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ELECTRO-OPTICAL BIREFRINGENCE INVESTIGATION OF NEMATIC LIQUID CRYSTAL TNC-1285

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Abstract

The change of the electric birefringence is investigated when is applying alternating electric field on a thin film (thickness $d=3\cdot10^{-5}$m) of the TNC-1285 nematic phase, production of "Merck"-W.Germany. The investigation has been taken in nematic phase, for three temperatures. From the measurements are obtained the optical contrast and the rise and decay times of the molecules of the liquid crystal. Elastic splay constant K_{11} is calculated by means of decay and rise times for temperatures T=295.8K; T=309.2K.

1. Introduction

In order to investigate the anisotropic properties and the character of the optic behaviour it is necessary to orient the liquid crystal molecules towards to the walls of the cell /1/. If the polarizer and the analyzer are crossed (the angle between them $\Psi=\Pi/2$), and the angle between the polarizer (the incident beam polarization vector) and projection of the nematic optical axis on the electrodes plane (the initial direction of the nematic liquid crystal director) is Φ, then the transmitted light intensity I is /2,3/:

$$I = I_o \sin^2 2\phi \sin^2\frac{\delta}{2} \qquad (1)$$

where:

$$\delta = \frac{2\Pi}{\lambda}(n_{eff}-n_o) \qquad d = \frac{2\Pi}{\lambda} d\langle\Delta n\rangle, \qquad (2)$$

I_o-intensity of the incident light with wavelenght λ, $n_{eff}-n_o=\Delta n$ is difference between refractive indexes for the extraordinary and the ordinary beam, n_{eff} and n_o.

If we assume that the nematic film consists of several homogenous sub-groups of molecules which are oriented in angle interval $\Delta\phi$, then (1) becomes:

$$I = I_o\langle\sin^2 2\phi\rangle \sin^2\frac{\delta}{2} \qquad (3)$$

where <...> is angle averaging over $\Delta\phi$ that corresponds to any subgroup of molecules in the effect.

If we assume that the nematic film is thin, the birefringence at crossed polarizer and analyzer is:

$$\Delta n = n_{eff}-n_{o}=(n_{eff}-n_{0})\ \sin^{2}\theta \qquad (4)$$

where θ is the angle between the initial director orientation of the nematic film and the electric field direction.

According to (3) and (4), the transmitted light intensity through the film change from some maximal up to minimal value, changing $\sin^{2}\frac{\delta}{2}$ from 1 to 0, depending on the degree of defromation of ordered layers.

The contrast of the liquid crystal film transmission K is:

$$K = \frac{I-I_{o}}{I_{o}} = \frac{I_{o}+\Delta I-I_{o}}{I_{o}} = \frac{\Delta I}{I_{o}}\%, \qquad (5)$$

where I_{o} is the transmitted light intensity through liquid crystal film without electric field, and I is the transmitted light intensity with applied electric field.

The relation between the threshold voltage $U_{th}= E_{th}\cdot d$ at deformation of liquid crystal with thickness d,the elastic constant K_{11} and the dielectric constant $\varepsilon_{\parallel}$-paralel and $\varepsilon_{\perp}$-normal on the long molecular axis is given by equation:

$$U_{th}= \Pi\left(\frac{4\Pi K_{11}}{\varepsilon_{\parallel}-\varepsilon_{\perp}}\right)^{1/2} \qquad (6)$$

The time requiréd for reaching the constant part of the efect,"rise time" (τ_{rise}) and coming down, "decay time" (τ_{fall}) at voltages up to threshold voltage is given with:

$$\tau_{r}= \frac{4\Pi\gamma_{1}d^{2}}{\Delta\varepsilon U^{2}-4\Pi^{3}K_{11}}, \qquad (7)$$

$$\tau_{f}= \frac{\gamma_{1}}{K_{11}}\left(\frac{d}{\Pi}\right)^{2}, \qquad (11)$$

γ - coefficient of the liquid crystal dynamic viscosity.

2. Experiment

Electro-optical effects can be observed in nematic films with thickness from $5\cdot10^{-6}$m to $5\cdot10^{-5}$m placed between two condụcting glass electrodes,with $In_{2}O_{3}$ or SnO_{2} film with R≈300Ω/cm^{2} /1/. For nematic liquid crystals with positive dielectric anisotropy ($\Delta\varepsilon=\varepsilon_{\parallel}-\varepsilon_{\perp}>0$), planar orientation is necessary (θ=0). It can be made by 1% solution of PVA in $H_{2}O$ (Fig.1.a). In case of negative dielectric anisotropy ($\Delta\varepsilon=\varepsilon_{\parallel}-\varepsilon_{\perp}<0$), homotropic orientation is necessery ($\theta=\Pi/2$). It can be

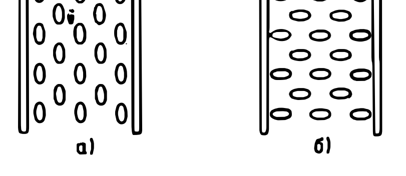

Fig.1

made by 1% solution of licitin in chloroform (Fig.1.b).

According to the specifications from the firm "Merck", the investigated liquid crystal TNC-1285 shows the following characteristics: it is nematic phase at temperatures from $-3^{\circ}C$ to $+68^{\circ}C$; $\Delta\varepsilon=\varepsilon_{\parallel}-\varepsilon_{\perp}=+13.8$ at $20^{\circ}C$ and $\nu=1kHz$; $\Delta n=+0.18$ at $20^{\circ}C$ and $\lambda=589nm$. Its kinematic viscosity coefficient $\gamma=36.4mm^2/s$ at $20^{\circ}C$. The film with thickness d=0.03mm is placed between conducting glass electrodes with SnO_2 film. The film thickness is determined by placing a teflon limiter between the planeparallel glas plates.

The principal scheme of the aparatus for observing light birefringence in nematic crystal is given in Fig.2.

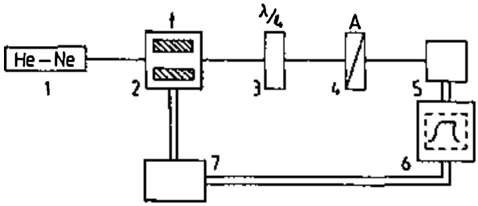

Fig.2 1. He-Ne laser;
2. cell; 3. λ/4-plate;
4. Nicol - prism;
5. silicon photo - diode;
6. oscillograph;
7. alternative electric field generator

The investigations have been made for three temperatures: 295.8K; 309K; 316K. The temperature was measured with precison of $0.1^{\circ}C$.

3. Results and discussion

The following figures are oscilograms recorded at given voltage and time precision, when alternative electric field with different strenght and frequency $\nu=500Hz$ is applied on nematic liquid crystal film.

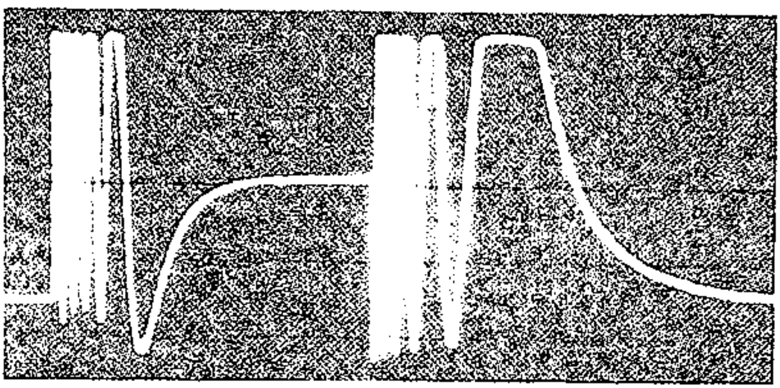

Fig.3. T=316.7K; $U_{ef}=0.39V$; $\nu=500Hz$. Recorded at 2V/div. and 1ms/div. on the oscillograph.

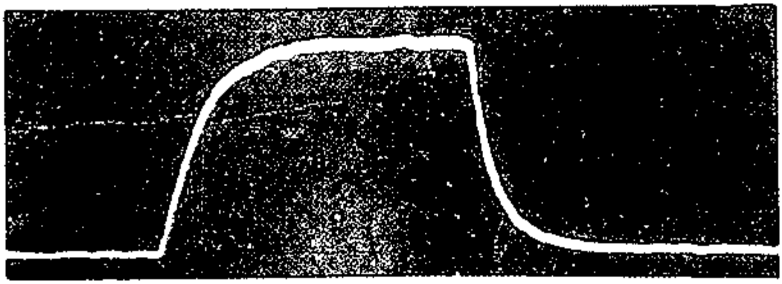

Fig.4. T=309K; U_{ef}=0.18V; ν=500Hz. Recorded at 1V/div. and 5ms/div. on the oscilograph.

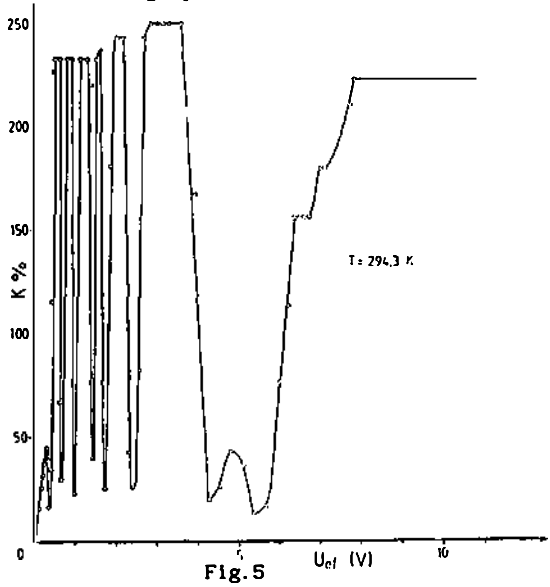

Fig.5

The curve contrast K%, versus applied voltage with frequency ν=500Hz at temperature T=295.8K obtained from (5) is given in Fig 5. The results for times τ_r and τ_f are shown in Table 1. From the contrast curve (Fig.5) is obtained the threshold voltage (U_{th}=0.35V)

Table 1

	295.8K		309.2K		316.7K
U_{ef}(V)	τ_f(s)	τ_r(s)	τ_f(s)	τ_r(s)	τ_f(s)
0.19	2.43	3.40	1.42	2.21	
0.32	3.20	1.30			
0.39	3.46		1.81	0.61	0.62
0.41	3.59				
0.49	4.18				
1.06	4.56				
1.42					0.68
7.09					0.71

The results for the elastic constant K_{11} for the molecules of the liquid crystal are shown in Table 2.

Table 2

U_{ef}(V)	295.8K τ_f(s)	295.8K K_{11}(10^{-12}N)	295.8K τ_r(s)	295.8K K_{11}(10^{-12}N)	309K τ_f(s)	309K K_{11}(10^{-12}N)	309K τ_r(s)	309K K_{11}(10^{-12}N)
0.19	2.43	1.35	3.40	0.93	1.42	2.31	2.21	1.45
0.32	3.20	1.03	1.30	2.39				

The electro-optical signal is not modulated when the applied alternative electric field with frequency over 500Hz is under the threshold voltage (Fig.4). Threshold voltage decreases with the increasing of the temperature of nematic liquid crystal. We get modulated electro-optical signal for alternative electric field with frequencies over 500Hz and applied voltages over treshold voltage (Fig.3). This shows that for applied over threshold voltages there are orientational effects in the nematic film that are combination of S-,B- and T-deformations/1,4,5/. In addition, this shows that it is possible to registrate phase difference of the transmitted eliptical polarized light as a result of the inverze flow in the nematic film. The obtained values for the constant K_{11} gradually decreases by increasing the applied effective voltage at given temperature. It is in agreement with the results of K_{11} for different types of nematic liquid crystal.

5. References

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