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A BOUNDARY INDUCED CHOLESTERIC-NEMATIC PHASE TRANSITION

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Long pitch cholesteric liquid crystals were prepared in thin samples with homeotropic boundary conditions. When the sample thickness was less than the cholesteric pitch, the cholesteric twist was destroyed, and a homeotropically aligned nematic resulted.

INTRODUCTION

The cholesteric-nematic transition induced by external fields was treated theoretically by De Gennes[1] and Meyer[2], and first observed in an electric field by Wysoki, Adams and Haas[3]. Subsequent investigators[4,5] of long pitch cholesterics have commented on unusual observations made when the pitch is approximately equal to the thickness of the liquid crystal layer. But, these authors give no details as to the nature of the irregularities which they note.

During an investigation of the electrically induced cholesteric-nematic phase transition it became apparent that the boundary conditions play an important role in the phase change. These wall effects are particularly important when the sample thickness approaches the pitch of the cholesteric helix and the surfaces have been treated to give homeotropic alignment. The homeotropic boundary conditions are not compatible with a regular, uniform helix, and if the sample is thin enough, the boundary conditions dominate, and a nematic phase is observed.

RESULTS AND DISCUSSION

Using a long pitch cholesteric liquid crystal with homeotropic boundary conditions, a homeotropically aligned nematic phase is observed when the sample thickness is less than the undisturbed pitch of the helix. Long pitch cholesteric mixtures were prepared from cholesteryl nonanoate

(1-5%) dissolved in the nematic biphenyl mixture E-7*. The cholesteric pitches of the mixtures were determined by the "Cano technique"[6,7] using a convex lens on a flat glass plate.

To measure the sample thickness at the cholesteric-nematic boundary, a lens and a flat plate were treated with lecithin or N,N-dimethyl-N-octadecyl-3-aminopropyltrimethoxysilyl chloride (DMOAP) to create homeotropic surface orientation[8]. When viewed in the microscope through crossed polarizers the effect is quite striking as shown in Figure 1a. The boundary seen in Figure 1 is distinct, and the diameter of the circle is easily measured. When the sample thickness at this boundary is calculated it is found to be equal to the undisturbed pitch of the mixture. This was true for all pitch lengths studied, and this relationship is shown in Figure 2 and Table 1.

Another notable effect visible in Figure 1 is the increase in complexity of the cholesteric texture as the sample thickness increases. If the sample is heated above the mesophase to isotropic transition temperature and re-cooled the image seen remains essentially unchanged.

The hypothesis that the dark circle in Figure 1 represents homeotropically aligned nematic liquid crystal is substantiated by conoscopic observations. A sample having a thickness less than the undisturbed pitch gives a uniaxial interference figure. When viewed using a gypsum first-order-red plate the color pattern of an optically positive uniaxial material[9] is seen. This optical behavior is consistent with a homeotropically aligned nematic phase[3].

Since homeotropic boundary conditions cause an unwinding of the helix in thin samples, the effects of homeotropic boundaries can be regarded as analogous to the effects of magnetic and electric fields. Using this analogy for somewhat thicker samples, one would expect an increase in the observed pitch (over the undisturbed pitch) and a diminution in the magnetic or electric field strengths needed to cause the cholesteric-nematic phase change. Both of these consequences have been previously observed[4,5].

In a related work, Greubel[10] has described experimentally and theoretically the existence of a thickness dependent metastable nematic state. The observations described above

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*Obtained from BDH Ltd., Poole, Dorset, England

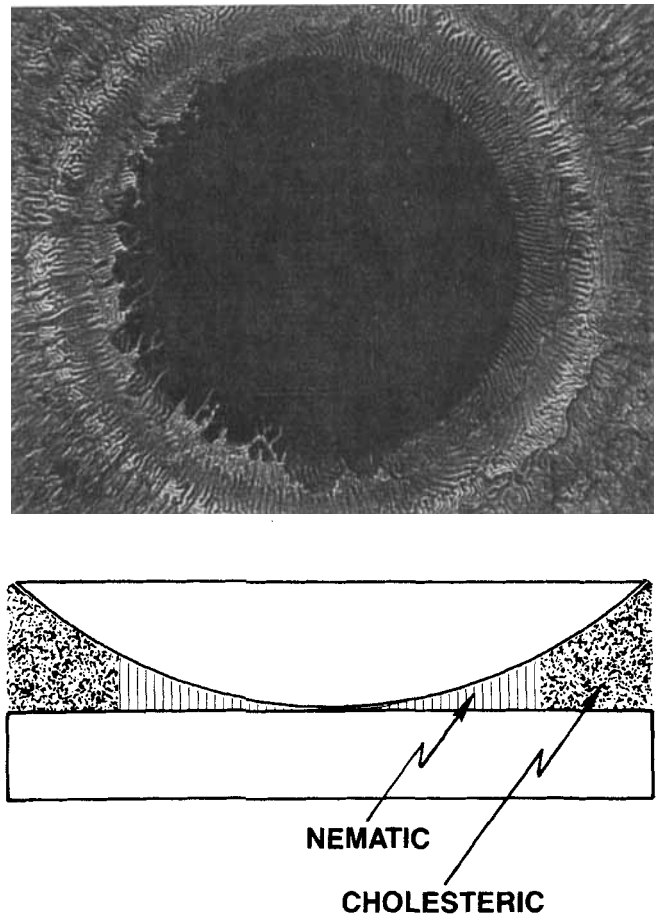

FIGURE 1a. Photograph (44X) of cholesteric-nematic transition as seen between crossed polarizers.

b. Side view diagram of experiment.

are in accord with those of Greubel, except that in this case the nematic phase is the most stable phase in thin samples. Greubel observes a metastable nematic after the application of a field, however, in the experiments described above, I observe a spontaneous phase change in thin samples. The fact that the nematic is reformed after cooling from above

the isotropic transition temperature also indicates that the nematic is the most stable phase in thin samples of long pitch cholesteric materials having homeotropic boundary conditions. For the liquid crystal mixture studied in this work, spontaneous transition to the nematic phase is observed when the thickness becomes equal to or less than the undisturbed pitch.

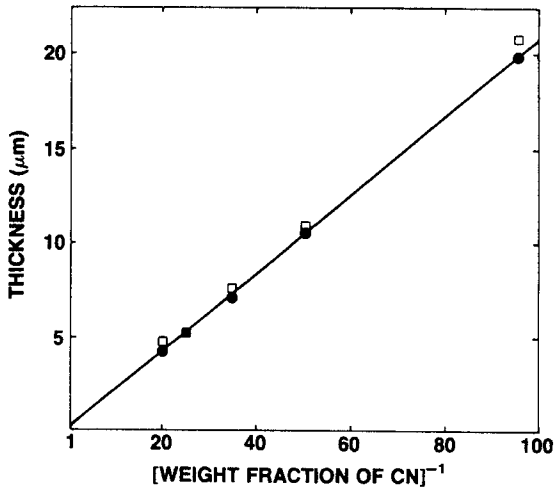

Figure 2.

The dependence of cholesteric — nematic transition thickness and cholesteric pitch on cholesteryl nonanoate (CN) concentration.

□ — Undisturbed pitch measured by Cano method.

● — Cholesteric — Nematic transition thickness with homeotropic boundary conditions.

TABLE 1. Pitch by Cano method and thickness of cholesteric-nematic transition for various CN concentrations.

% CN	Cano Pitch (μm)	Transition Zone Thickness (μm)
1.06	20.5	19.5
2.00	10.8	10.4
2.91	7.31	7.02
4.05	5.23	5.10
5.00	4.43	4.26

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