Transmission Factor of N-(4-methoxybenzylidene)-4-butylaniline (MBBA) Liquid Crystalline Layer Between Crossed Polarizers

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The aim of this paper is to obtain information about the transmission factor of MBBA crystalline layer between crossed polarizers. The liquid crystalline layer is kept in a special cell and an external electrostatic field is applied between the walls of the cell. The birefringence of MBBA in the spectral range 470-750nm was calculated by using Cauchy formula on the basis of three experimental values of the main refractive indices of the liquid crystal in an external electric field of about 53.57kV/m previously determined.

Keywords: MBBA in external electrostatic field, birefringence, Cauchy formula, transmission factor

Between isotropic liquids and crystalline solids liquid crystals (LCs) are intermediate phases (named mesophases) [1] consisting of complex molecular systems which involve short and long range intermolecular interactions [2].

In accordance with the physical parameters controlling the existence of the liquid crystalline phases there are two types of liquid crystals thermotropic and lyotropic. Thermotropic LC materials usually contain a single type of chemical compound and their mesophases appear primarily as function of temperature [1]. Lyotropic liquid crystals are mixtures in which one is a simple liquid and the other one is an amphilic compound. In the case of lyotropic LCs the most important variable that influences the existence of the liquid crystalline phase is the concentration [3].

The mesophases can be distinguished by their optical properties revealed in phenomena such as reflection, refraction, nonlinear response, optical waveguide and light scattering [4].

The uniax liquid crystals are characterized by two values of the refractive index: the ordinary value (n_o) and the extraordinary value (n_e) [5]. Ordinary value is measured with light having the electric field perpendicular on the optical axis and the extraordinary value is measured with light having the electric field in the principal section plane determined by the optical axis and the light propagation direction [5, 6].

The birefringence of the liquid crystals is the difference between the extraordinary and the ordinary refractive indices and it can be considered as function of the internal degree of order [6].

In Optics, there are a few wavelengths in the visible range for which the main refractive indices of MBBA liquid crystal were measured, but some empirical relationships permit us to estimate, in some approximations, the refractive indices at each light wavelength in a given spectral range. The refractive index of a transparent material can be estimated by the Cauchy formula [7-9]:

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \qquad (1)$$

where n is the refractive index, λ is the wavelength of light, A, B and C are material-dependent specific constants. The coefficients A, B and C can be determined by fitting the equation (1) for measured refractive indices at three wavelengths [9]. The Cauchy's formula is typically used in the transparence range of the material for normal dispersion [8].

In the anisotropic uniax media the dispersion of extraordinary (e) and ordinary (o) refractive indices can be expressed by (2) [7]:

$$n_{e,o} = A_{e,o} + \frac{B_{e,o}}{\lambda^2} + \frac{C_{e,o}}{\lambda^4} \qquad (2)$$

Consequently, the dispersion of the visible birefringence [8] can be estimated using relation:

$$\Delta n = n_e - n_o = (A_e - A_o) + \frac{B_e - B_o}{\lambda^2} + \frac{C_e - C_o}{\lambda^4} \qquad (3)$$

Experimental part

The main refractive indices and the birefringence of MBBA LC in the presence of an external electric field applied between the internal walls of the cell were previously determined for some monochromatic visible radiations [10]. Pure N-(4-methoxybenzylidene)-4-butylaniline was purhased from Merck Company and used at 23°C.

The method for the birefringence determination was described in a previous paper [11].

In this paper, the LC was studied in the presence of an external electric field (E=53.57kV/m) applied between the internal walls of the cell.

Results and discussions

The main refractive indices of MBBA LC in the presence of an electrostatic field were measured with Rayleigh interferometer for three different wavelengths of light (table 1) [10].

Cauchy fitting coefficients for dispersion of the main refractive indices of MBBA LC in the presence of

Table 1
THE MAIN REFRACTIVE INDICES OF MBBA LC AT E=53.57kV/m (L=14μm, T=296K)

λ (nm)	n_o	n_e	Δn
546.07	1.5966	1.7517	0.1551
589.3	1.5666	1.7167	0.1501
656.27	1.5768	1.7208	0.1440

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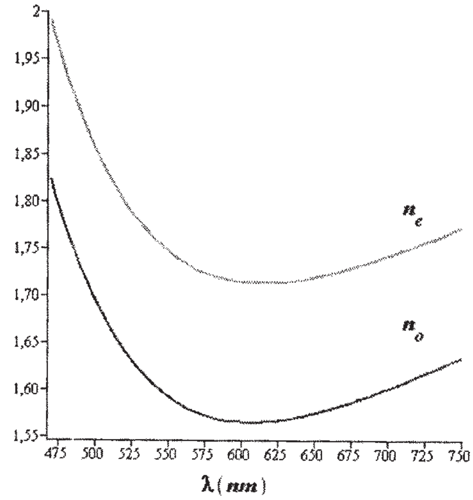

Fig. 1. Main refractive indices of MBBA LC at 53.57kV/m vs. wavelength

electrostatic field (table 2) were calculated using experimental data from table 1.

The dispersion of the refractive indices (n_o and n_e) was simulated by using the Cauchy coefficients for ordinary and extraordinary refractive indices from table 2.

The main refractive indices of MBBA LC in the presence of an external electric field can be established on the basis of the figure 1. For example, one can estimate that the ordinary and the extraordinary refractive indices are 1.567 and 1.713 at wavelength λ=600nm.

The birefringence of the MBBA LC was simulated for λ between 470 and 750nm (fig. 2). The simulation enlarges the spectral range in which the main refractive indices and the birefringence can be evaluated.

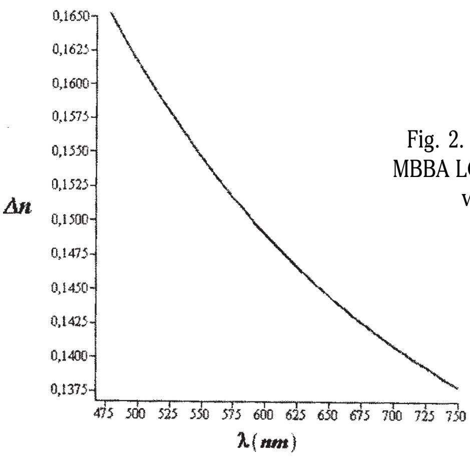

Fig. 2. Birefringence of MBBA LC at 53.57kV/m vs. wavelength

Application

The simulated values of the birefringence were used in order to determine the transmission factor of a LC layer between two crossed polarizers (for the case θ=45° where θ is the angle between the optical axis and the transmission direction of the polarizer) [12-15]. The transmission factor of the device is [11, 13]:

$$T = \frac{1}{2} \cdot \sin^2 \frac{\pi \cdot \Delta n \cdot L}{\lambda} \tag{4}$$

where L is the thickness of the LC layer, Δn is the birefringence and λ is the light wavelength.

The transmission factor of the device was simulated in function of the wavelength and the birefringence. The 3D graph was obtained for the thickness of the LC layer L=14μm.

Table 2

CAUCHY FITTING COEFFICIENTS FOR THE ORDINARY AND EXTRAORDINARY REFRACTIVE INDICES

A_o	2.147975933
B_o (m^2)	$-4.296079823 \cdot 10^{-13}$
C_o (m^4)	$7.90782455 \cdot 10^{-26}$
A_e	2.264063531
B_e (m^2)	$-4.167122747 \cdot 10^{-13}$
C_e (m^4)	$7.8970173537 \cdot 10^{-26}$

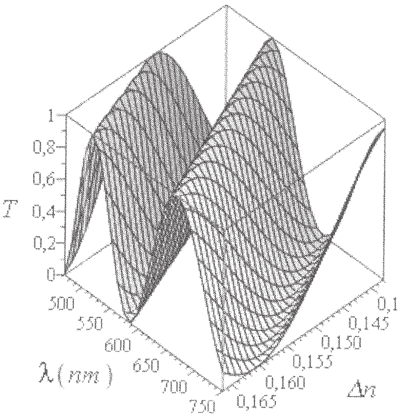

Fig. 3. Transmission factor (T) of MBBA layer at 53.57kV/m between crossed polarizers vs. wavelength (λ) and birefringence (Δn)

From figure 3 one can observe that the maxima of the transmission factor for Δn=0.16 are at aproximativelly 497nm and 640nm. When the birefringence decreases at 0.145 the maximum of the transmission factor is at 580nm and in the channeled spectrum there is only one band.

Conclusions

The values of the main refractive indices of a MBBA LC in the presence of external electric field of about 53.57kV/m were experimentally determined for three wavelengths. The dispersion of the ordinary and extraordinary refractive indices in the spectral range 470 – 750nm was simulated using the determined refractive indices and the Cauchy formula. Depending on the birefringence values, one or two transmission maxima were observed in the simulated spectrum of MBBA layer placed in electrostatic field.

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