The Physical Properties Of Liquid Crystals

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Personal Details
After I completed my National Certificate in GMIT I transferred to DIT for the Technician Diploma in Applied Science. After obtaining the Diploma, I decided to pursue the Degree in Physics and Physics Technology. The options I chose were Medical Imaging, Biophysics, Optical Communications, Nuclear Physics and Fluid Dynamics. While completing my Diploma I was offered the chance to do my project in Teradyne Ireland in Blanchardstown and so I continued to work there for the rest of that summer. Teradyne manufactures parts for mobile phones for EMC, Motorola and others.

Project Summary
The aim of this project was to investigate the physical origin of the temperature dependence of the order parameter and susceptibility near the Smectic A – Smectic C transition in liquid crystals. It involved the measurement of the critical parameters $\alpha$, $\beta$ and $\gamma$. The results of these measurements would then be compared with the theoretical values predicted by De Gennes and Landau.

Liquid Crystal Phases
The nematic phase of calamitic liquid crystals is the simplest liquid crystal phase. In this phase the molecules maintain a preferred orientational direction as they diffuse throughout the sample. There is no positional order in this phase (figure 1). The name comes from the Greek word for thread, since in a polarising microscope there are often many dark lines visible in thick film samples. These lines are defects in the orientational order and are called disclinations. The preferred direction is under-defined at these disclinations.

In addition to the orientational order of nematics, there is positional order since the centres of mass are arranged in layers. The molecules do not all point the same direction all the time. They merely tend to point more in one direction over time than other directions. This direction is referred to as the director of the liquid crystal. If the director is perpendicular to the layers in which molecules are more likely to be, then it is called Smectic A Liquid Crystal (figure 1). If the director makes any other angle other than 90° to these layers, it is Smectic C phase. The name Smectic comes from the Greek word for soap, since the mechanical properties of these phases reminded early researchers of soap systems.

Experimental Work
Electroconducting plates on the samples were connected to the output leads of an Agilent Function Generator. This produced the required applied electric field across the samples. A photodiode was attached to a microscope and the signal read on an oscilloscope. The function generator was set for a square wave.

In this method the frequency was adjusted to 0.03Hz. Readings were taken of the measurement on the rotating table, which was attached to the microscope. A gain was found where the image was the darkest and readings were then collected.

Figure 1: Liquid Crystal Phases
by finding the darkest images at angles $\Psi_1$ and at $\Psi_2$. These were noted to find the order parameter $\theta$ from:

$$\theta = (\Psi_1 - \Psi_2)/2$$

The temperature dependence of the order parameter was obtained from the fitting of the data. A value of 0.35 should be found according to the De Gennes model and the results achieved in the experiment were $0.34 \pm 0.01$. It is clear that these results are reasonably close to those expected whereas in the Landau model the results would be expected to be around 0.5. Good quality data were ensured through the use of a lock-in amplifier, which amplifies only the signal and not the noise so a clear precise result is calculated. This experiment shows how the applied field changes the molecular arrangement of the liquid crystal and this changes the polarisation of the light passing through it.

**Spontaneous Polarisation Experiments**

For this experiment, the approach used was that developed some years ago by V.M. Vaksman and Y. P. Panarin. They had proposed a universal procedure for measuring the ferroelectric liquid crystal (FLC) parameters, which enables the values of $P_s$ and $\theta$ to be obtained from a single experiment.

I was unable to measure the heat capacity parameter $\alpha$ within the duration of the project, since the differential scanning calorimeter (DSC) required to do the measurements started to malfunction and required repair.

The liquid crystals used were MX6061. The graphs were drawn with the help of Microcal ORIGIN software and the $\beta$ and $\gamma$ values were calculated using the following two equations:

$$\theta(T) = y = k(T_c - x)^\theta$$
$$\chi(T) = k^*(T_c/\gamma)(T_c - T)^\gamma$$

The value of $\beta$ obtained from the fitting of experimental results (figure 1) was found to be 0.34389 which is closer to the theoretical value of 0.35 obtained by De Gennes. By comparison the theoretical value obtained for the same by Landau was 0.5. I found the value of $\gamma$ to be 0.53566 which was closer to the value of 1 predicted by Landau.

De Gennes value for the same happened to be 1.34.

It could be concluded that the critical exponent obtained from the primary order parameter measurements (tilt angle) is closer to the De Gennes model and that the critical exponent from the secondary order parameter measurements gives a value closer to the Landau approach. We believe that the value obtained from the primary order parameter is more realistic and the Smectic A-Smectic C transition is better explained by the De Gennes model than the Landau one.