orientational order refers to the extent to which the molecules

align along a specific direction on a long-range basis. A crystal has orientational and three-dimensional positional order, whereas a liquid has none. In contrast, liquid crystal phases have long range orientational order, but their long range positional order is generally at most two dimensional, although some exotic, very anisotropic three dimensionally ordered structures such as the smectic B and the twist-grain boundary phase are included in this family.

Depending on the degree of positional order, different liquid crystal phases arise, e.g.

• no positional order, giving rise to the **nematic phase**;

• one dimensional positional order, giving rise to **smectic phases;**

• two dimensional positional order, giving rise to the **columnar phase.**

Additionally, liquid crystals are also classified into:

Thermotropics: These have small organic molecules, usually rod-like or disk-like, which show mesomorphic behaviour as a function of temperature.

Lyotropics: These contain mixtures of organic molecules which show mesomorphic behaviour as a function of concentration of one or more of the molecular species in the mixture, as well as temperature.

III. EXTERNAL INFLUENCES ON LIQUID CRYSTALS

Scientists and engineers are able to use liquid crystals in a variety of applications because external perturbations can cause significant changes in the macroscopic properties of the liquid crystal system by forcing the director to align in specific directions. Both electric and magnetic fields can be used to induce these changes. The magnitude of the fields involved, as well as the speed at which the molecules re-align when the fields are changed, are important characteristics the industry deals with. Also, surface preparations can be used in liquid crystal devices to force specific orientations of the director.

IV. Freedericksz Transition in Nematic Liquid Crystals

An important example of the electro-optic effect, fundamental to the operation of many liquid crystal displays, is the Freedericksz transition. It is an electric-field induced transition in nematic liquid crystals oriented homogeneously between two glass plates, from an unperturbed to a non-uniformly deformed state. In the unperturbed state, which is maintained as long as the electric field E is below a threshold value Eth, the director (and the optic axis) is uniformly oriented parallel to the glass plate. If the sample is kept between two crossed polarizers and the optic axis is rotated by 45° with respect to one of the polarizers, below the threshold voltage the light will pass through the sample. When the dielectric anisotropy of the molecules is positive, if an electric field is applied perpendicular to the glass plate, the molecules try to align along the field direction. In the deformed state which results, many molecules become perpendicular to the glass plate and the intensity falls down. Thus, depending on the off and on state of the applied field we can get on and off states in the transmitted intensity.

Applications

Liquid crystal technology has had a major effect in many areas of science and engineering, as well as device technology. Applications for this special kind of material are still being discovered and continue to provide effective solutions to many different problems.

V. Liquid Crystal Displays

The most common application of liquid crystal technology is liquid crystal displays (LCDs.) This field has grown into a multi-billion dollar industry, and many significant scientific and engineering discoveries have been made.

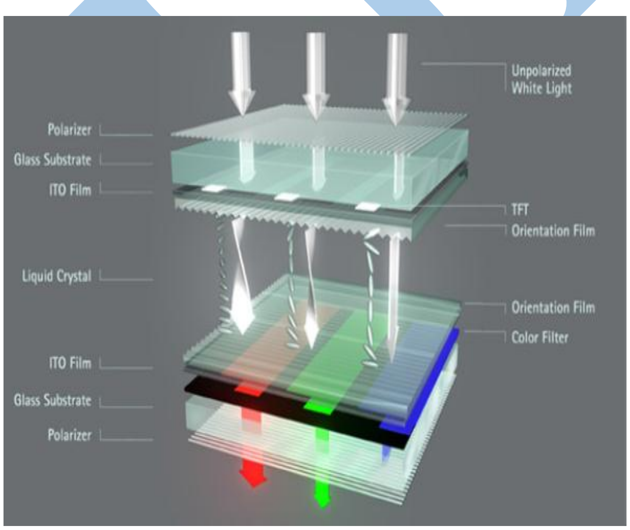

Figure 1: Active-matrix liquid crystal display

VI. Liquid Crystal Thermometers

As demonstrated earlier, chiral nematic (cholesteric) liquid crystals reflect light with a wavelength equal to the pitch. Because the pitch is dependent upon temperature, the color reflected also is dependent upon temperature. Liquid crystals make it possible to accurately gauge temperature just by looking at the color of the thermometer. By mixing different compounds, a device for practically any temperature range can be built.

Optical Imaging

An application of liquid crystals that is only now being explored is optical imaging and recording. In this technology, a liquid crystal cell is placed between two layers of photoconductor. Light is applied to the photoconductor, which increases the material's conductivity. This causes an electric field to develop in the liquid crystal corresponding to the intensity of the light. The electric pattern can be transmitted by an electrode, which enables the image to be recorded.

Polymer dispersed liquid crystals

PDLCs consist of liquid crystal droplets that are dispersed in a solid polymer matrix . The resulting material is a sort of "swiss cheese" polymer with liquid crystal droplets filling in the holes. These tiny droplets (a few microns across for practical applications) are responsible for the unique behavior of the material. By changing the orientation of the liquid crystal molecules with an electric field, it is possible to vary the intensity of transmitted light.

VII. Other Liquid Crystal Applications

Liquid crystals have a multitude of other uses. They are used for nondestructive mechanical testing of materials under stress. This technique is also used for the visualization of RF (radio frequency) waves in waveguides. They are used in medical applications where, for example, transient pressure transmitted by a walking foot on the ground is measured. Low molar mass (LMM) liquid crystals have applications including erasable optical disks, full color "electronic slides" for computer-aided drawing (CAD), and light modulators for color electronic imaging.

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