Non–Metallic Material Science

https://ojs.bilpublishing.com/index.php/nmms

ARTICLE

Thermo-Chromic Response of Polymer Stabilized Cholesteric Liquid Crystal for Thermal Imaging

Rishi Kumar[1,2*] **KK Raina**[2]

1. Department of Physics,Guru Nanak College, Budhlada, 151502, India
2. School of Physics and Materials Science, Thapar University, Patiala, 147004, India

ARTICLE INFO

Article history
Received: 26 March 2019
Accepted: 12 August 2019
Published Online: 30 October 2019

Keywords:
Polymer stabilized cholesteric texture (PSCT)
Cholesteric liquid crystal (CLC)
Morphological study
Thermo-chromic Responses

ABSTRACT

Cholesteric liquid crystal (Ch-LC) exhibits many remarkable optical properties due to formation of a macroscopic helical structure. A low amount of monomer (5wt.%) is dispersed into cholesteric liquid crystal and get polymerized under UV radiations to form polymer stabilized cholesteric texture (PSCT). The thermo-chromic response made this device suitable for the developing applications in thermal imaging. Temperature based measurements of PSCT exploits the key property of some polymer stabilized cholesteric liquid crystals (PSCLC) to reflect definite colors at specific temperatures. The selective color of PSCT texture shifts with raise in temperature from 30°C to 85°C, which can be utilized in thermal imaging applications.

1. Introduction

Chirality is the necessary parameter to be thought of in polymer stabilised cholesteric liquid crystals for the display applications in technology like privacy windows, electrically controlled shutter, bistable reflective displays, color filters, Fresnel lens and thermally activated color imaging sensors [1-8]. Normally thermotropic liquid crystals consist of rod-like molecules show one or several additional mesophases in the temperature range between the crystalline, and the isotropic liquid state which is used for the development of liquid crystal based devices [9-12]. These mesophases are mostly category of fluids and their physical properties depend on the orientations of the molecules with characteristic phase. The smectic phases itself thought of as chiral phases. However chirality in nematic phases is evoked by acceptable dispersions of chiral molecules in nematic liquid crystals [13-19], that forms layer structures. The French physicist, G. Friedel [8], delineated the cholesteric phase by introducing small amount of chiral non-ceramic compound into nematic phase. The key property for the configuration assignment of chiral molecules is that the induction of oppositely-handed cholesteric by enantiomers. Thermochromic liquid crystal devices exploit in show technologies on the idea of optical property of these chiral nematic phase. For the electro-optic application of liquid crystals in displays, Researchers [20-25] focused on the development of larger numbers of light modulated devices by doping of chiral molecules in polymer liquid crystal dispersions to

**Corresponding Author:*
Rishi Kumar,
Department of Physics,Guru Nanak College, Budhlada, 151502, India; School of Physics and Materials Science, Thapar University, Patiala, 147004, India;
Email: rishikumar.phd@gmail.com

  DOI: https://doi.org/10.30564/omms.v1i2.849

form complex and stable polymer stabilized cholesteric textures (PSCT).

Polymer stabilized cholesteric liquid crystals (PSLCs) can be created by dispersion of a small amount of photo-reactive monomers into a liquid crystal (LC) with low molar mass. Anisotropic polymer network is formed after ultraviolet (UV) light exposure. In most cases, the polymer network keeps the order of the LC environment from which it was formed originally and thence contributes to the electro-optic characteristics by providing alignment to the liquid crystal molecules. The various parameters like nature of liquid crystal and polymer, refractive index, liquid crystal anisotropy, curing temperature and intensity affects the electro optic performance of shutter devices. Most of the analysis work is currently dominant for controlling the color contrast and switching responses of these shutters which are formed by using acrylate polymers [26-30].

In this paper, we have made an attempt to construct temperature sensing device by inducing chirality in polymer stabilized liquid crystal composite films. We investigated here thermo-chromic responses and characteristic states of PSCT textures with the assistance of optical microscopy, which can be helpful for the development of PSCLC composite film in thermal imaging.

2. Experiment

In this investigation, an active chiral dopant CB15 (M/S E. Merck Dramstdt, Germany) was doped (5 wt. %) into room temperature nematic liquid crystal BL036 (purchased from E. Merck, UK) for inducing chirality in the sample. Nematic LC (BL036) exhibits nematic-isotropic transition (T_{NI}) at 95^{o}C and show their characteristic optical properties such as birefringence (Δn) 0.267 and extra ordinary refractive index (n_e) 1.527. An optical adhesive NOA65 [22] was mixed in very small amount (5 wt. %) for controlling the anisotropic network morphology in polymer stabilized cholesteric texture (PSCT). Refractive index of the dispersed NOA65 optical adhesive (n_p) was 1.52. Now the composite mixture was sandwiched into two antiparllel planer aligned polyamide coated ITO glass substrate via capillary action on hot stage to form homogeneous composite film. Rubbing of polyamide film by nylon cloth encouraged the homogenous aligned liquid crystal molecules in antiparllel direction. Film thickness was controlled 5μm by using glass bead spacers. Then cell was sealed with optical adhesive epoxy glue. After that phase separation is achieved by curing the cell into UV radiations (I~2mW/cm^2) for an hour by polymerization induced phase separation (PIPS) technique [28-30]. Then sample cell was allowed to cool down at room temperature. Electrical contact with conducing ITO substrate was created by using indium solder.

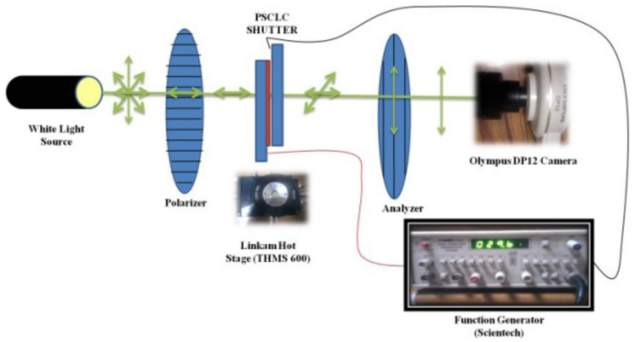

Figure 1. Experimental Setup for thermal analysis connected with optical microscope

Temperature dependence study of the sample cell was carried by heating the sample from room temperature @ 0.1^{o}C/min with the help of Linkam controlled hot stage (Model TP94 and THMS600). Film morphology of PSCLC sample cell was studied under cross polarizer at 100X magnification through Olympus polarizing microscope (Model BX-51P) fitted with charge coupled device (CCD) camera interfaced with computer. Photomultiplier tube (Model RCA931-A) was used for measuring thermo-optic response of PSCLC sample under application of electric field by using function generator (Model Scientech-4060). The data was acquired with computer interfaced digital storage oscilloscope (Model Tektronix TDS2024). For Thermo-chromic analysis, each recorded texture was analyzed by using OLYSIA BIOREPORT software to determine red (R), green (G), blue (B) pixel value of an optical texture.

3. Results and Discussion

3.1 Thermally Switching

Temperature dependent morphology of PSCLC film was investigated through transmission mode based optical polarizing microscope, (setup shown in figure 1).

The oily streaks texture was observed in sample under crossed polarizer's when the liquid crystalline helix was confined with planer anchoring. In planer aligned cell with layers parallel to the conducting substrates, oily streaks appear as long bands that divide the ideal domains of liquid crystal molecules to form Grandjean polygenic texture as shown in Figure2(a-c).

DOI: https://doi.org/10.30564/omms.v1i2.849

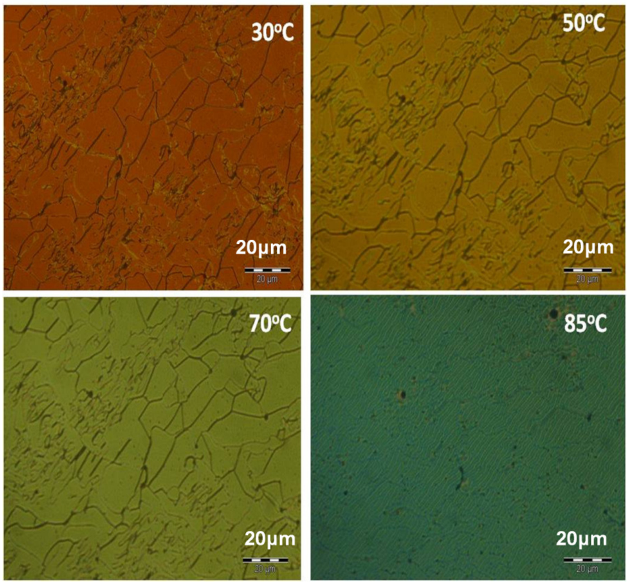

Figure 2. Morphology analysis through optical microscope under crossed polarizers at corresponding temperature (a). 30°C (b). 50°C (c). 70°C (d). 85°C respectively

As we raise the temperature from 30°C, selective reflections phenomenon occurs due to which change in color observed, which can be utilized for expanding thermo-chromism applications. This color change is due to the angular oscillations of liquid crystalline helix by providing thermal energy to LC molecules with raise in temperature. This phenomenon can be explained on the basis of theory of thermal expansion of liquid crystal, The Angular oscillations <θ> of liquid crystal can be defined mathematically [15] as

$$< \theta >= \frac{AK_B T}{2I\omega^4} \quad (1)$$

Where K_B =Boltzmann constant, A= Anharmonicity coefficient, ω = Angular frequency, I= Moment of inertia of molecules.

From equation 1, with raise in temperature, more is the angular oscillations and during the rotation of liquid crystalline molecules in the helix under the restriction of polymer network, selective color corresponds to characteristic wavelength is produced in Grandjean oily streak texture at a certain orientation. By attaining sufficient amount of thermal energy, these polygenic boundaries become unstable and start breaking with characteristic change in color of texture [Figure 2(c)]. The boundaries of these domains start disappear and start merging into each other's. While attaining the temperature 85°C, the transition of texture from oily streak Grandjean (polygenic) texture to under lying helix (ULH) texture was observed [Figure 2(d)] under crossed polarizer's. This ULH texture shows high thermal energy as compare to Grandjean texture (oily streak defects) as it appears at higher temperature. The fingerprint appears in ULH texture shows pitch of 0.8μm.

3.2 Thermo-chromic Responses

Figure 3 predicts the thermo-chromic response for the polymer stabilized liquid crystal textures at different temperature range.

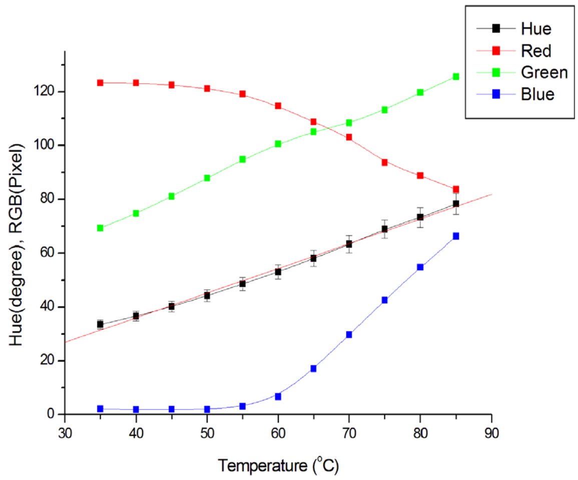

Figure 3. Temperature dependence of Hue and RGB variation for true color response.

We report here RGB pixel value and hue responses as a function of temperature for polymer stabilized textures for the purity of color, which is the combination of those characteristics of light that produce sensation of hue, saturation and intensity in normal human observer. Hue (H) gives the direct measure of color at which light emission from heat transfer surface occurs. With the help of OLYSIA BIOREPORT software, we have determined the value of RGB pixels and Hue response for different PSCLC textures taken from 35°C to 90°C temperature. After recording the Hue (H) values, it was fitted by equation [31]

$$H = \cos^{-1}\left|\frac{0.5\times(R-G)+(R-B)}{(R-G)^2+(R-B)(G-B)^{0.5}}\right| \quad (2)$$

Here R, G, B is value of red, green, blue respectively, which is getting record from OLYSIA software. Figure 3 represent the linear behavior of hue versus temperature in the range 35°C to 85°C, which is useful scale for the application of PSCLC sample as thermal imaging sensor.

4. Conclusion

In summary, we conclude that the morphology of PSCT textures show temperature dependence and gives appear-

DOI: https://doi.org/10.30564/omms.v1i2.849

ance of characteristic color as temperature is raised from 30°C. Therefore it can be used in thermal imaging. Also their responses can be engineered to accurate temperatures, but their color range is limited by their principle of operation and followed by linear behavior of hue in the specific range of temperature. Hence this PSCLC film can also worked as temperature indicators that modify the incident white light and display color whose wavelength is proportional to temperature.

References

[1] Hongwen Ren and Shin-Tson We, "Reflective reversed mode polymer stablized cholestric texture light switches", J.Appl.Phys. 2002, 92: 797.

[2] J.W. Doane, N.A. Voz, B.-G. Wu, and S. Zumer, "Field controlled scattering from nematic microdroplets " Appl. Phys. Lett. 1986, 48: 269.

[3] Ji Ma, Lei Shi and Deng ka Yang, "Bistable polymer stabilized cholesteric texture light shutter" Appl. Phys. Express, 2010, 3: 021702.

[4] R. Bao, C.-M. Liu, and D.-K. Yang, "Smart bistable polymer stablised cholestric texture light shutter"Appl. Phys. Express, 2009, 2: 112401.

[5] P.P. Crooker and D.K. Yang, "Polymer dispersed chiral liquid crystal color display" Appl. Phys. Lett. 1990, 57: 2529.

[6] K. Kato, K. Tananka, S. Tsuru and S. Sakai, "Reflective color display using polymer dispersed cholestric liquid cryst.", Jpn. J. Appl. Phys. 1994, 33: 2635-2640.

[7] H.–H. Liang, C.-C. Wu, P.-H. Wang, J.-Y. Lee, "Electro-thermal switchable bistable reverse mode polymer stabilized cholesteric texture light shutter", Opt . Mater. 2011, 33: 1195-1202.

[8] Friedel, G., Les états mésomorphes de la matière, "Annl. Phys. 1922, 18: 273.

[9] C.-Y. Huang, S. -Weike, Y.-S. Chih, "Electro-optical performance of Polymer Stabilized Cholesteric texture cell: the influence of chiral dopent and monomer concentration", Optics Communications, 2006, 266: 198-202.

[10] J.B. Guo, H. Yang, R. Li, N. Ji, X. Dong, H. Wu, J. Wei," Effect of network conc. On the performance of Polymer stabilized cholesteric liquid crystal with double handed circularly polarized light reflection band", J. Phys. Chem.C, 2009, 113: 16538-16543.

[11] S.W. Kang, S. Sprunt and L.C. Chien, "Structure and morphology of polymer stabilized cholesteric diffraction gratings"Appl. Phys. Lett. 2000, 76: 3516.

[12] S.H. Kim, L.-C. Chien and L. Komitov, "Short pitch cholestric electro-optical device stabilized by non uniform polymer network", Appl. Phys. Lett. 2005, 86: 161118.

[13] I. Dierking,"Recent development in polymer stabilized liquid crystal", Polym. Chem. 2010, 1: 1153-59.

[14] J. Guo, H. Wu, F. Chen, L. Zhang, W. He, H. Yang and J. Wei," Fabrication of multi-pitched photonic structure in cholesteric liquid crystal based on polymer template with helical structure", J. Mater. Chem. 2010, 20: 4094-4102.

[15] P.S. Drazic, "Liquid Crystal Dispersion" World Scientific Singapore, 1995.

[16] R. Kumar; K.K. Raina; "Electrically modulated fluorescence in optically active polymer stabilised cholesteric liquid crystal shutter" Liquid Crystals, 2014, 41: 228-233.

[17] K.K. Raina and P. Kumar, "Polymer dispersed liquid crystal composite films-deoplet orientation and optical response." Journal of the Indian Institute of Science, 2009, 89: 243-248.

[18] S.-Y. Lua and L.-C. Chien, "A polymer stabilized single layer color cholesteric liquid crystal display with anisotropic reflection." Applied physics letters, 2007, 91: 131119.

[19] Rui Bao, Cheng-Mei Liu and Deng-Ke Yang, "Smart Bistable Polymer Stabilized Cholesteric Texture Light Shutter" Applied Physics Express, 2009, 2: 112401.

[20] S. Wang, J. He, Y. Zeng, B. Yan, Y. Wang, "Effect of polymer structures on electro-optical properties of polymer stabilized liquid crystal films" Front. Chem. Eng. China, 2008, 2: 265–268.

[21] C. V. Rajaram, S. D.Hudson, L. C. Chien, "Morphology of polymer stabilized liquid crystal" Chem. Mater. 1995, 7: 2300-2308.

[22] E.Merck, Data sheet.

[23] Norland, N.J., USA, Data sheet.

[24] D.K. Yang and S.T. Wu; "Fundamentals of liquid crystal devices (New York: John Wiley and Sons Inc)

[25] G. Diankov, H. Naradikian and T. Angelov, Polymer-stabilized liquid crystal indicator used in thermometry, J. Mater. Sci.: Mater. Electron, 2003, 14: 831–832.

[26] H. Guillard, P. Sixou, L. Reboul, A. Perichaud; "Electrooptical characterization of polymer stabilized cholesteric liquid crystals" Polymer, 2001, 42: 9753-9762.

[27] X.T. Yahn, H. Cao, Z. Yang, H. Yang; "A selective reflecting film with a temperature-dependent pitch length." Chienese chemical letters, 2010, 2: 279-282.

[28] S. Chandrashekar, Liquid Crystal 2nd Edn., Cam-

bridge University Press, Singapore, 1992.

[29] Kumar, R., Raina, K.K., “Optical and electrical control of circularly polarised fluorescence in CdSe quantum dots dispersed polymer stabilised cholesteric liquid crystal shutter,” Liquid Crystals, 2016, 43: 994-1001.

[30] Middha, M., Kumar, R., Raina, K.K., “Effects of chirality on optical and electro-optic behavior of nematic liquid crystals doped with functionalized silver nanoparticles,” Journal of Molecular Liquids, 2016, 219: 631-636.

[31] J. Stasieka, A. Stasieka, M. Jewartowski, M.W. Collins, “Liquid crystal thermography and true-colour digital image processing” Optics & Laser Technology, 2006, 38: 243–256.

  DOI: https://doi.org/10.30564/omms.v1i2.849