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Texture transformations and thermo-optical properties of nematic mesogen at *nematic–isotropic liquid* phase transition

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ABSTRACT

Study of the thermo-morfologic, thermotropic and thermo-optical properties of monomorphic nematic mesogen has been carried out. Temperature behavior of the mean the refractive index n, ordinary n_o and extraordinary n_e refractive indexes, and birefringence Δn have been investigated. The principal polarizabilities α_0 and α_e, effective geometry parameter α_{eg}, average polarizability α_{ave} and polarizability anisotropy $\Delta\alpha$ were estimated. Peculiarities of the biphasic regions of the direct *nematic mesophase–isotropic liquid* and inverse *isotropic liquid–nematic mesophase* have been investigated.

1. Introduction

Nematic liquid crystals (NLCs) are one of the main types of liquid crystalline materials. NLCs have the long-range orientational order but have not any translational and position order [1–5]. These liquid crystals are sufficiently sensitive to various external effects, e.g. thermic, electric and magnetic fields, deformations, flows. NLCs are optically single axis and optically positive mesogens. Therefore NLCs have great possibilities of application in techniques, technology and in addressing–reading systems, and at present use in different microelectronic and optoelectronic devices [6–11].

Because of rich thermo-optical, electro-optical and magneto-optical properties of NLCs, studies of their optical properties are important topics from both fundamental and application points of view. For various applications, nematic mesophases with different width of liquid crystalline thermal interval and with different phase transition temperatures are necessary. Therefore these materials have aroused interest in the past one–two decades [12–19].

In this work temperature behavior of the mean refractive index n and the refractive indexes of the ordinary n_0 and extraordinary n_e rays, and the birefringence Δn have been studied in monomorphic nematic liquid crystal with enantiotropic nematic mesophase. Studies have been carried out in large temperature interval and in the region of the *nematic mesophase–isotropic liquid* phase transition. Based on these dates, the principal polarizabilities α_0 and α_e, average polarizability α_{ave} and effective geometry parameter α_{eg} have been determined by using the isotropic internal field model (Vuks approach). Additionally, the thermo-morphologic properties and peculiarities of the direct *nematic mesophase–isotropic liquid* (N–I) and reverse isotropic liquid–nematic mesophase (I–N) phase transitions have been investigated.

2. Experimental

2.1. Materials

In this work, 4-(hexyloxy)phenyl 4′-butoxybenzoate (HPBB) liquid crystal has been investigated. This material is a thermotropic monomorphic nematogen. HPBB displays enantiotropic nematic mesophase in large temperature interval, exhibits the thermotropic phase transitions, and is thermal stable and stable to moisture.

The structural formula of this material is given in Fig. 1.

2.2. Methods

In this work, the thermo-morphologic properties have been studied. For these studies a polarizing optical microscopy technique (POM) has been used. As is well known, the POM is a sufficiently convenient and informative method for the investigation of mesomorphic and morphologic properties of liquid crystals and also for the identification of liquid crystalline mesophases [20–24]. Our setup consisted of a trinoculer polarizing microscope, microphotographic system, optical filters, and λ-plates from Olympic Optical Co. and also an original heater-thermostat, differential Cu–Co thermocouples, a multimeter, a power supply, and a digital temperature controller. The study of thermotropic peculiarities of the biphasic regions of the phase transitions have been carried out by using the CTW device. The CTW device was

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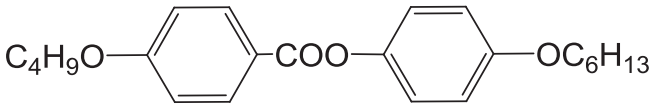

Fig. 1. The molecular structure of the nematic mesogen, examined in this study.

presented in [25–27] and provides the observations of all of the thermic states of liquid crystalline materials in the real scale of time and in a wide temperature range and also the calculation of the phase transition temperatures and the temperature widths of the biphasic regions with an accuracy not less than 10^{-3} K [26–28]. Temperature gradient along the long axes of the sandwich-cell was kept as 2.43 K·mm^{-1}.

The refractive indexes n, n_e and n_o of HPBB were measured by using the polithermic refractometry setup (PR). The PR setup consisted of an Abbe's Precision Refractometer with Digital Thermometer from Atago Co. Ltd (model 2T, cat. no. 1220) and recirculation immersion thermostat Ultraterm 200. An accuracy for the refractive indexes measurements was as 0.1%. Temperature of liquid crystal under investigation was controlled by Cu–Co thermocouple, placing in close vicinity of the samples with an accuracy of ± 0.1 K.

For determination of the refractive indexes n_e and n_o, peculiarities of polarizers, and homeotropic and planar orientation of liquid crystalline materials have been used. To obtain the orientation in liquid crystalline state, the prisms of refractometer were treated. The deposition on the prisms the mixture of 1% lecithin in ethyl alcohol provided the homeotropic orientation (yielding n_e) of HPBB. The deposition on the prisms a film of polyvinylalcohol, that was subsequently rubbed with velvet tissue, induced the planar orientation (yielding n_o) of liquid crystals under investigations. Degree of the homeotropic orientation was checked on control samples by POM and estimations of the conoscopic pictures. Homogeneity of the planar orientation has been examined by the POM and estimated by the optical polarization (OP) degree. The value of the OP degree has been determined as

$$P = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \quad (1)$$

Here I_{min} is the intensity of light, transmitted from sample, placed parallel to the polarizer (or analyzer); I_{max} is the intensity of light, transmitted from the sandwich-cell, placed under 45° to the polarizer (or analyzer). The degree of the planar orientation for HPBB was determined as $P \approx 0.91$.

3. Results and discussions

Investigations of the thermo-morphologic properties of HPBB showed that this liquid crystal exhibits the marble-like texture (Fig. 2). As is seen in Fig. 2, the marble-like texture of HPBB consists of separate regions. These regions are divided one from the other by definite boundaries and have different colors. The boundaries are the places of texture where the break of optical continuity of nematic mesophase takes place. The optical and morphologic investigations showed that some of these walls were placed perpendicular to the reference surfaces of the sandwich-cell, but others were placed tilted to these surfaces. Besides, the optical investigations showed also that separate regions of the marble-like texture are characterized by definite orientation. But the orientation character of each region is different from the orientation character of neighboring regions. By analysis of the structural, morphologic and optical properties of the marble-like formations and by comparison of orientational peculiarities of the marble-like formations, the sketch of texture under investigation was constructed (Fig. 3). The heavy lines in Fig. 3 denote the boundaries between separate formations. These boundaries are the inversion walls. The arrows into marble formations represent an alignment of the director in these formations. The marble-like textures are typical for nematic mesophase and were observed for various nematic liquid crystals [1,29,30].

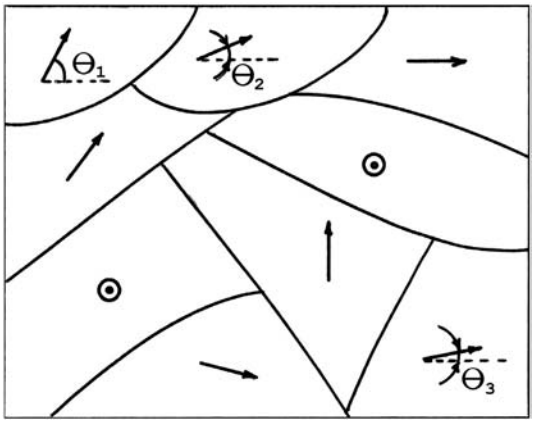

Fig. 3. Sketch of the marble-like texture. ⊙ represents the homeotropic alignment of the director in corresponding mosaics.

In this work the thermo-optical properties of HPBB have been investigated. In Fig. 4 temperature dependences of the refractive indexes n, n_e and n_o for HPBB are presented. As is seen in these figures, temperature dependences of the n for liquid crystals under investigation exhibit practically linear behavior with slight fluctuations in the region of the N–I phase transition. n_e and n_o show linear behavior in 343.0–349.0 K temperature interval. Then n_e decreases with an increase in temperature, while n_o shows some increase near the clearing temperature. In the N–I phase transition region, a disappearance of the refractive indexes n_e and n_o takes place (Fig. 4). Such behavior of n_e and n_o is connected with disappearance of the optical anisotropic properties and appearance of the optical isotropic properties of liquid crystalline materials at

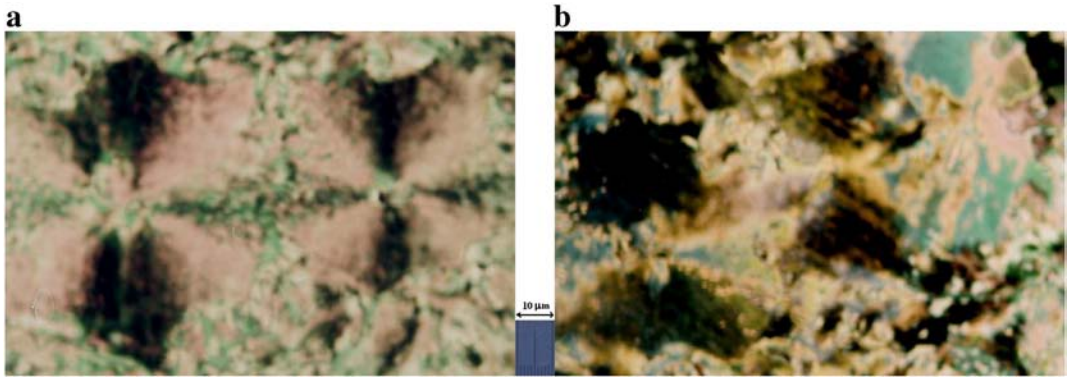

Fig. 2. Typical textures of HPBB. Crossed polarizers; Magnification ×100; a) Texture at 345.0 K; b) Texture at 357.7 K.