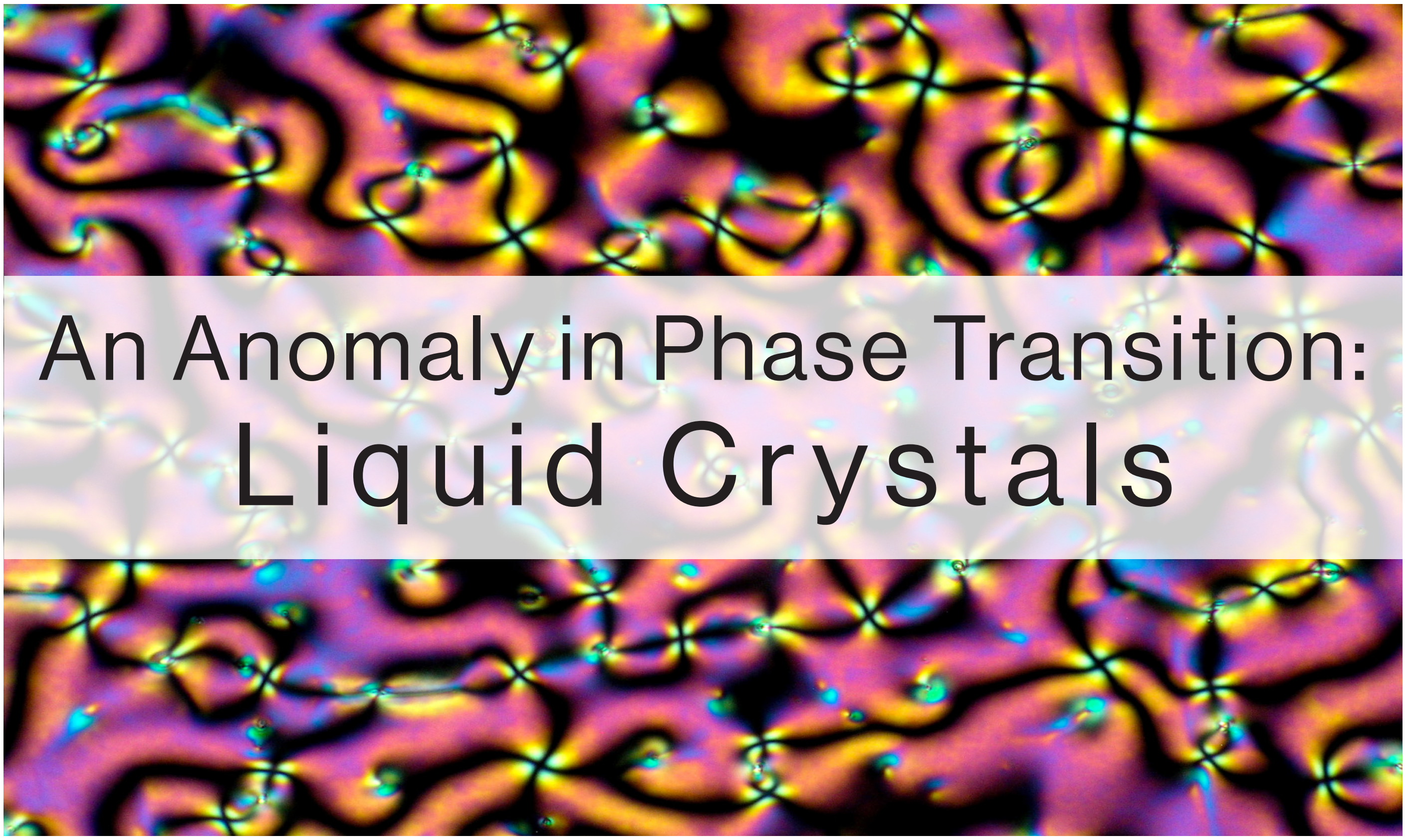

An Anomaly in Phase Transition: Liquid Crystals

BY: PHILLIS WAN

In 1888, while Austrian botanist Federich Reinitzer was investigating the properties of various chemical compounds, he observed that the compound cholesteryl benzoate appeared to have two distinct melting points. The solid compound first melted into a cloudy, murky liquid at 145°C, then became transparent at 179°C.[1] Stumped, Reinitzer sent a sample of this material to his physicist friend Otto Lehmann. Upon further investigation, Lehmann discovered that despite being a liquid, the cloudy substance exhibited similar properties to that of a crystal, thereby coining the term liquid crystal. A century later, these unusual properties have made this compound a cornerstone of human society.

Properties of Liquid Crystals

Liquid crystals are birefringent, meaning that they exhibit a different refractive index (a measure of how much light slows down when passing through a specific medium) depending on the direction of the light passing through.[2]

Birefringence is commonly associated with solid crystal structures, where the ordered arrangement of atoms results in differing optical properties along different directions. As shown in Figure 1, polarized light travels at different velocities along a different dimension of the crystal, which results in it being "split" by the birefringent crystal. Liquid crystals stand at the unique intersection between solid crystal and liquid, retaining the property of birefringence while preserving a liquid form.[3]

The specific compound studied by Reinitzer and Lehmann is a type of liquid crystal called cholesteric liquid crystal. The molecules in this type of structure are positioned and rotated around an axis, resulting in a periodicity that repeats itself at regular intervals.[4]

Following Reinitzer and Lehmann's discovery, other types of liquid crystals were identified. The most common form of liquid crystals is the nematic liquid crystal, where the molecules are aligned in the same direction, but free to drift around randomly, similar to ordinary liquids.[4] However, their orientation can be controlled by applying an

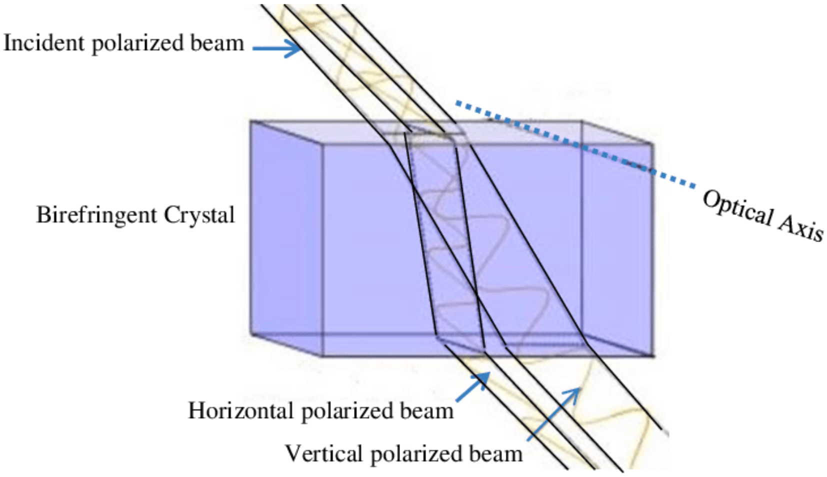

Figure 1: Birefringence arises due to refraction of polarized light by two optical axes.

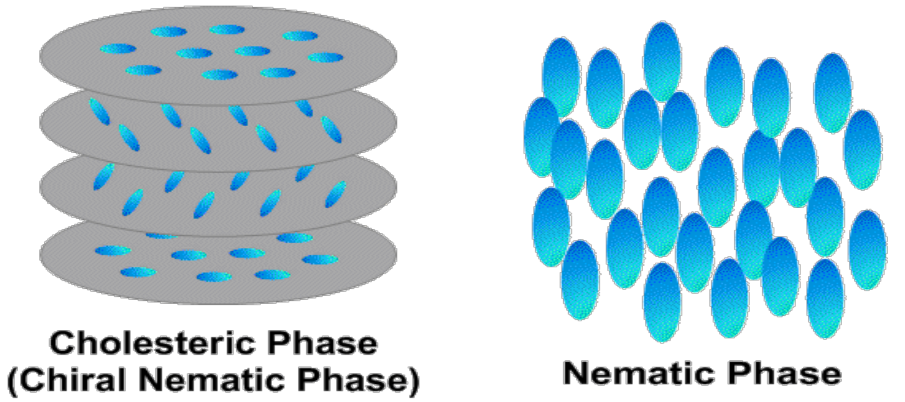

Figure 2: Cholesteric and Nematic Liquid Crystals.

external electric field, thereby altering the optical properties of the liquid crystal.

Applications of Liquid Crystals

As peculiar as liquid crystals may sound, they are actually integral to modern technological life. Liquid crystals play an important role in Liquid Crystal Display (LCD), which are used in everyday electronic screens to display the desired pixels and images depending on the orientation of light passing through.[6]

A thin liquid crystal layer is sandwiched between two glass panels, which have electrodes that apply an electric field to control the orientation of the liquid crystals. The orientation of the molecules then influences the passage of light and creates the image displayed on the screen. The two most commonly used LCD panels are Twisted Nematic (TN) Panels and In-Plane Switching panels (IPS).

In TN panels, the electrodes are coated with an alignment layer that twists the liquid crystal by 90 degrees when no external field is presented. TN is the oldest type of LCD panel, due to its cheap cost and fast response time.[6]

When the voltage is off, light twists along the liquid crystal and passes through to the other side. When the voltage is on, the liquid crystal untwists and is aligned perpendicular to the glass surface. The light no longer twists and retains its original orientation, and it is blocked by a light filter on the other side.[7] Color and resolution of the TN display is compromised; however, its simplicity and fast response speed allow TN panels to be valuable for many video game enthusiasts.

In-plane switching (IPS) panels use nematic liquid crystals, where the molecules are oriented parallel to the surface of the display and are able to shift horizontally to create rich colors and better viewing angles.[6]

By taking advantage of the key properties of liquid crystals, current LCD technologies precisely control the rotation of the molecules with an electric field to display each pixel on electronic screens with great accuracy. Without liquid crystal display, electronic devices would display images with lower resolution, consume more power, and become significantly bulkier compared to older display methods such as cathode ray tube and plasma display.

Outside of Electronics

While they are well-known in the

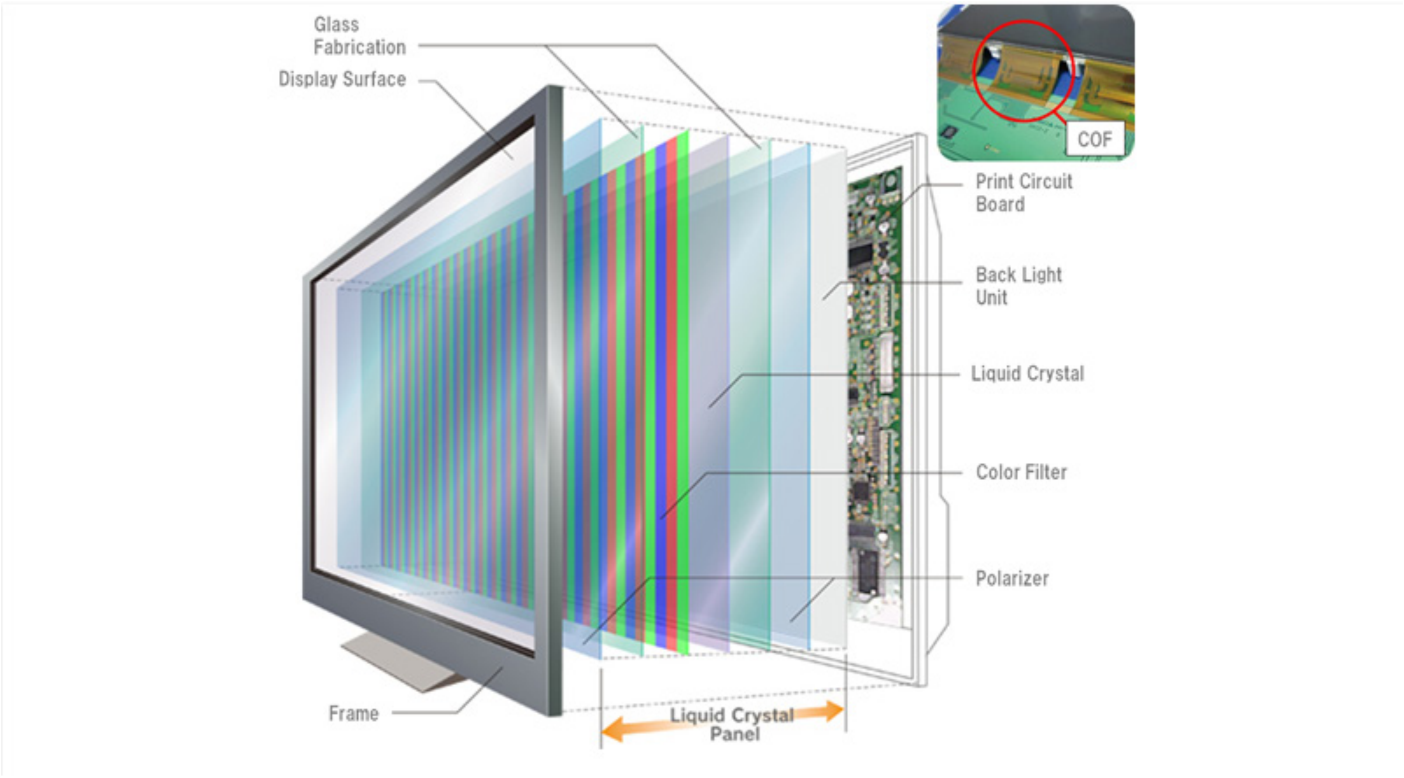

Figure 3: Liquid Crystal Panel.

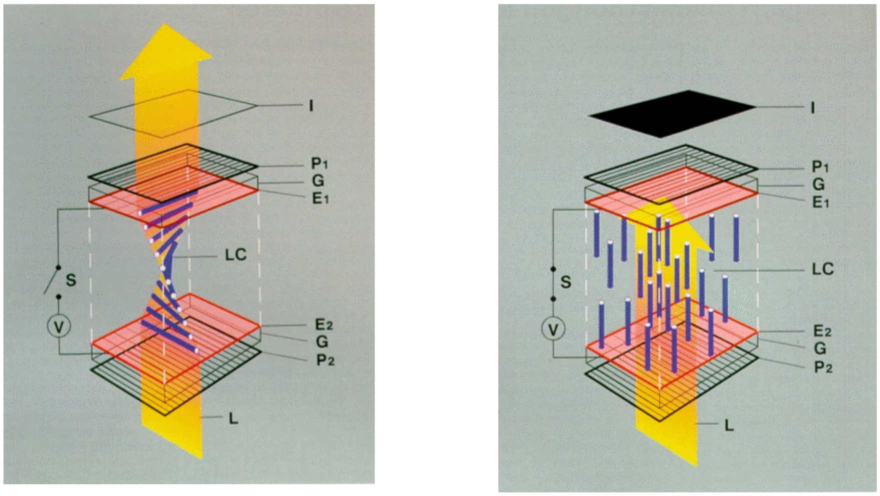

Figure 4: Exploded view of a TN liquid crystal cell showing the states when the voltage is absent (left) and when the voltage is applied (right). L stands for Light that passes through the system; P1 and P2 represent the polarizers; E1 and E2 represent the electrodes; G stands for glass; LC stands for liquid crystals; I stands for image.

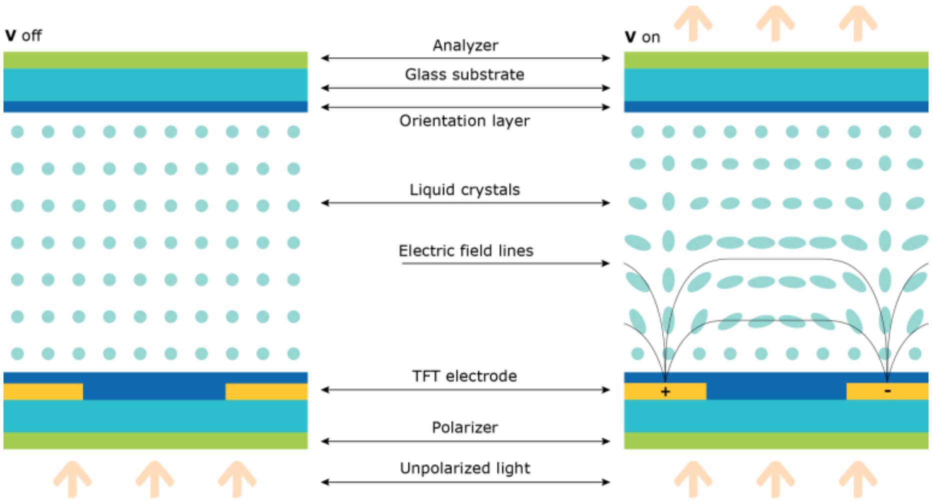

Figure 5: Diagram and Components of an IPS (In-Plane Switching) panel. This diagram shows how the liquid crystal molecules partially align themselves with the electric field created by the voltage.

electronics industry, liquid crystals are commonly found in biological systems as well. In fact, lipids (fats and oils) are a class of molecules that self-assemble into a variety of liquid crystalline structures called lyotropic liquid crystals.[8] In contrast to the thermotropic liquid crystals used in electronic screens, lyotropic liquid crystals are formed by molecules that are both polar (partially charged) and nonpolar, which allows them to self-assemble and adapt to changes in solvent concentrations.

Due to their high solubility, stability, and low susceptibility to oxidation (chemical changes resulted from added oxygen), lyotropic liquid crystals hold immense potential for improving the performance of drug delivery systems. Lipid-based lyotropic liquid crystals open up a plethora of opportunities for potential novel nano-scale drug carriers, and their ability to self-assemble into different geometries offers much inspiration for the development of "smart" drugs that can modulate their shape to ensure safe transportation into the body of the patient.[8]

Reinitzer and Lehmann never could have imagined the scope of impact that their investigation of cholesteryl benzoate would have on society today. Liquid crystals have become an essential feature of portable electronics, replacing heavy old methods of screen display with lightweight, high resolution, and energy efficient technology. Furthermore, they hold much potential for the development of smart drug carriers, all as a result of liquid crystal's special properties due to their unique structure.

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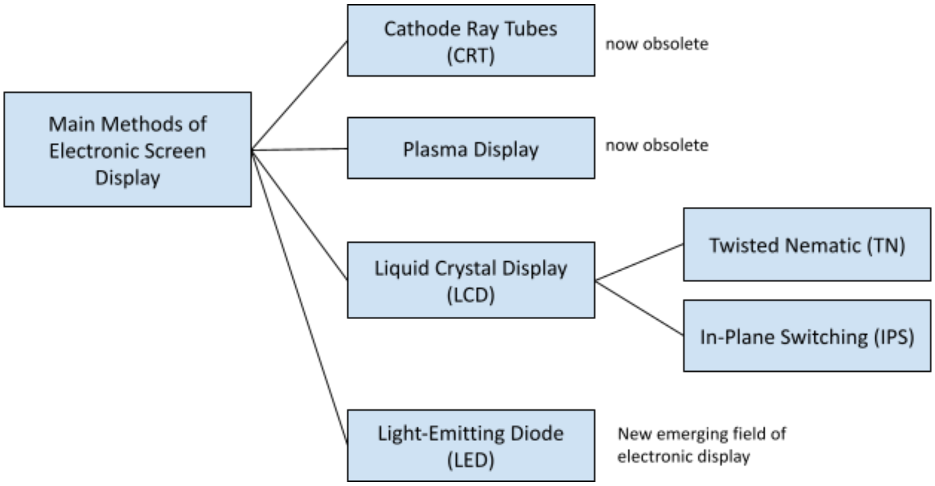

Figure 6: Flowchart of the main methods of electronic display.

for so generously reviewing my article for accuracy and providing detailed and thoughtful feedback.

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