Ternary liquid crystal combination having complicated E7/6CB/6BA electro-optical, thermal, and dielectric characteristics

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Abstract:

In this work, a new liquid crystal mixture complex was devised and synthesised using the nematic liquid crystal mixture E7, hexylcyanobiphenyl (6CB) and hexylbenzoic acid (6BA) (6BA). The thermal and morphological characteristics were studied by differential scanning calorimetry (DSC) and polarised optical microscopy (POM) (POM). The DSC and POM data demonstrate that the liquid crystal complexes display liquid crystalline qualities with smectic and nematic phase. While the E7 ratio is 80 percent , the mixed complex has the broadest nematic range and shows E7 features. When the E7 weight ratio is less than 80 percent , with the creation of hydrogen bonds the number of mesogenic phases rises and the nematic range declines. The electrical characteristics of acquired samples were examined using impedance spectroscopy method. The birefringence and contrast ratio of samples also studied with the assistance of light transmittance experiment.

Keywords: Electro-optical characteristics, birefringence, contrast ratio, DSC, and POM are all terms related to liquid crystal mixes.

1. Introduction:

Functional soft materials between liquids and crystals, liquid crystals (LC) have lengthy orientation orders [1–2]. Researchers are interested in LCs despite the fact that they were developed by Friedrich Reinitzer in 1888. LC screens, cellphones PCs tablet, optical and biological sensors, [3-8] are some of the most common uses. There are primarily two methods for fine-tuning the thermal and electro-optical characteristics of LCs materials. There are two primary approaches to creating novel materials with improved properties: synthesis of new LC materials or obtaining LC mixes, and dispersion (grafting or doping) of nanostructures and/or polymers and/or dyes into LCs. Some binary and ternary LC mixtures' physical, thermal, and textural features have been examined by our team of scientists [16-19]. Sundaram et al [20] provided a simple and inexpensive method for producing mesogenic 7OBA and nonmesogenic citric acid LC complexes. In addition, researchers are interested in hydrogen bonded liquid crystals complexes because new materials may be created through intermolecular hydrogen bonding [21]. Researchers have looked at binary complexes of 4-methoxycinnamic acid (4MCA) and p-n-alkloxy benzoic acid (nOBA) [22]. Ferroelectric liquid crystals between dextrolevotartaric acid and nBAO, n=7 to 12, have been studied by Mahalingam and co-workers [23]. Although TiO2 nanoparticles and fluorescent dye dispersion were reported in literature to increase nematic LCs' birefringence [24, 25], this was not the only method. Furthermore, it was discovered that adding TiO2 nanoparticles to nematic LCs reduced dielectric anisotropy [26]. Manohar et al [27] have showed that lnP/ZnS core/shell quantum dots (QDs) nanoparticles also boosted the birefringence value. The 0.25 wt % concentration of Cd1-xZnxS/ZnS core/shell QDs greatly boosted the ACCEPTED MANUSCRIPT memory parameter [28]. [20, 21]. The phase transition of an E7 LC mixture containing carbon nanotubes has been found to be somewhat altered [29]. Gold nanoparticle doping in polymer dispersion LCs improved dielectric anisotropy [30]. Thersold voltage of nematic LCs may be considerably reduced by Fe magnetic nanoparticles [31] as well. Thermal, dielectric, and birefringence characteristics of the novel LC mixture created by utilising E7 nematic E7 and 6CB and 6BA mixtures were studied in this work.

2. Experimental:

Materials:

Faculty of Advanced Technologies and Chemistry, Military University of Technology Poland, acquired E7 liquid crystal combination. Hexylcyanobiphenyl and 4-hexobenzoic acid liquid crystals were purchased from Sigma Aldrich, respectively. Figure 1 depicts the molecular structures of the liquid crystals that were employed in this study. Instec supplied the planer alignment LC cells with cell gaps of 8 nm.

Preparation of E7/6BA/6CB ternary mixture:

This can be seen in Table 1 where the four ternary combinations were formed by weighing at 80/15/6CB/5BA, 60/30/6CB/10BA, 40/45/15/6Ba and 20/60/6CB/20%/6Aa ratios. These are known as M1, M2, M3 and M4.. and are represented by the letters E7, 15/6CB, and 20/6BA, respectively. The LCs were heated on a heating table after being weighed. Mechanical stirring was used to mix the heated sample for 15 minutes during the phase transition time. Our prior studies [12–15] go into great depth regarding the mixing procedure.

Instruments and characterization:

Using a Nikon (Tokyo, Japan) Polarized Optical Microscope (POM) coupled with a digital camera, the morphological texture of produced samples was examined. It was decided to employ a heating stage with a temperature precision of 0.1 0C (LTS120 with PE95 LinkPad, Linkam Scientific Instruments, Ltd., England). The texture and phase transition of the created liquid crystal mixtures were studied using Nikon Imaging Software Nis-Elements. It was discovered in our prior studies [32-34] on the manufacturing of liquid crystal cells that we employed for the POM study. The thermal characteristics of the produced combinations were examined using DSC (Perkin-Elmer DSC-8000). An aluminium pan was used to encapsulate a 2 mg sample that had been weighed using a balance. At a rate of 120C/min, the sample was chilled to -75 °C and subsequently heated to 75°C under nitrogen environment. To determine the electrical characteristics of the mixes, impedance tests were carried out. With planer alignment (Instec Inc.), the prepared solutions were capillary loaded into ITO cells. At room temperature, dielectric measurements were made using an HP4194A impedance analyzer in the 100 Hz-10 MHz frequency band.

3. Results and Discussions:

DSC Research Thermal parametric data such as phase transition temperature and enthalpy may be obtained using differential scanning calorimetry (DSC), a technique for determining the phase transition parameters of liquid crystal materials. Polarizing optical microscopy (POM) may be used in conjunction with DSC measurements to determine the phase transition that followed DSC peaks. Phase transition temperatures and enthalpy change measurements may be used in DSC to derive critical factors such as phase order, phase transition activation energy, and phase stability. Only the temperatures and enthalpies of phase transitions were measured in this investigation. Results from DSC were shown in Table 2. E7/6CB/6BA combination complex DSC data are shown in Figure 2 after continuous heating. The 6CB/6BA combination generated at a 3:1 ratio has the greatest nematic range among the 6CB, 6BA, and their mixes. That's why a novel sort of liquid crystal complexes were formed when the 6CB/6BA ratio was held constant and subsequently combined with E7 at varying speeds. While the E7:E7 ratio in the combination was 80%, the sample displayed two phase transition peaks as shown in Figure 2 and Table 2. An E7 combination with this rate of heating will be quite near to the pure range of the E7 nematic range (124.19°C). One nematic-to-isotropic transition is reported to occur at 59-61oC and no additional phase changes between 61 and -62oC are reported [31,32], while only a glass transition is reported to occur at almost -62oC. M1, a liquid crystal mixture complex produced at this pace, has the potential to outperform E7 in technological applications. The frequency of phase transition peaks rises when the E7 ratio lowers to 60-20 percent, as seen in Figure 2b,c,d, resulting in a decrease in nematic range. This has a negative effect on the compounds' liquid crystal characteristics. Figure 2b,c,d shows an exothermic peak between -30°C and -20°C, indicating the formation of hydrogen bonds between the liquid crystal molecules in the mixture. The smectic phase has been generated as a result of hydrogen bonding, obscuring the individual components. For example, following the exothermic peak, there are a series of endothermic peaks that signify phase change, or in other words, the conversion of the Smectic phase to Nematic and then Nematic to Isotropic phases. As a result, the phase sequence seen during heating is Crystal (Cr)-Smectic A (SmA)-Nematic (Ne) (N). POM investigations have also validated the phase change designations.

POM Studies:

Liquid crystal cells with two glass coverslips were utilised to examine the produced compounds' morphological features. It was a capillary force that filled the liquid crystal cell with the synthetic complexes. Continuous heating and cooling with POM was applied to these LC cells, which were then cooled and imaged at various temperatures. At various temperatures, 80 percent E7 + 15% 6CB + 5% 6BA, known as M1, has a distinct morphological texture. Observations at 40 degrees Celsius are shown in Figure 3a. At temperatures ranging from ambient to 58°C, this phase was seen. At 57-60 °C, the nematic isotropic transition occurred. It is also shown in Figure 3b that nematic isotropic transition occurs at 58°C for a continuous heating. This so-called M4 complex's morphological textures at various temperatures are seen in Figure 4. Figure 4a shows that 6BA molecules in E7 are uniformly dispersed in a tiny spherical shape when seen at ambient temperature. Smectic A refers to the layered molecular distribution that characterises this phase. Nematic phase is shown in Figure 4b, which was detected at 45°C. As a result, the alterations detected in DSC tests at temperatures below room ACCEPTED MANUSCRIPT temperature couldn't be noticed in POM studies. When compared to previously published findings, the POM results were in line with those of the conventional literature [33, 34, 35].

Dielectric Studies:

Dielectric spectroscopy was used to examine the electrical characteristics of the liquid crystalline mixes that were formed. Detailed information on the structure and mechanism of liquid crystal molecules may be gleaned through dielectric research. Cole-Cole Eq [37] was used to evaluate the observed dielectric relaxation data. In other words, if jw = ′ () + ′ 1+(jw)1 (1) w and are the relaxation time, angular frequency, and dielectric strength, respectively. This is called the dielectric strength, and it is equal to the ratio of the low frequency dielectric constant to the high frequency dielectric constant. For pure E7, M1, and M2, the real and imaginary parts of the dielectric constant are shown in Figure 5 as a function of frequency. With a drop in the E7 nematic mixture ratio, the dielectric strength values fall. Table 3 shows the low- and high-frequency dielectric constants, as well as the predicted dielectric strengths for each sample. When doing a dielectric investigation, the kind and concentration of nematic molecules is critical. No other kind of molecule interacts with LC molecules, although the concentrations of LC molecules altered for every combo. Increasing the proportion of low dielectric strength materials leads in a drop in the dielectric strength of the resultant mixture, which we can deduce from the decrease in dielectric strength of pure E7 LC. Furthermore, the introduction of LC complexes results in a rise in critical frequencies, which means that energy loss shifts to higher frequencies [15, 41].

Optical Transmission Studies:

Experiments were carried out on optical transmission with the use of various optical tools including a laser and an optical analyzer and photo detector (Figure 6). The 650 nm laser light's intensity would be 0 if there was no liquid crystal cell between the crossing polarizer and analyzer in the experiment setup. An angle of 45° was found to be the optimal angle for placing the planer-aligned, LC-cell-based nematic director between the analyzer and the polarizer in order to produce both ordinary and extraordinary rays [27, 42, 43]. When it comes to liquid crystals, optical birefringence [44] is one of the most essential features. Formulas for calculating the birefringence n of liquid crystal mixes are as follows: It is equal to the sum of the squares of the sines of the numbers m, 2, 4, etc., multiplied by 2sin 1 (2a) = (m + 1) 2sin1 II min I _max I min for m=1, 3, 5...... (2b) There are three variables in this manuscript: the number of maximum peaks observed in an optical transmittance experiment, the maximum and minimum light intensities measured during the experiment, and a total phase retardation related to birefringence, which is given by the equation = (2) n d (3). The thickness of the LC cells and the laser wavelength are used to calculate the relationship between m and n d(3). Table 4 lists the LC cell thicknesses, phase retardations, and birefringence values employed in the experiment. Pure E7 nematic liquid crystal combination has a birefringence value of 0.2121, which is quite similar to the literature value [45]. This might be a result of the laser light's different wavelengths and the temperature of the environment. In both our experiment and the literature, we used laser light with a wavelength of 650 nm and 630 nm, respectively. As the laser light's wavelength rises, it is evident that the birefringence value drops [46-48]. The birefringence values of M1 and M2 samples were improved compared to pure E7, which is crucial for developing electro-optical applications. [49]. Contrast ratio is another key LCs display characteristic (CR). High CR is a critical component of LC-based electro-optical systems, and should not be overlooked. In this case, the comparison of new LC mixed complexes to virgin LCs is definitely interesting. The following equation [50] was used to compute the CR of LC samples: Transmax/Transmin = ACCEPTED MANUSCRIPT Contrast Ratio Transmin and Transmax are the transmittances at the smallest and highest transmittances during the orderly switching of nematic LC molecules, respectively, in this case (Transmax = 4). Table 5 displays the obtained Transmax, Transmin, and CR values. The CR experiments reveal that the new LC complexes developed are extremely similar to the pure E7 nematic LC mixture in terms of CR.

4. Conclusion:

The generated liquid crystal mixes' thermal, morphological, dielectric, and electro-optical characteristics were all examined in this work. Smectic and nematic phases were seen in the liquid crystal complex E7/6CB/6BA in the POM and DSC experiments, and the nematic range of the combination decreased with decreasing E7 weight ratio. Between liquid crystal molecules, hydrogen connections were also formed. The M1 combination, which has a broad nematic range, has better qualities than the E7 liquid crystal in this experiment. The POM experiment was used to confirm the phase transition temperatures. LC mixed complexes have more dielectric anisotropy than pure E7, according to a dielectric analysis, which also revealed that the critical frequencies had migrated upward. The birefringence and contrast ratio were calculated using optical transmittance measurements. The LC complexes have been shown to have no deleterious effect on these important parameters.

Nothing to worry about as far as possible

References:

[1] H.K. Bisoyi, S. Kumar, Liquid-crystal nanoscience: an emerging avenue of soft selfassembly, Chemical Society Reviews, 40 (2011) 306-319.

[2] A.A. Zaki, H. Ahmed, M. Hagar, Impact of fluorine orientation on the optical properties of difluorophenylazophenyl benzoates liquid crystal, Materials Chemistry and Physics, 216 (2018) 316-324.

[3] J.C. Jones, The fiftieth anniversary of the liquid crystal display, Liquid Crystals Today, 27 (2018) 44-70.

[4] F. Reinitzer, Beiträgezurkenntniss des cholesterins, MonatsheftefürChemie und verwandteTeileandererWissenschaften, 9 (1888) 421-441.

[5] S. Lalik, A. Deptuch, P. Fryń, T. Jaworska–Gołąb, D. Węgłowska, M. Marzec, Physical properties of new binary ferroelectric mixture, Journal of Molecular Liquids, 274 (2019) 540- 549.

[6] R. Basu, A. Garvey, D. Kinnamon, Effects of graphene on electro-optic response and iontransport in a nematic liquid crystal, Journal of Applied Physics, 117 (2015) 074301.

[7] K. Praseetha, M. Divyasree, K. Chandrasekharan, S. Varghese, Enhanced optical nonlinearity in nematic liquid crystal on doping with CdSe quantum dot, Journal of Molecular Liquids, 273 (2019) 497-503.

[8] G. Pathak, A. Rastogi, B.P. Singh, A. Srivastava, O. Strzezysz, R. Manohar, Investigation of several essential display features for the low birefringent nematic liquid crystal dispersed with polymer, Applied Physics A, 124 (2018) 732.

[9] R. Mishra, J. Hazarika, A. Hazarika, B. Gogoi, R. Dubey, D. Bhattacharjee, K.N. Singh, P.R. Alapati, Dielectric properties of a strongly polar nematic liquid crystal compound doped with gold nanoparticles, LiqCryst, (2018) 1-11.

[10] J. Kumar, V. Prasad, M. Manjunath, Quantum dots dispersed hockey stick nematic liquid crystal: Studies on dielectric permittivity, elastic constants and electrical conductivity, Journal of Molecular Liquids, (2018).

[11] P.K. Tripathi, A. Kumar, K.K. Pandey, Dielectric Study of Multiwall Carbon Nanotube Dispersed Nematic Liquid Crystal Mixture, Materials Today: Proceedings, 5 (2018) 9182- 9186.

[12] G. Kocakülah, G. Önsal, O. Köysal, Electro-optical and dielectric performance analysis: the influence of azo dye on polymer/LC composite structures, Applied Physics A, 125 (2019) 30.

[13] K. Sandhya, N. Pushpavathi, S.K. Prasad, D.S. Rao, Influence of ZnO nanoparticles on the polarization, dielectric and electro-optic behaviour in the smectic C* and hexatic I* phases, Journal of Molecular Liquids, 275 (2019) 421-430.

[14] D. Jayoti, P. Malik, S.K. Prasad, Effect of ZnO nanoparticles on the morphology, dielectric, electro-optic and photo luminescence properties of a confined ferroelectric liquid crystal material, Journal of Molecular Liquids, 250 (2018) 381-387.

[15] H. Eskalen, Ş. Özgan, M. Okumuş, S. Kerl, Thermal and Electro-optical Properties of Graphene Oxide/Dye-Doped Nematic Liquid Crystal, Braz J Phys, (2019) 1-7.

[16] Ş. Özgan, M. Okumuş, Thermal and spectrophotometric analysis of liquid crystal 8CB/8OCB mixtures, Braz J Phys, 41 (2011) 118. ACCEPTED MANUSCRIPT

[17] M. Okumuş, Ş. Özgan, S. Yılmaz, Thermal and optical properties of some hydrogenbonded liquid crystal mixtures, Braz J Phys, 44 (2014) 326-333.

[18] M. Okumuş, H. Eskalen, M. Sünkür, Ş. Özgan, Mesogenic properties of PAA/6BA binary liquid crystal complexes, Journal of Molecular Structure, 1178 (2019) 428-435.

[19] M. Okumuş, Synthesis and characterization of hydrogen bonded liquid crystal complexes by 4-octyloxy benzoic acid and some dicarboxylic acids, Journal of Molecular Liquids, 266 (2018) 529-534.

[20] S. Sundaram, R. Jayaprakasam, R. Praveena, T. Rajasekaran, T. Senthil, V. Vijayakumar, Study of variation in thermal width of nematic and induced smectic ordering phase of citric acid (CA) and 4-heptyloxybenzoic acid (7OBA) hydrogen bonded liquid crystal complexes, International Journal of Modern Physics B, 32 (2018) 1850013ED