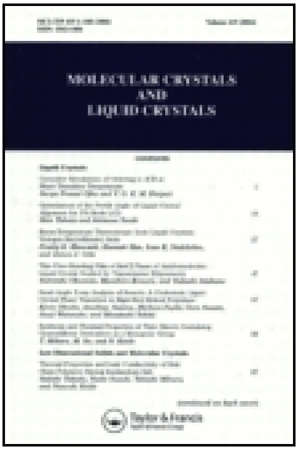

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Simple, Accurate and Low Cost Optical Techniques for the Measurement of 1. Birefringence in Liquid Crystals and 2. Variation of the Angle of the Small Angled Prism with Temperature

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Simple, Accurate and Low Cost Optical Techniques for the Measurement of 1. Birefringence in Liquid Crystals and 2. Variation of the Angle of the Small Angled Prism with Temperature

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Two optical techniques are developed for the accurate measurement of birefringence in liquid crystals and the observation of the variation of the angle with temperature of the small angled prism used for the measurement of refractive indices in liquid crystals. It has been observed that the small variation of the angle of the prism makes a considerable variation in the birefringence. Hence, a simple technique has been developed for this measurement. The second optical setup developed works on the principle of Newton's rings and gives directly the birefringence of a liquid crystal. The development details and the preliminary results are presented and discussed in the light of the available techniques.

Keywords: birefringence; Newton's rings; refractive indices; small angled prism

The manuscript is arranged in two parts. Part 1 describes the development and the experimental results obtained and the evaluation of order parameter in LC phases of *p*-*n*-dodecyloxy benzoic acid, (12Oba) compound. Part 2 narrates the simple technique used for the determination of the angle of small angled prism that is being generally used in refractive index measurements.

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1. BIREFRINGENCE IN LIQUID CRYSTALS

Introduction

As pointed by de Gennes [1] the anisotropy of physical quantity can be a measure of orientational order parameter. In the case of uniaxial liquid crystal phase this parameter can be defined as

$$Q = \delta A / \Delta A \tag{1}$$

where δA is the anisotropy of any arbitrary physical quantity A ($A_{\parallel} - A_p$) and ΔA is the hypothetical anisotropy of A in the case of perfect order. Kuczyski *et al*. [2] proposed a simple procedure for determination of the order parameter from birefringence measurements forming Newton's rings applied for nematic and smectic liquid crystal phases. The authors made an attempt, based on the procedure adopted by Kuczyski *et al*. [2], to develop a low cost set up indigenously for the measurement of birefringence, δn.

Development of Experimental Setup and Results

In the development, a monocular student microscope fitted with polarizer and analyzer along with a monochromatic light source is taken. A calibrated ocular scale is fitted in the eye piece of the microscope. A glass plate and plano convex lens (radius of curvature = 15 mm) is fixed in a metal mount with a central hole. The experimental setup is shown in Figure 1. The total mount is kept in a hot stage (Fig. 2) whose temperature is controlled by a variac used for varying the voltage. The temperature can be controlled with $\pm 0.1^{\circ}$C accuracy. The liquid crystal sample is introduced between the glass plate and lens. Set the polarizer and the analyzer in the crossed position. The hot stage along with the LC sample mount is placed on the microscope stage. Then, adjust the hot stage axis to coincide with the microscope axis. Adjust the reflector of the microscope to pass the light through LC sample to get bright field of view in the eye piece. Focus the polarizing microscope to obtain the Newton's rings until they are clear for measurement. The Newton's rings obtained in the case of 12Oba are shown in Figure 3 at a particular temperature. These rings result from the interference of the ordinary and extra ordinary rays after passing through analyzer. By using the scale, we can measure the ring diameter with ease and with the accuracy of less than $\pm 10^{-3}$. The temperature is measured by thermocouple sensor, which is placed in the hot stage. Transmitted system of Newton's rings formed at

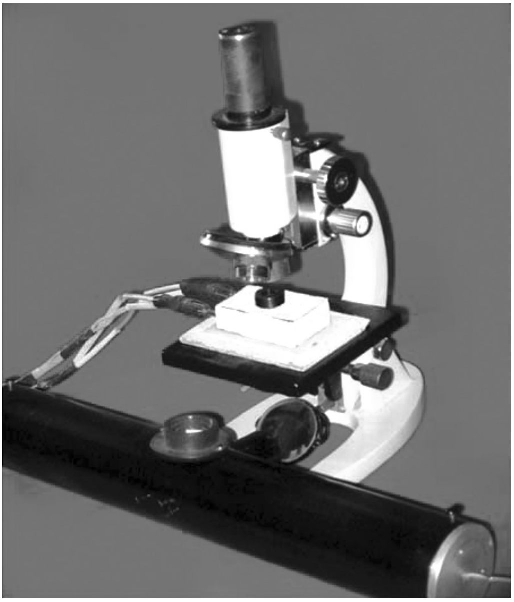

FIGURE 1 Indigenously developed Microscope.

different temperatures in nematic and smectic-C phases are shown in Figure 4. To check the proposed setup's accuracy in the measurement and its validity, we have performed measurements on standard samples and the results obtained are in agreement with the data available in the literature. The birefringence is determined from the ring diameter as follows.

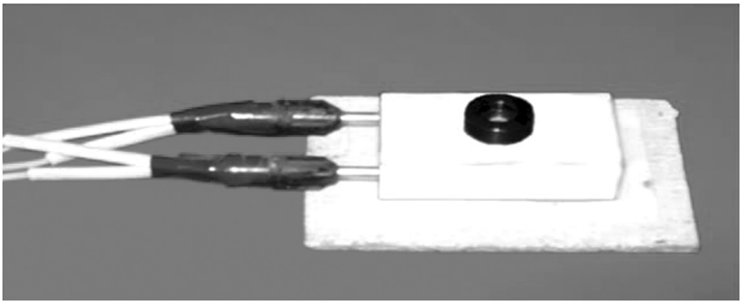

FIGURE 2 Hot stage with sample.

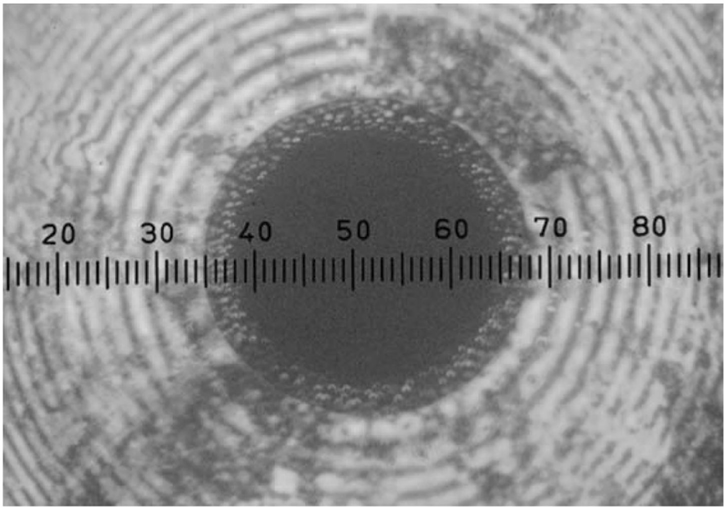

FIGURE 3 Newton's rings with ocular scale sin 12Oba.

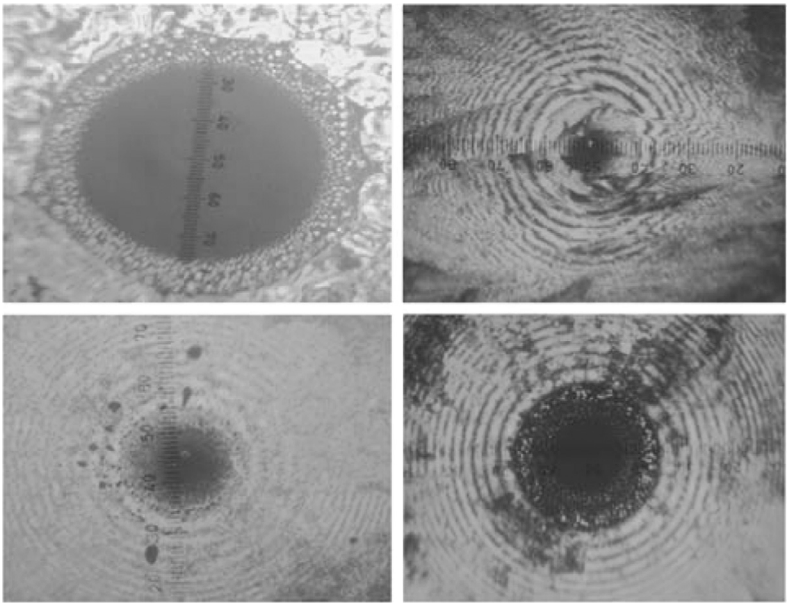

FIGURE 4 Newton's rings at different temperatures in nematic and smectic-C Phase.

Determination of Birefringence (δn)

$$\delta n = K\lambda/Y \tag{2}$$

where

δn = birefringence at observed temperature
K = ring number
λ = wavelength of the light source
Y = thickness of the film and Y is given as
$Y = X^2/2\,R$
R = radius of the curvature of the lens
X = radius of the ring

Then the order parameter is

$$S = \delta n/\Delta n \tag{3}$$

where δn is birefringence at observed temperature, and Δn is birefringence at perfect order. The temperature dependence of the birefringence of 12Oba is shown in Figure 5.

The birefringence at perfect order, Δn is obtained by following the procedure adopted by Kuczyski *et al*. [2] and the procedure is as follows.

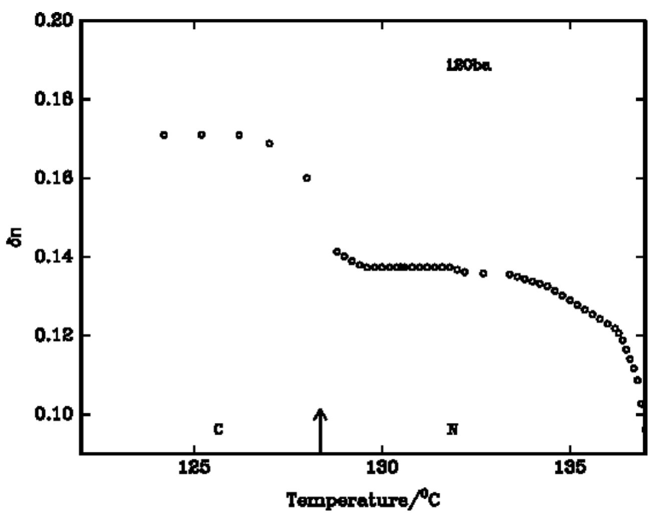

FIGURE 5 Temperature dependence of birefringence δn in 12Oba.

The birefringence δn which is a function of temperature is fitted to the following equation:

$$\delta n = \Delta n \cdot \left(1 - \frac{T}{T^*}\right)^{\beta} \tag{4}$$

where T is the absolute temperature, T^* and β are constants (T^* is about 1–4 K higher than the clearing temperature and the exponent β is close to 0.20). This procedure enables one to extrapolate δn to the absolute zero temperature. In practice, the three adjustable parameters T^*, Δn and β were obtained by fitting the experimental data for δn to the following equation written in the logarithmic form:

$$\log \delta n = \log \Delta n + \beta \cdot \log\left(\frac{T^* - T}{T^*}\right) \tag{5}$$

In the present investigations, the values of log Δn and β are calculated by the linear regression method. The parameter T^* is adjusted to get the best correlation coefficient of the linear regression. Thus, S is given by

$$\mathrm{S} = \frac{\delta n}{\Delta n} \tag{6}$$

The linear fit for the compound, 12Oba is presented in Figure 6. The order parameter S determined in this way (Eq. 6) describes not only the nematic order parameter but also the order parameter in smectic-C phase also as in this evaluation no internal field is considered to describe the nematic molecule. The temperature dependence of the order parameter of 12Oba in nematic and smectic phases is shown in Figure 7.

The salient features of the study are

1. Temperature dependence of birefringence (δn) measurements is carried out in 12Oba nematic and smectic-C Phases. Following the method described by Kuczynski [2] *et al.* the Δn [2], birefringence in perfect order (Fig. 6) was obtained.
2. The order parameter in nematic and smectic-C phases was computed using the Δn value obtained from Figure 7.
3. The advantage of this method lies in the evaluation of order parameters in phases other than nematic also as the order parameter is

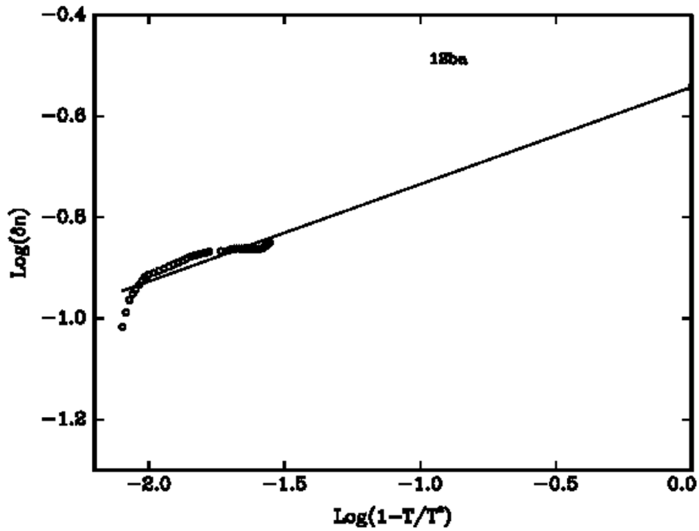

FIGURE 6 Log-Log plot of the birefringence δn versus reduced temperature for the compound 12Oba.

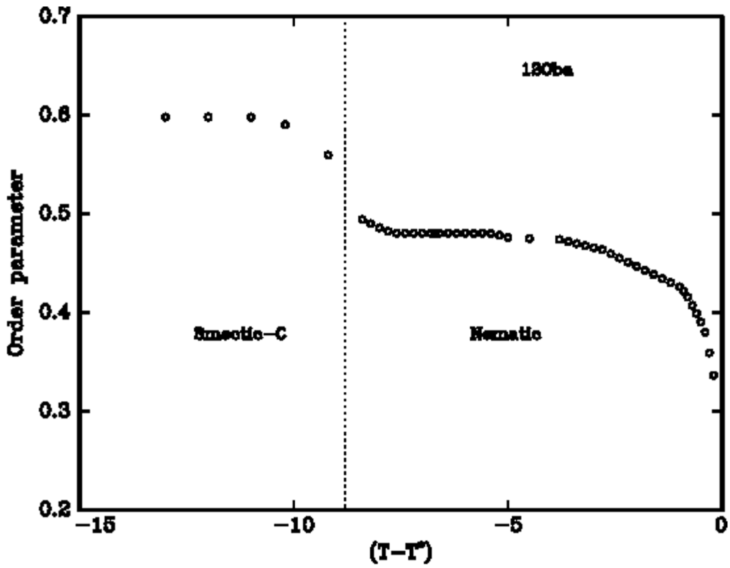

FIGURE 7 Temperature dependence of the order parameter of 12Oba using δn method in nematic and smectic-C phases.

calculated directly from birefringence without assuming any local field that the molecule experiences. The order parameter variation is in agreement with those obtained using other techniques [3–7].

4. By using the experimental setup we can measure the values with ease and accuracy.

2. VARIATION OF THE ANGLE OF THE SMALL ANGLED PRISM WITH TEMPERATURE

Introduction

The measurement of optical birefringence and measurement of both refractive indices are very important in determining the molecular polarizabilities and orientational order parameter. To measure the optical parameters one of the most frequently used method is wedge method. In this method the accuracy depends on the angle of the wedge cell. The authors made an attempt to study the temperature variation of the angle of the wedge cell by collimator technique with great accuracy. In the experiment the wedge angle is kept at 0.6 to 0.7°. The spacer used in the cell is also made out of the same glass material which is used for optical flat plates.

Experimental

The experimental set up used for the measurements is shown in Figure 8. The small angled prism is made out of two optical flats having dimensions $25\,mm \times 50\,mm \times 3$ to $4\,mm$ thick and their flatness is better than $\lambda/4$ and parallelism is better than 2 arc seconds. When the cell is placed on the stage of the autocollimator, the collimated beam incidents on the cell plates and gives two reflected rays, one from the top plate of the cell and the other from the bottom plate of the cell. These two reflected beams enter into the objective of the collimator and forms two images perpendicular to the reference scale and in the plane of reference scale. The separation between the two reflected scales can be measured over the reference scale. This separation is calibrated in minutes so that the angle of the cell can be measured. By using attached drumhead scale we can measure up to an accuracy of 1.5″ of an arc. Figure 9 shows the view through the eye piece. By using the hot stage we can measure the angle variation of the cell with temperature. Figure 10 shows the variation of the angle of the cell with temperature.

FIGURE 8 Autocollimator for the determination of variation of the angle of the small angle cell with temperature.

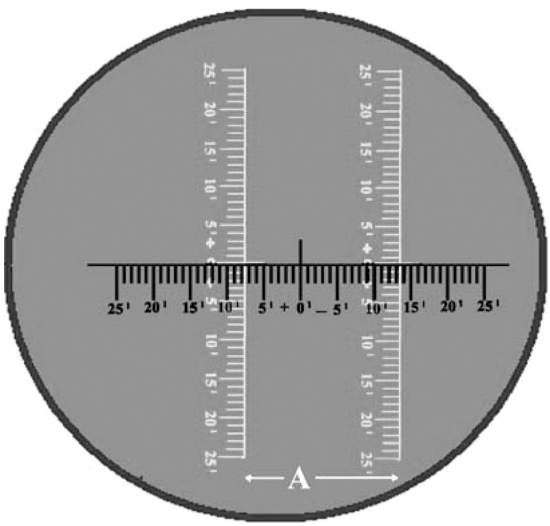

FIGURE 9 Eye piece view to find the angle of the small angle cell.

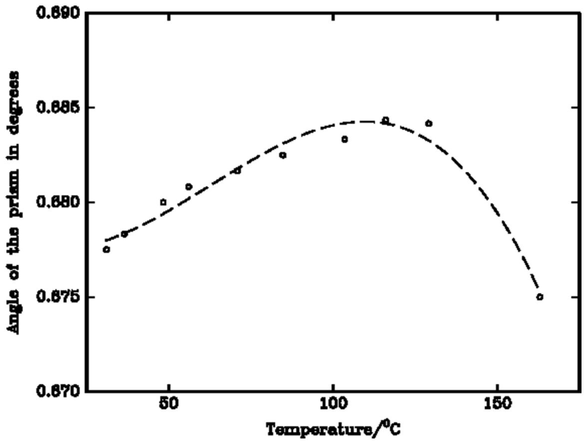

FIGURE 10 Temperature dependence of the angle of the small angle prism.

Results and Discussions

The variation of the angle of the prism is measured from room temperature to nearly 150°C. Initially the angle of the prism increases with the temperature. At higher temperatures i.e., greater than 130°C the angle of the prism decreases with temperature.

This can be interpreted as, initially, the spacer thickness is dominating and hence it exhibits a small but noticeable increase in the angle of the prism. At higher temperature, i.e., greater than 130°C, the length of the cell plates increases thereby decreasing the domination of the spacer showing a steep fall of the angle of the prism. The total variations either increase or decrease is less than 1.5%. As this variation is very small, this correction may not influence the refractive indices values to great extent as the prism angle is very much grater than the variation of the angle in the temperature region used in the experiment.

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