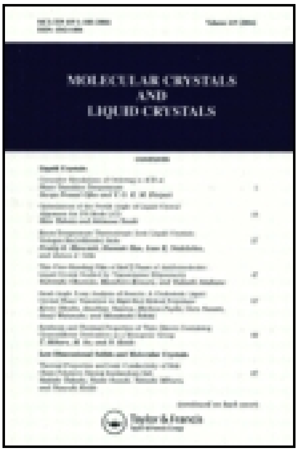

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The Effect of Nematic Liquid Crystal Optical and Dielectric Properties on the Efficiency of Dynamic Light Scattering

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THE EFFECT OF NEMATIC LIQUID CRYSTAL OPTICAL AND DIELECTRIC PROPERTIES ON THE EFFICIENCY OF DYNAMIC LIGHT SCATTERING

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Abstract It has been shown experimentally that the efficiency of the diffuse component light scattering by liquid crystal elements based on nematics with different structures,possessing the effect of dynamic light scattering, grows with the increase of optic and dielectriic anisotropy of the molecules of the liquid crystal material.

Keywords: light scattering, optical anisotropies, nematics

INTRODUCTION

The effect of dynamic light scattering (DLS) in nematic liquid crystals (NLC) [1] finds its practical application in creating optical elements with controlled light scattering, translucent screens, atmospheric phenomena simulants etc [2-4]. The dependence of the form of NLC light scattering indices in the DLS regime on the controlling voltage and on different constructive factors (orientation and thickness of NLC layer) have repeatedly been studied [5,6]. At the same time the effect of NLC molecular parameters on the efficiency of light scattering has not been adequately explored. For example, only the variation of the normal (non-scattered) radiation component, passed through a liquid crystal element (LCE) at the angular photorecorder aperture of 1° for different NLC has been considered in [7]. The results of [8] enable to draw the conclusion that with the increase of NLC dielectric permittivity anisotropy the light scattering intensity increases in the direction which forms an angle of 15°with the normal to the surface of the plane-parallel cell (the fixed photorecorder position). However these studies do not allow us to obtain the complete picture on the regularities of light scattering in NLC.

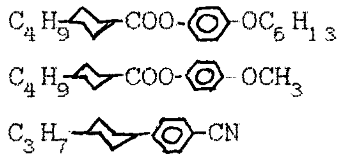
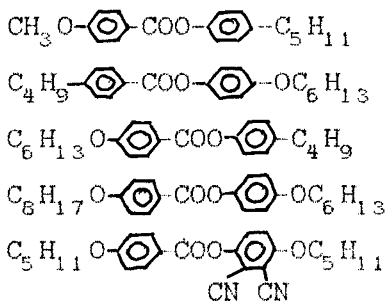
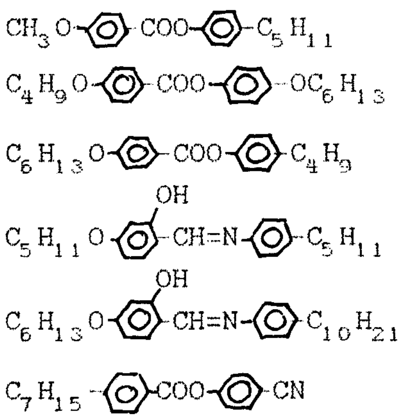
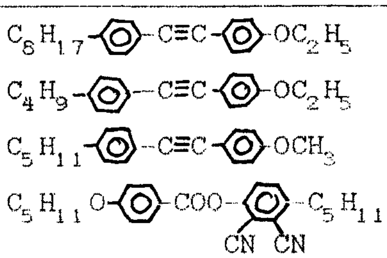
The goal of the present paper is to conduct systematic research on the effects of refractive indices anisotropy and of dielectric anisotropy on the forms of light scattering indices by NLC of different structures. The importance of this work with respect to practice is dictated by necessity to optimize the parameters of NLC materia ls which possess the maximum light scattering efficiency under given conditions.

OBJECTS OF STUDY

In order to solve the problem two groups of NLC-mixtures which exhibit the DLS effect have been prepared. The first group is composed of materials having values of dielectric anisotropy $\Delta\varepsilon$ close to each other and different values of optical anisotropy Δn (Table 1). In comparison mixtures of the second group have quite close Δn values and different $\Delta\varepsilon$ (Table 2). All the mixtures contain the same quantity of ionic additive 0,03% $(C_5H_{11})_4NBr$. All the initial materials have been synthetized in Vilnius University.

Plane-parallel LCE are made dismountable. Transparent conductive layers deposited on the internal surfaces of glass plates, have specificresistance 500-1000 Ω/□. The NLC layer thickness measured by interference technique is 50 ± 2 μm. The director orientation on the electrode surface is not specified as the initial transparency is not required.

TABLE 1

	NLC-mixtures	Content,%	$\varepsilon_{\perp}$	$\Delta\varepsilon$	Δn	t_{tr} °C
1.		50,6				
		45,6	4,47	-0,38	0,079	69,0
		3,8				
2		28,0				
		28,0				
		24,0	6,38	-0,40	0,133	54,4
		18,8				
		1,2				
3		22,5				
		22,5				
		19,4	5,64	-0,38	0,168	57,0
		24,7				
		9,9				
		1,0				
4		37,0				
		33,0	3,67	-0,38	0,256	69,5
		27,2				
		2,8				

t_{tr} - transfluence temperature (nematic transfer into isotropic liquid)

TABLE 2

	NLC-mixtures	Content,%	$\varepsilon_{\perp}$	$\Delta\varepsilon$	Δn	t_{tr} °C
5	$C_8H_{17}-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	26,4				
	$C_4H_9-C_6H_4-C\equiv C-C_6H_4-OC_2H$	23,5				
	$C_5H_{11}-C_6H_4-C\equiv C-C_6H_4-OCH_3$	19,4	4,04	-0,26	0,214	61,5
	$C_4H_9-C_6H_4-COO-C_6H_4-OC_6H_{13}$	29,7				
	$C_5H_{11}O-C_6H_4-COO-C_6H_2(CN)_2-OC_5H_{11}$	1,0				
6	$C_8H_{17}-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	25,4				
	$C_4H_9-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	22,5				
	$C_5H_{11}-C_6H_4-C\equiv C-C_6H_4-OCH_3$	18,6	5,14	-0,97	0,208	60,0
	$C_4H_9-C_6H_4-COO-C_6H_4-OC_6H_{13}$	28,5				
	$C_5H_{11}-C_6H_4-COO-C_6H_2(CN)_2-OC_5H_{11}$	5,0				
7	$C_8H_{17}-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	24,0				
	$C_4H_9-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	21,3				
	$C_5H_{11}-C_6H_4-C\equiv C-C_6H_4-OCH_3$	17,7	6,62	-2,05	0,195	58,0
	$C_5H_{11}O-C_6H_4-C\equiv C-C_6H_4-OC_6H_{13}$	27,0				
	$C_5H_{11}O-C_6H_4-COO-C_6H_2(CN)_2-OC_5H_{11}$	4,1				
	$C_5H_{11}O-C_6H_4-COO-C_6H_2(CN)_2-OC_7H_{15}$	5,9				
8	$C_8H_{17}-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	23,4				
	$C_4H_9-C_6H_4-C\equiv C-C_6H_4-OC_2H_5$	20,7				
	$C_5H_{11}-C_6H_4-C\equiv C-C_6H_4-OCH_3$	17,2	7,40	-2,62	0,200	57,5
	$C_4H_9-C_6H_4-COO-C_6H_4-OC_6H_{13}$	26,2				
	$C_5H_{11}O-C_6H_4-COO-C_6H_2(CN)_2-OC_5H_{11}$	5,2				
	$C_5H_{11}O-C_6H_4-COO-C_6H_2(CN)_2-OC_7H_{15}$	7,3				

METHOD AND APPARATUS

The efficiency of NLC-mixtures light scattering is estimated by the form of LCE light scattering indicatrix. The sample whose indicatrix most approach in its form to Lambert´s one (other conditions being equal) is thought to have higher efficiency.

The experimental setup comprises a goniometer with telecentrical scheme of measurement [6], automatic angular scanning of photorecorder (FEU-79) and with laser radiation source (λ = 632,8 nm, radiation power 0,5 mW). A narrow laser beam is broadened by the telescope system to a beam 2 cm in diameter, which enable to average the useful signal over the LCE area. The $\lambda/4$ plate, transforming the original polarization into a circular one is placed before the LCE. This is done to eliminate the effect of light scattering angular anisotropy, connected with laser radiation linear polarization, on the result of measurements. The photorecorder angular aperture is 5´ and is controlled by a point diaphragm which is located in the rear focal plane of the photorecorder objective (the focal distance 180 mm). The signal from FEU passes to a logarithmic transducer and then to the recorder. This enables us to obtain indicatrixes on a semi-logarithmic scale. The testing radiation for the mixtures studied gets into the transparency band.

RESULTS AND DISCUSSION

Light scattering indicatrix for samples 1-4 having close $\Delta\varepsilon$ values and different Δn are measured at voltage 40, 60 and 80 V (f=50 Hz). They reveal a certain regularity, namely a monotone indicatrix broadening when the voltage increase. Comparison of different sample indicatrixes at same voltage highlights the increase of light scattering efficiency with the Δn parameter, which is most noticeable revealed at higher voltages. Figure 1a shows the indicatrixes of 1-4 samples at U=80 V. The regularity revealed is explained by the increase of refractive index gradient of the optical inhomogeneities responsible for light scattering with the increase of NLC content.

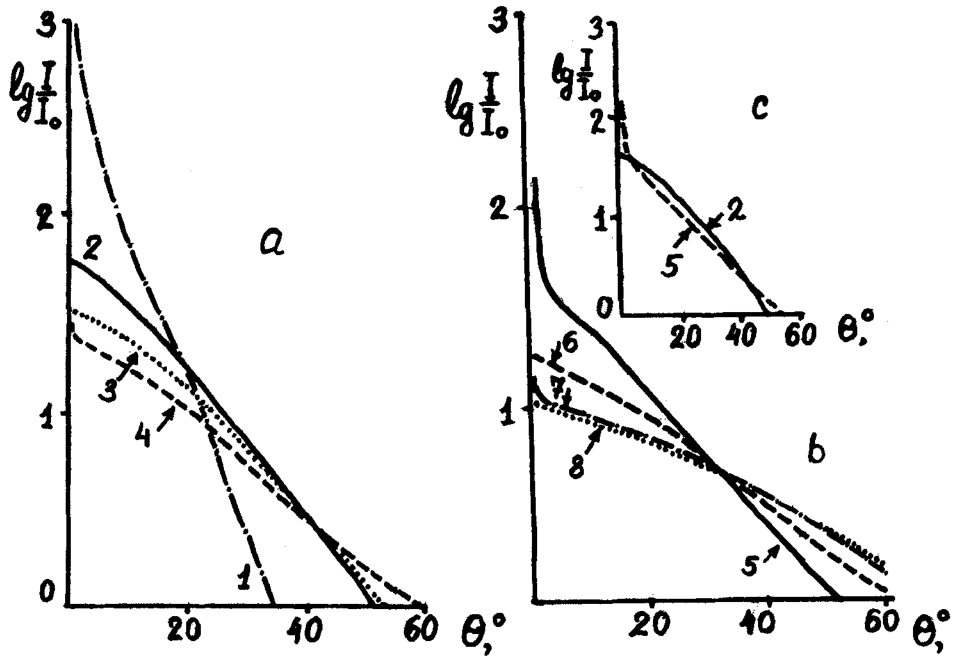


FIGURE 1 Light scattering indicatrixes for the samples 1–4 with close $\Delta\varepsilon$ values and different Δn (a), 5–8 with close Δn values and different $\Delta\varepsilon$ (b), 2,5 (c)with close values of the products $\Delta\varepsilon\ \Delta n$ or $\varepsilon_{\perp}\ \Delta n$ (U = 80 V, f= 50 Hz).

The indicatrixes of the samples 5–8 with close Δn values and different $\Delta\varepsilon$ for the voltages indicated show the same regularity as that observed for the samples 1–4. Here the larger range of $\Delta\varepsilon$ variation for the objects under consideration is accompanied by a larger variation of indicatrixes forms. Comparison of the indicatrixes obtained for samples 5–8 at the same voltages enables us to conclude that the light scattering is enhanced with increase of the dielectric anisotropy modulus of the mixture (Fig. 1b, U=80V). The observed regularity can be related to the increase of local deformations in NLC layer in the electric field with increase of modulus, which enlarges the refractive index gradient of optical inhomogeneities and hence, the efficiency of light scattering. The result obtained is confirmed additionally by comparison of the light scattering indicatrixes of the samples 4 and 7 of different groups, having relatively close values of Δn and essentialy different values of $\Delta\varepsilon$. Sample 7 with the larger $\Delta\varepsilon$ modulus has a higher light scattering efficiency than sample 4.

Moreover analysis of the data reveals approximate coincidence of the indicatrix forms for samples 2 and 5 (Fig.1c) having close values of the product $\Delta\varepsilon.\Delta n$ (difference less than 5%). This coincidence is manifested at different controlling voltages and becomes more accurate as the voltage increases. It is worth noting that in this case the products $\varepsilon_{\perp}.\Delta n$ coincide with even higher accuracy (difference $< 2\%$).

Another interesting observation is the practically complete (within the experimental errors) coincidence of the indicatrixes obtained for samples 6 and 7 with close values of Δn .The coincidence is observed at the voltage 80 V for the sample 6 and 60 V for sample 7 respectively, when $\varepsilon_{\perp}$ U = const (difference 4%) The question whether the observed coincidence are casual, or reveal definite physical regularities can be answered by complementary experiments which require special synthesis of NLC with preset physical parameters (Δn, $\Delta\varepsilon$, $\varepsilon_{\perp}$).

CONCLUSION

The efficiency of the luminous transmittance of the diffuse component by LCE for the considered mixtures with different structures increases with Δn, modulus of $\Delta\varepsilon$ and the value of controlling voltage, the other conditions being equal. These recommendations are quite useful for optimization of materials for different data displays.

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