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THERMOMECHANICAL COUPLING IN COMPENSATED CHOLESTERICS

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The thickness dependence of the thermo-mecnanical deformation is investigated in compensated cholesterics. The sign of the coupling coefficient is determined.

As a consequence of chirality the thermal and viscous properties of cholesteric liquid crystals are not independent.

Theoretical calculations - based on the continuum theory of Leslie - show that a temperature gradient may induce flow or elastic deformation and vice versa.[1,2] However these predictions has not yet been confirmed experimentally.

Recently we have reported on a new sensitive method for demonstrating the existence of this thermomechanical coupling in compensated cholesterics and we have estimated one of the phenomenological coupling coefficients.[3]

In this letter we present some new results, got by improving our experimental method.

We investigated the static deformation in a homeotropic layer of a compensated cholesteric mixture which was subjected to a temperature gradient parallel to the surfaces /x-y plane/. Using the continuum theory we have shown that the thermomechanical coupling induces a tilt of the director in the z-y plane, viz. perpendicularly to the temperature gradient.[3] The tilt angle in the layer:

$$\vartheta(z) = \frac{\lambda_{eff}}{K_3} \frac{L^2-4z^2}{8} \frac{dT}{dx} \ll 1 \qquad /1/$$

with $\lambda_{eff} = \lambda_3 + K_2 \frac{dq_o}{dT}$ /2/

Here λ_3 is the thermomechanical coupling coefficient, K_2 and K_3 are Frank's elastic moduli, L is the sample thickness, dT/dx is the temperature gradient, q_o is the wave vector of the cholesteric helix. ϑ is considered positive when tilted toward the y axis.

The distortion is observed by measuring the birefringence of the layer. At normal incidence of light the optical phase difference,

$$\Phi = \frac{\pi}{120} \frac{1}{\lambda} \frac{n_e^2-n_o^2}{n_e^2} n_o L^5 \frac{\lambda_{eff}^2}{K_3^2} \left(\frac{dT}{dx}\right)^2 \qquad /3/$$

is quadratic in the temperature gradient and goes with the 5-th power of the thickness.

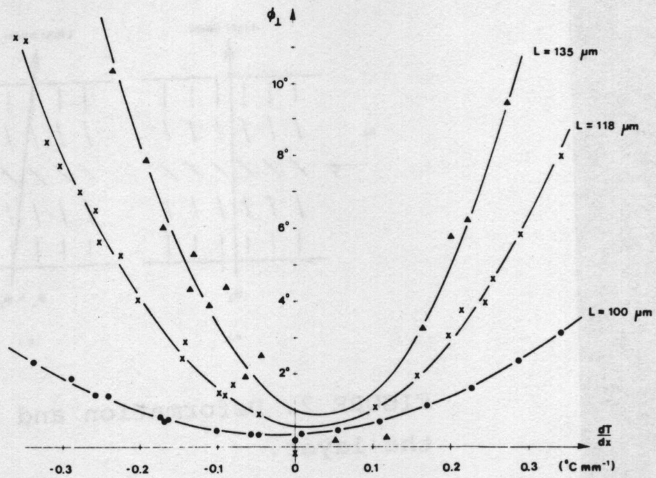

FIGURE 1. Birefringence versus temp. gradient at different thicknesses. Normal incidence. 5

EXPERIMENTAL

We investigated the thermomechanical deformation in the compensated mixture of cholesteryl-chloride /ChC/ and 4-cyano-4'-n-octyl-byphenil /8CB/ in 1:1 weight proportion.

In agreement with Eq.3. the birefringence measurements at normal incidence yielded a quadratic dependence on the temperature gradient. /Fig.1./ The predicted thickness dependence was also found. From the paraboles the absolute value of λ_{eff}/K_3 L was calculated /Fig.3./.

The sign of λ_{eff} was determined from birefringence measurements when the direction of propagation of light was tilted in the plane perpendicular to the temperature gradient. When tilted

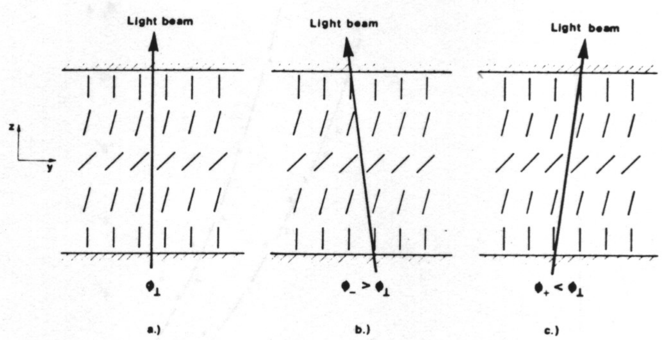

FIGURE 2. Deformation and light propagation in the layer.

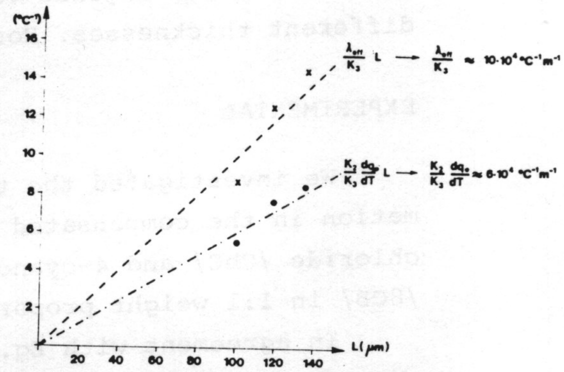

FIGURE 3. Thickness dependence and calculation of the coupling coefficient.

toward the director /Fig.2c./ the birefringence decreases, if tilted from the director /Fig.2b./ the birefringence increases compared to its value at normal incidence /Fig.2a./.

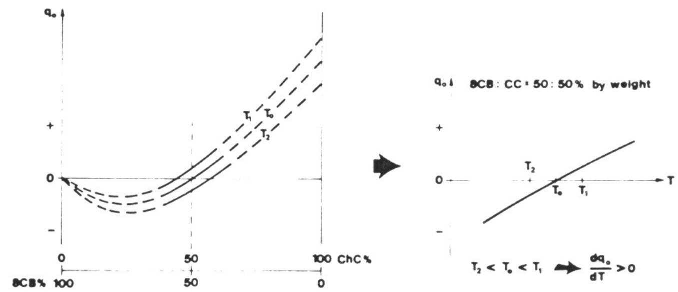

FIGURE 4. Wave vector of the helix versus composition and temperature.

For our mixture λ_{eff} turned out to be positive.

In order to get information about the λ_3 thermomechanical coupling coefficient itself we have to know the contribution of the temperature dependent pitch. From the hysteretic behaviour of the homeotropic - fingerprint texture transition the absolute value of $K_2/K_3\ dq_o/dT\ L$ can be measured directly /Fig.3./.[3]

The sign of $\frac{dq_o}{dT}$ was determined from the phase diagram of the compensated mixture.[4] Since the compensation temperature - where q_o changes sign - decreases when increasing the content of the right-handed cholesteric /ChC/ dq_o/dT has to be positive for our mixture /Fig.4./.

CONCLUSIONS

Using Eq.2. we can get from Fig.3. the relation of the λ_3 thermomechanical coupling coefficient and the K_3 elastic modulus.

$$\frac{\lambda_3}{K_3}=4\cdot 10^4\ {}^{o}C^{-1}\ m^{-1}$$

It means that the thermomechanical coupling is observable in compensated cholesteric mixtures even if the temperature dependent pitch has similar contribution in producing the described above deformation.

Though our method is not yet applicable for measurements in one-component cholesterics the λ_3 thermomechanical coupling coefficient is expected to be of similar order of magnitude in pure compounds and in compensated mixtures.

We hope these results may help to elucidate the mystery of the thermomechanical coupling in cholesteric liquid crystals.

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5. The measured birefringence in Fig.1. is a superposition of Eq.3. and a background which is different for each sample. It is related to the unsatisfying sample quality, like birefringence of the glasses, imperfect orientation, etc.