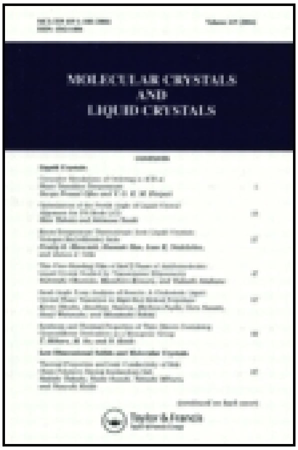

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Observation of Electro-Optical Effects in Blue Phase Systems

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Observation of Electro-Optical Effects in Blue Phase Systems[†]

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The blue phases of two cholesteric systems are studied under the influence of an electric field. The wavelength of maximum absorption due to the selective reflection of circularly polarized light of both blue phase I (BP I) and blue phase II (BP II) turns out to be shifted to longer wavelengths with increasing electric field. In addition to that, a phase transition from BP II to BP I is observed for one of the systems used. Under favorable conditions, brilliant color changes from blue to red are observed in the reflected light.

INTRODUCTION

Recent studies have shown that cholesteric systems with pitches below certain values usually exhibit one or more blue phases (BP I, BP II, . . .).[1–6] Even though theoretical explanations were presented, the structure of the blue phases cannot be considered to be finally understood.[7–11]

Striking optical properties of the blue phases are their reflection of circularly polarized light in a small wavelength range[12] and the very small or non-existent birefringence.

There have been two papers reporting the influence of an electric field on blue phases.[11,13] Field induced phase transitions from the blue phase to either the cholesteric or the unwound cholesteric-nematic state were seen. In addition to that, the results presented here demonstrate for the first time the possibility of continuously varying the wavelength of the selectively reflected light by applying an electric field to blue phases. Contrary to

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previous studies,[11] in the audio-frequency range, no hydrodynamic instabilities occur.

EXPERIMENTAL RESULTS

Two different cholesteric systems were used consisting of the chiral compound 4-cyano-4′-(2″-methylbutyl)-biphenyl (CB 15, BDH) and the nematic wide range mixtures ZLI 1612 (Merck) or RO-TN 404 (Hoffmann-La Roche) respectively. Both systems have a right-handed cholesteric structure and positive dielectric anisotropy. The phase transitions were observed using a microscope with crossed polarizers; the temperatures determined upon cooling are given in Figure 1.

The phase diagram of the system ZLI 1612/CB 15 has been studied in detail.[6] At the composition chosen here, the sample exhibits the polymorphism cholesteric–BPI–BPII–isotropic. The phase transition temperature isotropic–BPII given in Figure 1 indicates the first appearance of BPII, which on further cooling coexists with the isotropic phase over an extended temperature range. Here the BPII–BPI transition is rather sharply defined. The transition to the cholesteric state can be supercooled, so that, upon heating, the transition to the BPI is just below the BPI–BPII transition temperature. A similar behavior is observed for the system RO-TN 404/CB 15.

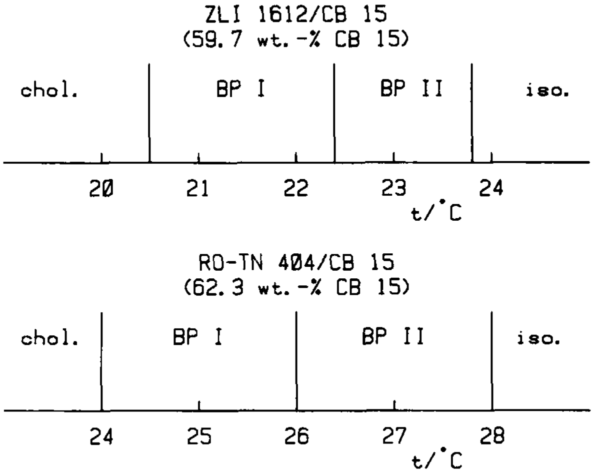

FIGURE 1 Transition temperatures for the two systems investigated.

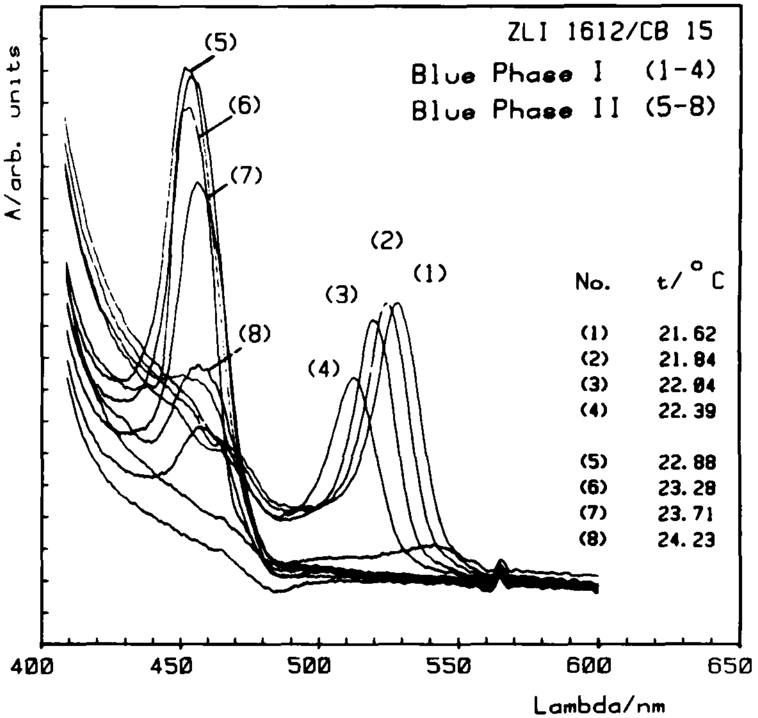

FIGURE 2 Absorption spectra of the system ZLI 1612/CB 15 at different temperatures (absorbance A in arbitrary units).

The optical properties were studied using TN-cells of a 23 μm thickness in a spectrophotometer (Cary 210, Varian). For circularly polarized light, an absorbance was only observed when the sense of rotation of the light was right-handed, corresponding to the fact that only right-handed circularly polarized light is reflected by our systems.

The temperature dependence of the absorption spectrum is shown in Figure 2. For BPI, the maximum wavelength λ_{max} strongly decreases with increasing temperature, whereas BPII exhibits a nearly temperature independent λ_{max}. An abrupt change of λ_{max} is observed at the BPI–BPII transition.

By applying an electric field of 1kHz, the maximum wavelength of absorbance of the blue phases is continuously increased. Figure 3 shows that λ_{max} can be shifted from 520 nm to 605 nm by applying a voltage of 0 to 80 V at a temperature of 22.3°C (BPI), the halfwidth remaining nearly constant. A similar dependence could be found for BPII (Figure 4). However, at a voltage of about 60 V, a wavelength jump of 75 nm occurs. A

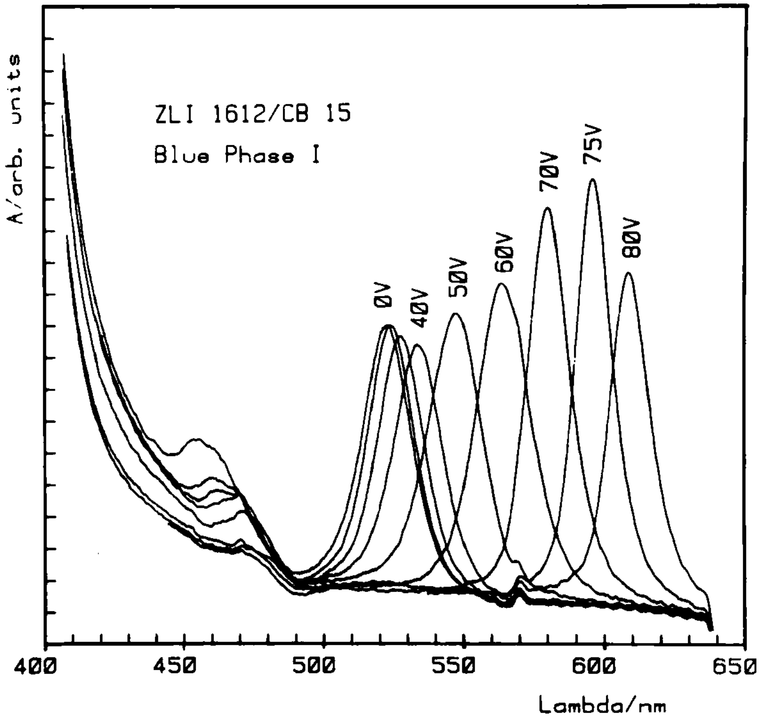

FIGURE 3 Absorption spectra of ZLI 1612/CB 15 as a function of applied voltage at 22.3°C, corresponding to BPI.

further increase of voltage again results in a continuous increase of λ_{max} until finally, a phase transition to the cholesteric state is induced.

In Figure 5, the wavelengths λ_{max} taken from Figure 3 and 4 are plotted against the applied voltage. From the shape of the low temperature curve (22.3°C, BPI), it is obvious that the sample remains in the BPI state throughout the entire voltage range investigated. However, for the higher temperature (23.4°C), the corresponding designation as BPII is only possible up to about 60 V where the wavelength jump takes place. Due to the fact that for voltages higher than 60 V the graph coincides with the BPI curve, we can conclude that a phase transition from BPII to BPI was induced by the electric field.

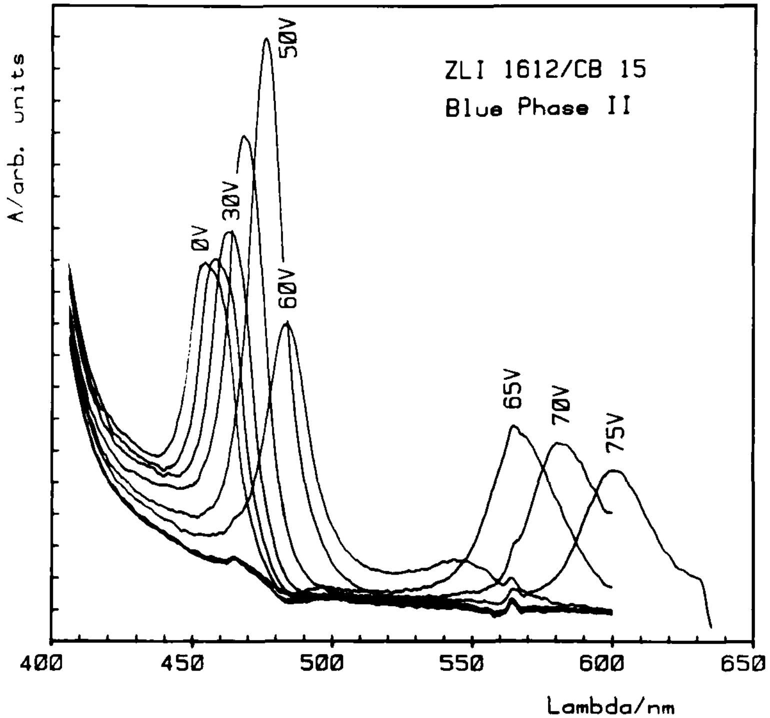

FIGURE 4 Absorption spectra of ZLI 1612/CB 15 as a function of applied voltage taken in the BPII region at 23.4°C.

A variation of driving frequency between 100 Hz and 5 kHz yields similar results. A further increase of frequency causes dielectric heating. From the temperature dependence shown in Figure 2, it is obvious that increasing temperature can by no means result in an increase in wavelength. Thus, dielectric heating cannot be an explanation for the field effect (Figure 5).

At frequencies less than 30 Hz hydrodynamic instabilities similar to those recently reported[13] are observed.

For the system RO-TN 404/CB 15, comparable results were obtained (Figure 6), the exception being that no phase transition was observed in the voltage range spectroscopically examined.

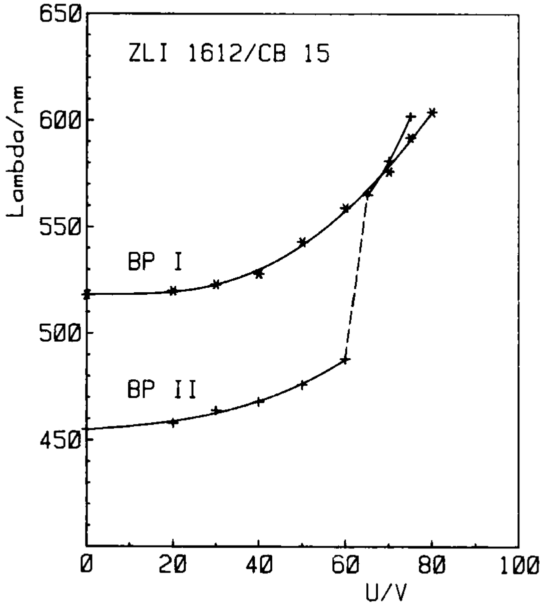

FIGURE 5 Maximum wavelength of absorption vs applied voltage for ZLI 1612/CB 15 taken at temperatures of 22.3°C (BPI) and 23.4°C (BPII).

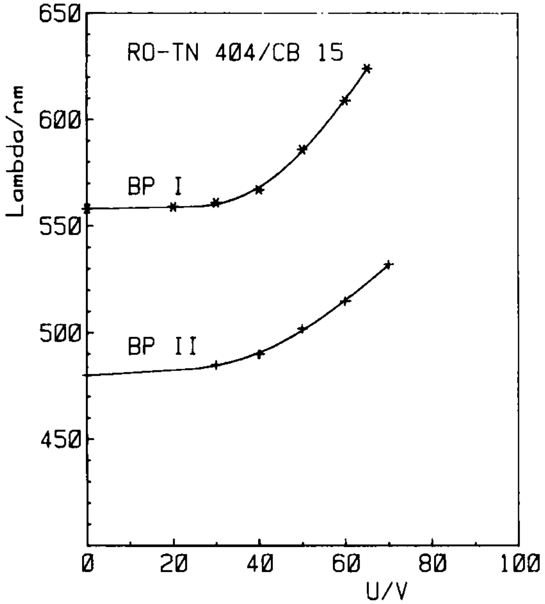

FIGURE 6 Maximum wavelength of absorption vs applied voltage for RO-TN 404/CB 15 taken at temperatures of 25.6°C (BPI) and 27.3°C (BPII).

DISCUSSION

The results given above show that with blue phases, electro-optical field effects are possible. According to the structures proposed so far, blue phases should exhibit isotropic dielectric behavior, corresponding to optical isotropy. The dielectric constant has indeed been found[14] to be equal to that in the isotropic phase for the blue phases of the systems investigated here. To explain the field effects, a deformation of the structure of the blue phases has to be assumed. It is anticipated that detailed theoretical and experimental studies of electro-optical properties of blue phases will help to clarify their structure. On the other hand, the brilliant color changes from blue to red of the selectively reflected light indicate that even electro-optic applications are possible.

Acknowledgment

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