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A NEWLY OBSERVED DISLOCATION NETWORK IN "BLUE" PHASE II OF CHOLESTERIC LIQUID CRYSTALS

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ABSTRACT

We have observed a dislocation lattice in "Blue" Phase II of cholesteric liquid crystals. The lattice appears when using substrates that have been aligned by a rubbed surfactant (e.g. PVA or polyimide). The data indicate that the dislocation lattice is an interface of edge dislocations caused by a mismatch of the lattice parameter of "Blue" Phase II due to temperature gradients in the sample. Experimental setup and results are presented.

I. INTRODUCTION

There has been increasing interest recently, both experimentally and theoretically, in the "blue" phases (BP) of chiral mesogens. In many of these compounds, there exist three "blue" phases which usually occur within 0.5°C below the isotropic point. They are commonly denoted as BP-I, BP-II and BP-III and occur in that order as a function of increasing temperature. With the exception of BP-III or "blue fog", the "blue" phases have been shown experimentally to posess cubic symmetry.[1,2] On the theoretical side, certain cubic groups have been shown to have lower free energy than that of the normal cholesteric right below the clearing point.[3-5]

Due to their cubic nature, one would expect these phases to exhibit defect features normally found in crystalline solids (e.g. grain boundaries, dislocations etc.). In fact one usually observes these defects[6] in samples where the surfaces are untreated, resulting in polycrystalline platelet texture. When the surfaces are treated with a surfactant and rubbed, one can obtain single crystal domains over large areas. We have observed dislocation arrays using reflected light in these single crystal domains and believe they occur from temperature gradients present in the sample.

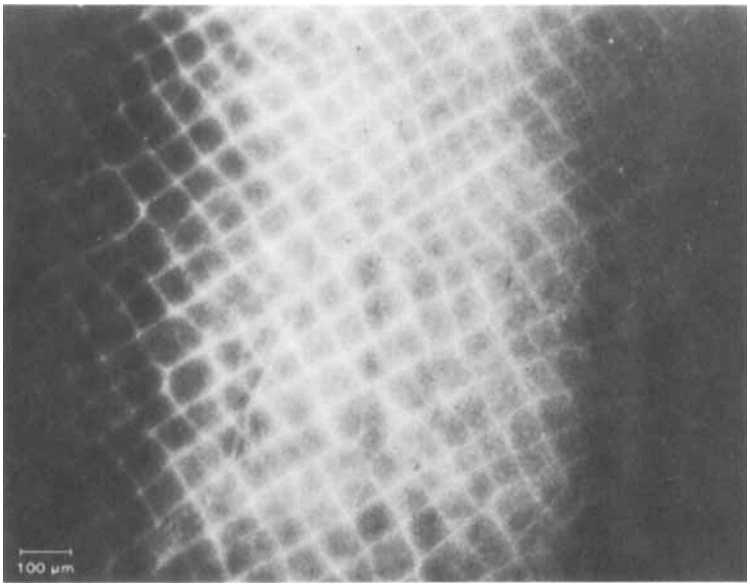

FIGURE 1. Photomicrograph of BP-II, illuminated with monochromatic (517 nm) light in reflection mode, showing the lattice of edge dislocations. Temperature gradient = 0.038 °C over the sample, surface treated with rubbed polyimide, spacer = 152μm.

II. EXPERIMENTAL

Using mixtures of 85% chloesteryl nonanoate and 15% cholesteryl chloride by weight and surfaces treated with rubbed PVA or polyimide and an unmodified Mettler FP-52 hotstage, we were able to observe a square network of lines in BP-II similar to the network in Fig. 1. This network was most easily seen in crossed polarizers using monochromatic light in reflection (in transmission, the network is practically invisible) after letting the sample sit for approximately 30 minutes or more. The network was not observed in BP-I no matter how long the sample sat.

One possibility as to the cause of this phenomenon was that it was due to a slight misalignment of the rubbing direction of the upper surface with respect to the lower surface. This would result in a twist boundary forming somewhere in the sample. The twist boundary has been well studied in metals[7] and results in a lattice of screw dislocations. It can be identified by changing the twist angle between the upper and lower regions and observing a change in the periodicity of the dislocation array. However, when this was done, no observable change was noticed indicating that this pattern is not due to a twist boundary.

The other theory considered was the following. It is an experimental fact that the lattice parameter of BP-II is a function of temperature. If there is a temperature gradient in the sample, then the lattice parameter will not be constant throughout. For large enough temperature gradients, it might be energetically favorable for edge dislocations to form. We measured the temperature difference between the upper and lower heaters in the Mettler hotstage and found that the upper heater was higher in temperature. We then decided to modify the hotstage to vary the gradient between the upper and lower heaters.

Fig. 2 shows a diagram of a modified Mettler FP-52 hotstage. The sample consists of two commercial quartz plates with a glass coverslip for a spacer. Copper plates, which have the same area as the quartz plates, are placed between the heaters and the sample and have thermocouples attached to them. This is to get a better average reading for the temperature of the heaters and to distribute the heat more uniformly over the sample. A resistor is connected in parallel with the top heater since it is normally hotter. The output from the thermocouples is just the difference in temperature between the upper and lower copper plates and is measured in the standard fashion shown.

III. RESULTS

Fig. 3 shows the behavior of the reciprocal of the dislocation spacing as a function of temperature gradient between the upper and lower thermocouples (rightr axis). These data points were calculated by taking an average spacing along one of the dislocation directions and another average along the other (i.e. normal to the first). These two averages were then averaged together to form an overall value for the dislocation spacing for a particular thermal gradient. When there was no measurable thermal gradient, the lattice disappeared, giving the point at the origin. The lattice was also observed to form under a reverse thermal gradient; i.e. when the upper heater was adjusted to a lower temperature with respect to the lower heater. This essentially gave the same data as shown in Fig. 3 except with a negative slope.

The temperature difference difference between the upper and lower regions in the liquid crystal sample is given in the left axis in Fig. 3. It is of course smaller than the temperature difference measured at the thermocouples, and was obtained as follows: The cholesteric liquid crystal was replaced by a nematic (M-18[8])

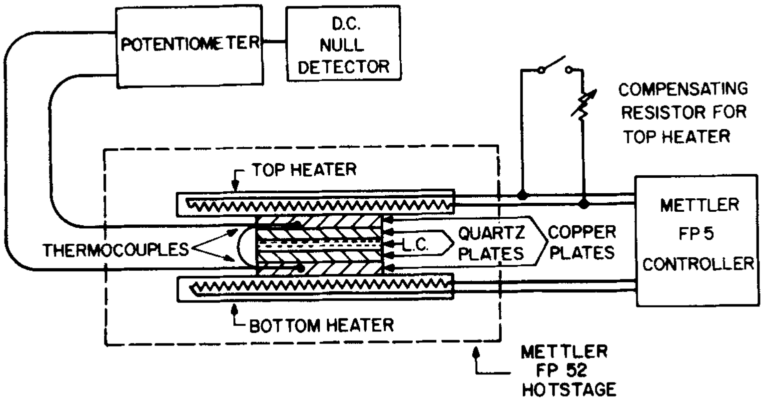

Figure 2. Setup used to measure and vary the temperature difference between the upper and lower heaters in the Mettler FP-52 hotstage.

under otherwise identical conditions. The nematic to isotropic transition profile was observed under a known *vertical* thermal gradient and an unknown lateral gradient using an identical spacer. The setpoint on the Mettler was changed while observing the N-I boundary touching the upper surface move until it was touching the corresponding point on the lower surface. Knowing the starting and stopping temperatures from the Mettler and the vertical gradient at the thermocouples, the actual gradient across the sample can be calculated.

IV. DISCUSSION

Fig. 4 shows a possible model for the dislocation array. The array forms under

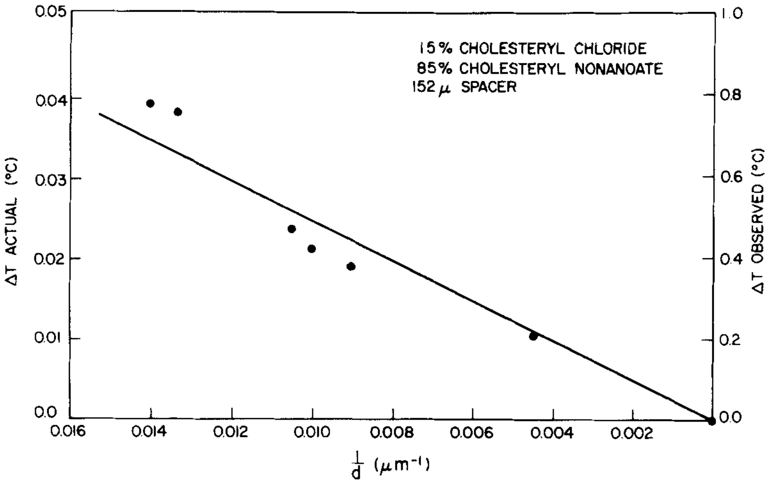

FIGURE 3. Dislocation spacing as a function of temperature difference measured at the thermocouples (right ordinate) and as a function of temperature gradient between the upper and lower quartz surfaces (left ordinate). Spacer thickness = $152\mu m$.

a temperature gradient which causes a mismatch in the lattice parameter resulting in a network of edge dislocations. The smaller lattice parameter corresponds to a higher temperature region and vice versa.

We try to fit the observed dislocation spacing with what one would expect using a geometrical approach similar to that in the literature.[9] The temperature dependence of the first reflection for BP-II was observed to be $-0.38°C^{-1}$. Two average BP lattice constants are assumed for the upper and lower half of the sample. A dislocation occurs every n-unit cells where $(n+1)a_{upper} = na_{lower}$ where the a's are the lattice constants. We also know that $a_{upper} = a_{lower}[1+\alpha(\Delta T/2)]$ where α is the temperature dependence of the lattice parameter and ΔT is the temperature difference between the upper and lower sample surfaces. The factor of 1/2 is

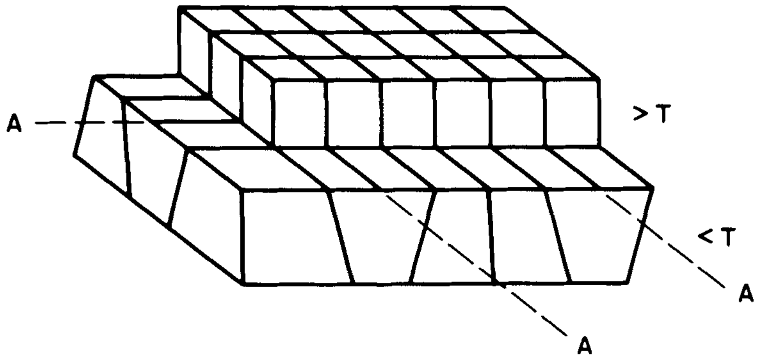

FIGURE 4. Proposed model for observed lattice. Dislocation lines are marked *A*. Interface is an array of edge dislocations.

difference between the upper and lower sample surfaces. The factor of 1/2 is included since we are taking a temperature average in the two halves of the sample. Solving for n and taking a ΔT of 0.03°C, $n = 174$. Therefore every 174 lattice parameters a dislocation should occur. Using a typical lattice parameter of 167nm for this material, the dislocation spacing is 29μm or 0.034μm^{-1}. This estimate is to be compared to the observed value of 0.013μm^{-1} in Fig. 3 for ΔT actual $=$ 0.03°C, which fits to within a factor of 3.

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