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The method of elasticity constants K_{22} and K_{33} determining for nematic-cholesteric mixtures of liquid crystals from the data of electrooptical measurements are described. The theoretical model and experimental results shows that it is necessary to take into consideration the influence of surface forces on threshold voltages of cholesteric-nematic transition.

Keywords: Nematic-cholesteric mixtures; elastic constants K_{22} and K_{33}

1. INTRODUCTION

The present work analysis the K_{22} and K_{33} elastic constants of liquid crystal nematic-cholesteric mixtures (NCM) based on electrooptical data from our studies. Based on theoretical model analyses and on experimental results, it is shown that in order to determine NCM elastic constants it is necessary to consider the influence of surface forces on threshold voltages of the cholesteric-nematic transition.

The operation of currently used liquid crystal displays is based mainly on the twist-effect or on supertwist birefringence effect. The working substance of these devices is nematic-cholesteric mixtures with low content of optically active additive (OAA). This NCM can be used also for construction of high-density information displays, based on cholesteric-nematic transition with an applied fields [1, 2, 3]. Investigation of NCM properties and of their parameter behavior will allow synthesizing of NCM with parameters

for practical devices. Frank elastic constants are the dominant parameters of NCM which determine electrooptical and temporal parameters of devices based on NCM. A simple method of determining of K_{22}, K_{33} elastic constants from electrooptical measurements using CNT, is discussed in this work. This discussion includes the results of an investigation of temperature dependence of these constants for different NCM.

2. THEORY

There are only a few methods for determining the elastic constants of nematic liquid crystal (LC) materials available today [4, 5] and methods of determining the nematic-cholesteric mixtures elastic constants are practically absent. Moreover, in some studies [6], it is shown that at low concentrations of OAA in nematic liquid crystal the K_{22} of NCM will be equal to K_{22} of nematic. Thus, subsequent investigations of CNT effect may shown that at low OAA amount in nematic matrix (up to 2 weigh.%) the elastic constant value varies and depends on OAA type [5, 8].

Determination of the NCM elastic constants is complicated by the absence of the general theoretical models of CNT process. The proposed models have their advantages and disadvantages and are acceptable in limited ranges.

The method of elastic constant K_{22}, K_{33} determination from expressions for threshold fields of nematic-cholesteric and inverse cholesteric-nematic transitions is proposed in [8]. It is shown in this work that the slope of $U_{cn}=f(d/P_0)$ is proportional to K_{22} elastic constant and the slope of $U_{nc}=f(d/P_0)$ is proportional to K_{22}/K_{33} ratio, where d-thickness of liquid crystal layer; P_0-free induced helix pitch; U_{nc}, U_{cn}-threshold voltages of cholesteric-nematic and inverse nematic-cholesteric transitions, correspondingly. The influence of surface on CNT threshold voltages is not considerated in this method. Therefore, this methods is acceptable only in cases when the thickness of liquid crystal is much greater than P_0 value, i.e. $d/P_0 \gg 1$.

Thus, while investigating LC materials with big helix pitch (tens of micrometers) it is hard to provide these conditions in the experiment and the use of this method leads to large errors.

In our present work we focus attention on one of the theoretical models of CNT process which completely and adequatly describes the experimental results and allows a more precisely determination of the NCM elastic constants for $d/P_0 > 1$.

This simple model was proposed in studies [9, 10] and developed in [11]. According to this approach the value of the critical electric fields of CNT

are determined as intersection points of curves of dependencies of free energy of correspondent states of director from electric field value [11]. Expressions for critical electric fields of texture ($E_{c,c}$) and phase (E_{cn}) of CNT and of inverse nematic-cholesteric transitions (E_{nc}) taking account of surface interaction are as follows:

$$E_{c,c} = 2\sqrt{2}\left[\frac{F_{sc} - F_{sc}}{d\varepsilon_0\Delta\varepsilon}\right]^{1/2} \tag{1}$$

$$E_{cn} = 2\sqrt{2}\left[\frac{\pi^2}{P_0^2}\left[\frac{K_{22}}{\varepsilon_0\Delta\varepsilon}\right] + \frac{F_{sn} - F_{sc}}{d\varepsilon_0\Delta\varepsilon}\right]^{1/2} \tag{2}$$

$$E_{nc} = \left[\frac{\pi}{P_0}\right]\left[\frac{4K_{22}^2 - [K_{33}(P_0/d)]^2}{\varepsilon_0\Delta\varepsilon K_{33}} + \frac{4F_{sn}}{d\varepsilon_0\Delta\varepsilon}\right]^{1/2} \tag{3}$$

where d – thickness of LC layer;
K_{22}, K_{33} – Frank elastic constants;
F_{se}, F_{sc}, F_{sn} – densities of surface free energy in planar confocal and nematic states correspondingly.

For planar anchoring conditions $F_{sc} = 0$; for homeotropic – $F_{sn} = 0$.

Based on this theoretical model, we developed the method of K_{22}, K_{33} NCM elastic constants determination from the electrooptical measurements of CNT parameters. We assumed that concentration dependencies of CNT threshold voltages are linear.

To simplify the calculations, expression (2) will be written as follows:

$$\frac{U_{cn}^2}{d} = \frac{(2\sqrt{2})^2\pi^2 K_{22}}{\varepsilon_0\Delta\varepsilon} * \frac{d}{P_0^2} + \frac{(2\sqrt{2})^2 F_{sn} - F_{sc}}{\varepsilon_0\Delta\varepsilon} \tag{4}$$

The expression (4) is a straight line with a slope which is depends on K_{22} and $\Delta\varepsilon$, a free term which allows to determine the $F_{sn} - F_{sc}$ value. Using expressions (1), and (3) and experimentally investigating CNT threshold voltages, induced helix pitch and dielectric parameters in a temperature range when the mesophase exists, the temperature dependencies of K_{22}, K_{33} NCM elastic constants can be determined. Using this method the influence of the surface on CNT electrooptical parameters can be estimated.

Additional points should be noted. Analysis of the theoretical models (expressions (3), (4) in cases when liquid crystal layer thickness d is less than induced helix free pitch value $P_0(d/P_0) < 1$), shows a dominant influence of surface conditions on CNT threshold field values. The dependence of CNT threshold voltage in $d/P_0 < 1$ range is determined by surface forces and uses of the experimental concentration dependence of the NCM elastic constants obtained in this case would be incorrect. Our subsequent experimental investigations proved these conclusions.

3. THE EXPERIMENT

Induced cholesteric mesophase with high pitch of helix structure and with $\Delta\varepsilon > 0$ were objects of our investigation. Mixtures of the strong polar cyanobiphenyl JKK-839 (8CB), which is characterized by a high value of dielectric anisotropy, and the weak polar azoxicompound JKK-440, which has wide temperature range of mesophase existence and low viscosity, as matrices for NCM. The terms of homologous series of cholesteryl esters of one-base carbon acids: propionate (X10), undecilate (X18), miristate (X15), palmitate (X2), were optically active additives.

The electrooptical investigations were carried out in sandwich cells with planar boundary conditions: the thickness of LC layer was 25 μm. The value of the induced helix pitch was determined by the Cano-Grandjan method and by the diffraction of a laser beam on "finger print" texture.

Concentration and temperature dependencies of $U_{c'c}$, U_{cn} and U_{nc}, the threshold voltages of texture, phase cholesteric and inverse nematic-cholesteric transitions, respectively were investigated through study of the electrooptical parameters.

The elastic constant K_{22} value can be obtained by experimentally determining $\Delta\varepsilon$ for a given material and constructing the concentration dependence of CNT threshold voltage in the form (Fig. 1),

$$\frac{U_{cn}^2}{d} = f\left[\frac{d}{P_0^2}\right] \tag{5}$$

Using expression (1) and the experimental value $U_{c'c}$ for a given material and considering that for planar threshold conditions $F_{sc'} = 0$ the value F_{sc} and F_{sn} (from equation (2)) can be determined. The influence of surface on threshold voltages of CNT is decreasing with an increase in d/P_0 ratio. As a

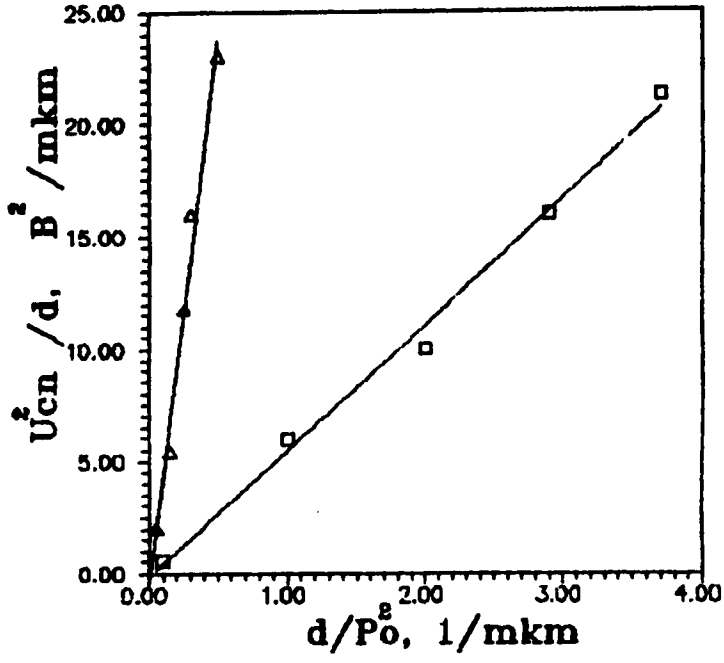

FIGURE 1 The dependence of $U_{cn}^2/d = f(d/P_0^2)$ for NCM JKK-440 (90.5 weigh.%) + JKK-839 (9.5 weigh.%) with cholesteryl esters: Δ–miristate: □–propionate.

result, segment $F_{sn} - F_{sc}$ which the experimental straight line intersects the ordinate is, decreasing and it's value is approaching zero.

The K_{33} elastic constant can be approximately determined using expression (3) and the experimental concentration dependencies of threshold voltages of inverse NCT. The main results of experimental investigations at $T = 298$ K are given in Table I.

TABLE I The elastic constants of synthesized mixtures

Nematic matrix	*OAA type*	$K_{22} \cdot 10^{-11}$, *N*	$K_{33} \cdot 10^{-11}$, *N*	$F_{sc} \cdot 10^{-5}$, *Joules*
JKK-440	X-10	1.6	5.0	0.13
(90.5 weigh.%)	X-18	1.8	6.2	0.12
JKK-839	X-15	2.2	7.1	0.11
(9.5 weigh.%)	X-2	1.9	9.3	0.11
JKK-440	X-10	0.8	2.1	0.26
(77.7 weigh.%)	X-18	2.8	7.6	0.25
JKK-839	X-15	5.3	14.2	0.24
(22.3 weigh.%)	X-2	2.9	12.3	0.24

4. CONCLUSIONS

The proposed methods allow to determine directly and simply the K_{22}, K_{33} elastic constants of nematic-cholesteric mixture from the electrooptical data. Moreover, the surface influence (F_{sn}, F_{sc}) on CNT threshold voltages can be estimated. The K_{22}, K_{33} elastic constants are independent of concentration and dependent on OAA type, at OAA concentration up to 2 weigh.%.

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