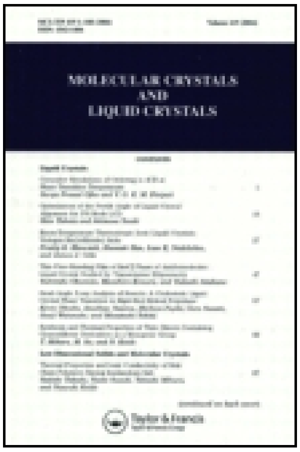

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Bragg Reflection and Circular Dichroism in Chiral Smectic and Nematic Liquid Crystals

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BRAGG REFLECTION AND CIRCULAR DICHROISM IN CHIRAL SMECTIC AND NEMATIC LIQUID CRYSTALS

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Abstract: The present paper deals with the findings of an experimental comparison of the optical properties of cholesteric (chiral nematic) and chiral smectic phases.[1]

The study involved 4-n-hexyloxyphenyl ester of 4'-(2''-methylbutyl)biphenyl-4-carboxylic acid[2] produced by BDH with selective reflection in the visible range in cholesteric and chiral smectic phases. All measurements were made for the single-domain planar structure samples. Figure 1 shows the temperature dependences of the wavelength of maximum selective reflection (λ_{max}) for light incident parallel to the helical axis in sandwich

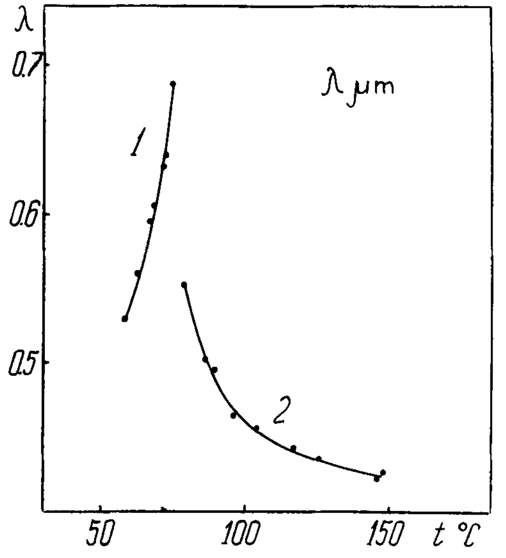

FIGURE 1

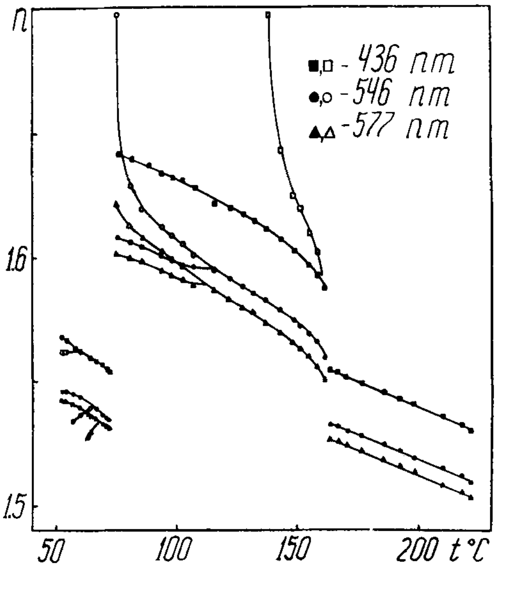

FIGURE 2

type cells for chiral smectic (1) and cholesteric (2) phases. λ_{max} for the chiral smectic phase corresponds to the second order of Bragg reflection and for cholesteric to the first order.[3]

We measured the refractive index n for both phases with a goniometer in wedge-shaped cells with an angle of $\sim 2^0$. The temperature dependence n in isotropic, cholesteric and chiral smectic phases for wavelengths 436 nm, 546 nm and 577 nm is shown in Figure 2. It is clear from this figure that at definite temperatures a division of the refractive index curves into two branches – both in the chiral smectic and cholesteric phases – is observed. The intensity of the beam corresponding to one of the branches gradually decreases (in transmitted light) and then this beam disappears (is reflected). The occurrence of these branches can be explained in the following way. The unpolarized light, which we used in measuring n, can be considered as a sum of two waves circularly polarized to the right and to the left. Near the Bragg reflection band we observe a transmitted beam and one that is beginning to be reflected, the two having different refractive indexes. For the beam beginning to be reflected the refractive index increases, approaching the value at which the electrical vector of the reflected wave begins to follow the long axis of the liquid crystal molecules. The increase of n is due to the fact that in the investigated crystal in the cholesteric phase the helix pitch increases with a decrease of temperature; and in the case of observation at the cooling of samples, the Bragg reflection band "approaches" the wavelengths, the refractive indexes of which we measured by the longer wavelength edge. In contrast, in the case of chiral smectic phase, the helix pitch decreases with decreasing temperature and Bragg band "approaches" the measurable wavelengths from the short-wave-side and the refractive index of the beam which undergoes reflection decreases. This has been proved theoretically.[3]

We measured the circular dichroism for the case of oblique incident light. Liquid crystal was located between two hypotenuse sides of a 45° prism. Visible light Bragg scattering orders at an oblique incidence light on a chiral smectic liquid crystal we revealed in [4]. Figure 3 presents the results of the measurement of the transmitted intensity of the left (light) and right (dark) circularly polarized light for the smectic phase at 63°C (○,●- angle of incidence 60°;□,■- 19.5°;△,▲- 54°). Data for the angle of incidence equalling 60° corresponds to the first order of diffraction, for 19.5° to the second order, but with 54° angle of incidence the short-wave minimum corresponds to the second order and the long wave to the first. (In determining the angle of beam incidence on liquid crystal the measured values of the refractive index from Figure 2 were used, but without consideration of the anisotropy of n). This figure shows that circular dichroism of selective scattering was observed only for the second order

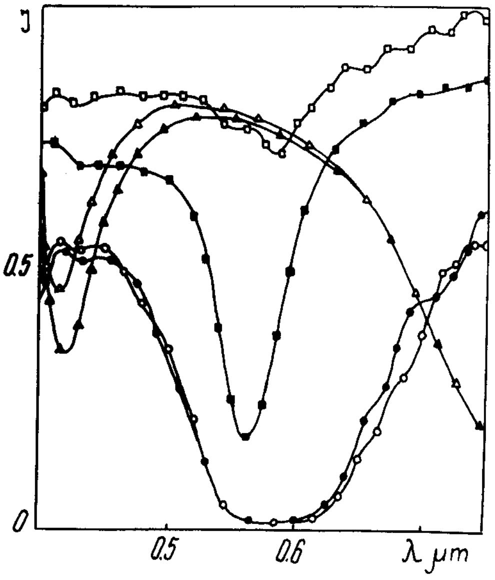

FIGURE 3

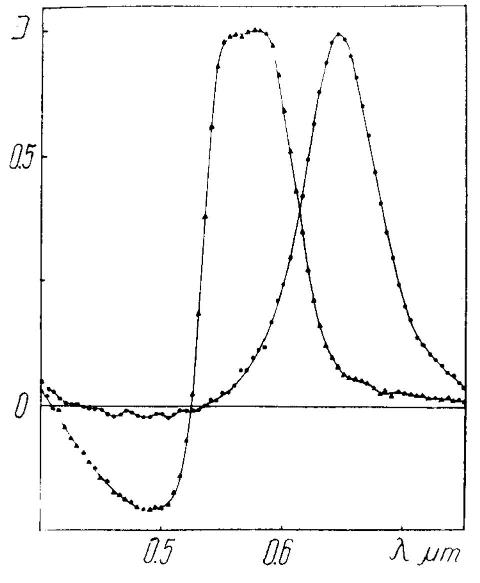

FIGURE 4

diffraction on chiral smectic structure, there being no dichroism for the first order. Thus a qualitative difference of the optical properties between the chiral smectic and cholesteric phases is revealed for first order diffraction.

We investigated induced circular dichroism as well. Anomalous transmission (Borrmann effect) in absorbing cholesteric liquid crystals was experimentally investigated in [5,6]. In [6] a quantitative coincidence of theory with experiment was achieved. The Borrmann effect was observed by us in the chiral smectic phase as well. To the investigated liquid crystal we added 1% of the dye p-nitrobenzene-bis-(benzeneazo)-p'-dimethylaniline. The temperature range of liquid crystalline phases was shifted towards low temperature as a result of this addition. Figure 4 shows the curves of circular dichroism with normal incidence of light in flat sandwich-type cells in the cholesteric phase at 73°C (▲) and in chiral smectic phase at 66.5°C (●). Circular dichroism was calculated by the following equation: $D = I_L - I_R / I_L + I_R$, where I_L and I_R are transmitted intensity for left and right circularly polarized light respectively. The small value of the Borrmann effect in the chiral smectic phase is due to the slope of molecules.

Thus in this paper the first attempt has been made at comparing the optical properties of chiral smectic and cholesteric. For light incident parallel to the helical axis no particular difference was noted between them. A difference was observed for the first order of diffraction at oblique incident light on chiral smectic liquid crystal. Our further experiments for this order will be carried out with σ and π, on plane-polarized light and the polarization of reflected and transmitted light will be analysed.

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