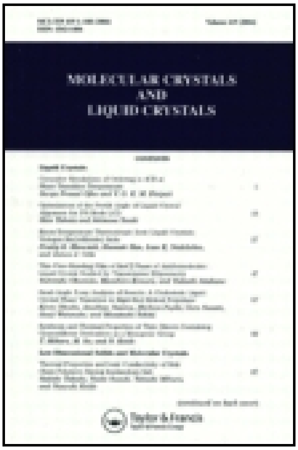

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Electric Field Effect on the Blue Phase of Mixtures of Liquid Crystalline Compounds

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Electric Field Effect on the Blue Phase of Mixtures of Liquid Crystalline Compounds

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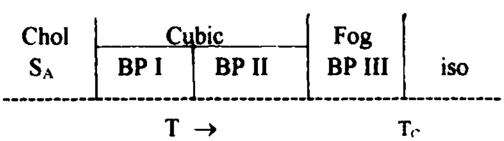
Mixtures of cholesteric and nematogenic compounds show Blue phases and also cholesteric phase. Electric field study shows important features and a significant new blue phase in these mixtures. Beautiful optical textures exhibited by these mixtures are reported in this paper.

Keywords: electric field; blue phase; liquid crystal

INTRODUCTION

The blue phase(BP) is recognized as frustrated phase which appears in a very small temperature range just below the transition point between the isotropic phase and cholesteric phase with short pitch[1-4]. This blue phase is mainly dependent on chirality, temperature and pitch of the cholesterogens[5]. In most of the systems three blue phases are identified which are thermodynamically stable, & sequentially they are BP I, BP II, BP III and isotropic phase with increasing temperature under polarizing microscope.



From the point of view of theoretical consideration, it is accepted that BP I and BP II possess a molecular axis distribution function of cubic phases, where as the fog BP III has no ordering associated with it[5]. Blue phase exhibit a very small birefringence and the reflection of circularly polarized light occurs in small wave length range[6]. It has been predicted that the BP I with intermediate chirality has a BCC structure with O^8 symmetry.

Experimental

The liquid crystalline compounds used in this investigation are cholesteryl nonanoate(CN) and 4,4'-hexyloxy azoxy benzene (HOB) obtained from Merck, USA and they were used after purification. Mixtures of different concentration were prepared and the phase transition temperatures were determined using DSC. The detailed optical texture studies were carried out with the help of Leitz polarizing microscope. The blue phase exists in very limited concentration of CN in HOB. It is interesting to note that the TGB has also exists in the process of phase transition from cholesteric to smectic phase for a particular concentration of CN in HOB. The sample with 30% of CN in HOB exhibits BP I, BP II and isotropic at temperatures 121.6°C, 121.9°C and 122.6°C respectively. In order to study the effect of electric field on blue phase, the mixture is taken in Tin oxide coated glass cell with 12 μm spacers and were driven with a square wave ac voltage source (150Hz) kept in a modified heating stage. In this investigation we report voltage Vs temperature phase diagram of BP system. It is observed that an induced blue phase occurs between BP I and BP II with a proper electric field strength.

Leitz polarizing microscope is used for the microscopic observations along the field direction. The voltage Vs temperature phase diagram is shown in Fig.1.

Result and Discussion

The phases BP I and BP II are characterized by different colours separated by a boundary. When an electric field is applied the colour of the BP I and BP II phases changes. On increasing field strength at constant temperature, the birefringence (Δn) of BP I increases. The phase boundary of BP I and BP II remains unaltered. At some threshold voltage a different texture develops between BP I and BP II phases, as seen in Figures 2 & 3. On further increasing field strength, the new texture grows at the expense of the BP I and supercedes the BP I completely. The phase boundary between BP II and the new texture remains constant with field. All transitions are reversible with electric field. But, at high field strengths, the BP II and the new texture appears dark and it is very difficult to detect the changes and then new texture will transform into cholesteric phase.

This electric field induced blue phase is designated as BP E. In BP I we have observed a hexagonal platelets of different colours between crossed polarisers and is shown in Fig. 4. Slight increase in voltage of ac frequency (200Hz) destroys the platelet texture and cholesteric phase penetrates. The BP II and BP E textures exhibit different reflective wave lengths. According to the Bragg's equation this could indicate different orientations of the blue phase II lattices[15]. However, the lattice reorientation is not expected to respond to reversible temperature changes, and to be independent of the field strength. Therefore, BP E is not identical with the BP II. Thus BP E may be a special case of BP I, because of the different selective reflection wave lengths. However, the birefringence of the BP I vanish on increasing voltage at a threshold field E_0 and never appears at higher fields. On decreasing field strength, BP I reappears sharply at E_0. This indicates a change of symmetry which is clearly due to a phase transition.

The VT phase diagram shown in Fig.1 illustrates the three phase transitions with field. The BP E - BP II transition is field independent. Where as the BP E - Ch transition exhibits the same dependence of the BP I - Ch transition, while the BP I - BP E phase transition temperature, decreases with increasing field strength. The field independence of BP I/BP II and BP E/ BP II transitions indicate that there is no change in permitivity between these phases. But above the BP E threshold voltage the BP I and BP II will have different permitivities[7-8]. The permitivity of BP I has a smaller value when compared to BP E which could be accounted by non-linear dielectric behaviour which has been detected by means of a field induced optical biaxiality[7]. We have also studied the electric field effect on cholesteric phase of the mixtures.

The electro-optical effect observed in cholesteric phase of the same liquid crystalline mixture corresponds to the same pitch of the helix and there is only a change in the orientation of the director. The influence of electric field on the textures of cholesteric phase has been reported earlier by several authors[9-11]. The anisotropy of electrical properties of the cholesteric liquid crystals is important to find the nature of the effect.

By applying the electric field to the cholesteric phase, a more ordered fingerprint pattern is observed. This finger print texture is then transformed to the cholesteric stripped pattern texture with increase in the magnitude of the field as shown in Fig.5. In this condition, for a field perpendicular to the walls of the cell, the deformation is a two dimensional spatially periodic and has a form of square grid with a side $w \propto (dp_0)^{1/2}$, where d is the cell thickness and p_0 is the equilibrium pitch of the helix. Usually such grid is observed in nemato-cholesteric mixtures showing large pitch [12-14].

This grid pattern is due to the periodic deformation, and is approximately π/d along the z-axis.

When an ac voltage is applied along with dc voltage, the liquid crystal undergoes considerable changes and Dynamic Scattering Mode (DSM) like fluctuations are observed. If the voltage is kept constant for some time, a completely stable and regular two-dimensional hexagonal grid pattern (HGP) is observed which is shown in Fig. 6. The HGP pattern is obtained at 250Hz 23V and with a dc 10V. With dc voltage alone the pattern is not clear as there is a not enough charge seggregation. The (ac+dc) HGP pattern is clear in contrast when compared with the ac or dc pattern and there is no grid pattern for frequency greater than f_c. The hexagonal form of the pattern deform gradually with increasing frequency and at some stage it is indistinguishable from the Cheveron texture. However the HGP is rather stable and is formed in a short time at 250Hz, 23V. From Fig. 6, it follows that an extremely regular HGP is formed when dc and ac voltages are applied together. With increase in voltage the angle of deviation of the director increases, and approaches the limit θ=90° for the whole layer which results in the hexagonal grid pattern. The formation of hexagonal grid pattern may be related to a local rotation of the helical axis through 90° [15,16].

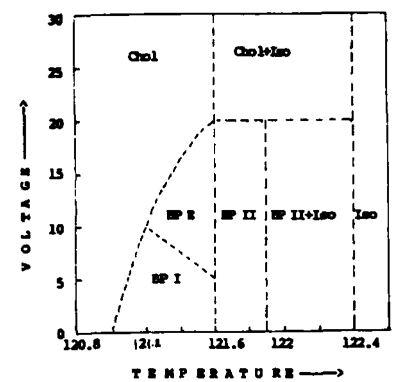


FIGURE 1 Electric field (V) - temperature (T) phase diagram of a mixture CN in HOB, sample thickness 12 μm.

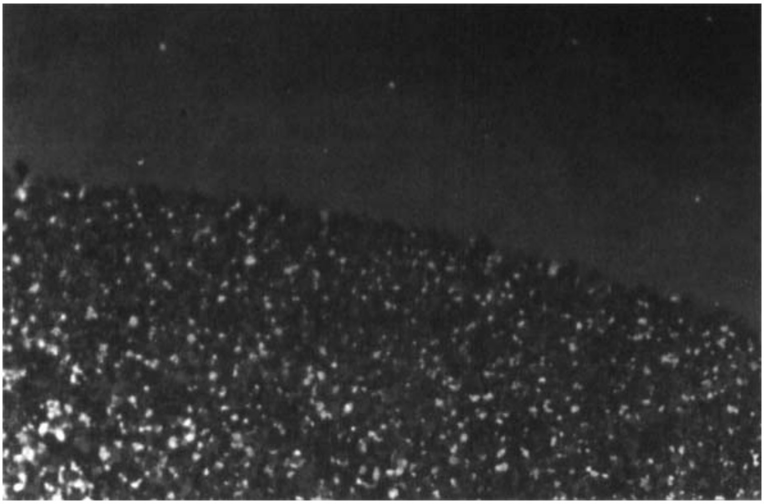


FIGURE 2 Microphotograph of BP II Mosaic texture in an electric field, at 121.8°C, ac 10V(150Hz), sample thickness 12μm(350X). (See Color Plate V at the back of this issue)

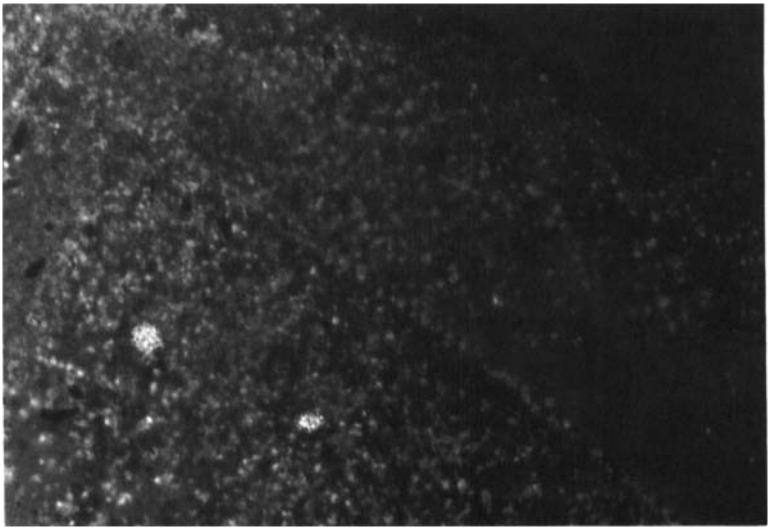


FIGURE 3 Microphotograph of BP II → BP I in an electric field at 121.6°C, ac 5V(150Hz), sample thickness 12μm(350X). (See Color Plate VI at the back of this issue)

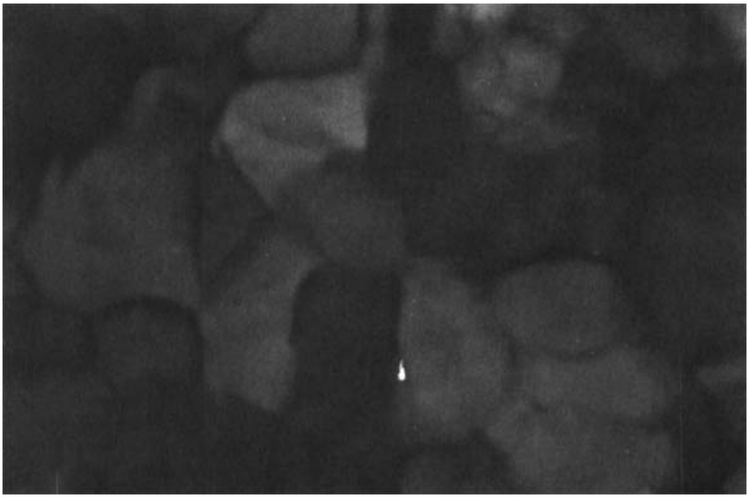
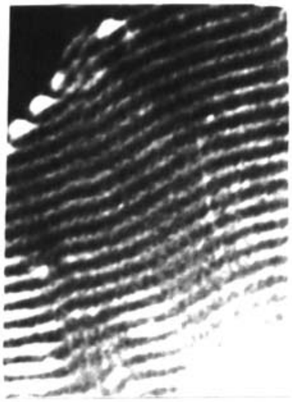


FIGURE 4 Microphotograph of BP I blue green platelets in an electric field at 121.2°C, ac 5V(150Hz), sample thickness 12μm (235X).(See Color Plate VII at the back of this issue)



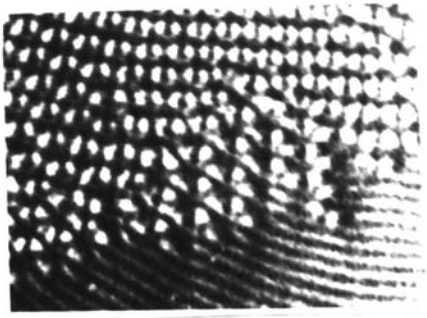


Fig. 5. **Fig. 6.**

FIGURE 5 Microphotograph of cholesteric stripped pattern texture in an electric field at 121°C, ac 23V(250 Hz), sample thickness 12μm(520x).

FIGURE 6 Microphotograph of hexagonal grid formation in an electric field at 121°C, ac 23V(250Hz), dc 10V, superposition with crossed polars (1035x).

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