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Thermal hysteresis shown by polymer dispersed cholesteric liquid crystals

Anita Kanwar[1,*], Sureshchandra J.Gupta[2]

[1]Dept. of Physics, VES College of Arts, Science & Commerce., Sindhi Society, Chembur, Mumbai-71, (INDIA)

[2]Dept. of Physics, University of Mumbai. Vidyanagari, Santacruz (E), Mumbai, (INDIA)

E-mail: anita_s_kanwar@yahoo.com

ABSTRACT

We present a comprehensive study on the mixtures of Polymer Dispersed Cholesteric Liquid Crystal (PDCLC) samples made using polymer PN393, nematic liquid crystal mixture TL205 doped with Cholesteryl material in different proportions. The phase transition temperatures of the samples thus prepared were studied using Fabry Perot Scattering Studies (FPSS) and Optical Polarization Microscopy (OPM). These temperatures were verified by Differential Temperature Analysis (DTA). We found that thermal response of the sample strongly depends upon the amount of the chiral dopant added to the sample. The thermal hysteresis effect shown by the samples depends on the heating and cooling rates. Concentration of the Cholesteric material and type of polymer used plays an important role in the variation of the width of the hysteresis curve. These temperature effects are completely reversible making them useful as switching devices.

KEYWORDS

Polymer dispersed cholesteric liquid crystal;
Cholesteryl material;
Fabry perot scattering studies;
Chiral dopant;
Thermal hysteresis.

INTRODUCTION

PDCLC[1] consist of tiny droplets of nematic and Cholesteric liquid crystals dispersed in an optically isotropic polymer matrix by choosing appropriate combinations and proportions of liquid crystal and polymer material. The optical, display and thermal properties of PDCLC attract researchers to explore new combined applications of polymers and liquid crystals. PDCLCs are made in variety of different ways[2]. Sample shows distinct morphologies depending upon method of preparation and phase-separation processes. We have used thermal phase separation method to prepare our samples. Several different techniques are often employed to study PDCLCs. The most widely used experimental technique is Optical Polarization Microscope (OPM) which reveals that each different liquid crystal phase has a distinct optical texture[3,4]. However, the identification of liquid crystal phases through PMS is often difficult and requires a lot of experience. We have introduced the simple spectroscopic technique of FPSS [5-7] i.e. studying the laser light scattered by the PDCLC using a Fabry-Perot etalon coupled to a spectrometer to determine most accurately; the mesophase transition temperatures (PTTs). The findings have been corroborated by the analysis of the thermal runs using OPM[8,9]. DTA technique is used to verify PTTs obtained using FPSS and OPM.

The primary objective of this work was to find the PTTs for several PDCLC films consisting of TL205/ PN393 and Cholesteryl Pelargonate (CP) in different proportions while heating and cooling and to study more extensively the changes in the transition temperature.

In particular, the effect of temperature on the electro-optical properties is topic of interest, but PTT variations with only temperature have rarely been investigated. We concentrated on Thermal hysteresis[10] effect shown by seven different PDCLC samples. All the samples exhibit a similar hysteresis behavior during cooling relative to heating with varying hysteresis width. Amount of chiral dopant added to the sample played very crucial role in deciding the width of the hysteresis curve.

EXPERIMENTAL DETAILS

The liquid crystals and the pre-polymer are mixed in the desired ratio by stirring at room temperature until the mixture is homogeneous. Samples are then heated to make an isotropic solution, which is then cooled at specific rate to induce phase separation. We concentrated our studies on 20% monomer solution and used 80% mixture of TL205 and cholesteric materials in different proportions. PDLC and PDCLC mixtures in appropriate proportions by weight have been investigated using the FPSS, OPM and DTA[11,12] methods. In the FPSS experiment, the Angular Diameters of the Fabry-Perot rings were measured at different temperatures till the mixture became isotropic. The temperatures were measured accurately using a Remote Sensing Infra-red thermometer having a resolution of 0.1^{0}C. For each of the samples, readings were taken in six different cycles for the diameter of one to five rings. Graphs show the plot of the temperature versus angular diameter for the 3rd, 4th & 5th rings, for cycle numbers three, four and five.

RESULTS AND DISCUSSIONS

TABLE 1 Shows the PTTs obtained using FPSS while heating and cooling where rate of heating and cooling is maintained as 1^{0}C per minute.

TABLE 1 : Showing comparision of PTTs using FPSS while heating and cooling with CP as chiral dopant at the rate of 1^{0}C

Sample (numbers are concentration in %)	PTTs (in^{0}C) while heating	PTTs (in^{0}C) while cooling	Hysteresis Width (in^{0}C)
80(90N+10CP) +20P	33.8, 39.8, 60.5, 70.3, 81.8*	33,39.5,56, 70, 81.1*	0.7
80(80N+20CP) +20P	33.8, 39.8, 46, 58.9, 70.5, 79.8*	32.7, 39, 45.2, 57.5, 66, 78.9*	0.9
80(70N+30CP) +20P	34, 42, 46, 53, 62, 70.4, 78.2*	34, 41.5, 45.4,61, 70.1, 77.0*	1.2
80(60N+40CP) +20P	32.4,39,43.4,46, 52.8,60.5,64.8,76.7*	39, 46, 52, 59.8, 63.8, 75.2*	1.7
80(50N+50CP) +20P	33.6,38.8,46, 56.3,60.4,62.4, 75.6*	38, 46, 55.4, 62, 73.7*	1.9
80(30N+70CP) +20P	36.8, 43.2, 52.8, 56, 61.5, 73.8*	38, 43, 52, 61.1, 71.5*	2.3
80(10N+90CP) +20P	32.8,36.5, 46.3,53.5,56,69.5, 72.1*	32.5, 36, 46.2, 56, 69.6*	2.5

A similar observation where rate of heating and cooling is 2^{0}C per minute is shown in TABLE 2.

TABLE 2 : Showing comparision of PTTs using FPSS while heating and cooling with CP as chiral dopant at the rate of 2^{0}C

Sample (numbers are concentration in %)	PTTs (in^{0}C) while heating	PTTs (in^{0}C) while cooling	Hysteresis Width (in^{0}C)
80(90N+10CP) +20P	33.5, 60.3, 70.6, 81*	33, 39, 59.6, 70, 80.1*	0.9
80(80N+20CP) +20P	33.6, 39.4, 46, 58.2, 70.3,79.5*	32.8,39.2, 45.2, 57, 66, 78.2*	1.3
80(70N+30CP) +20P	34, 42, 53, 62, 70.4, 78.2*	33.3,41.5,45.4,61, 69.4, 76.7*	1.5
80(60N+40CP) +20P	32.4, 39, 46, 52.8,60.5,64.8, 76.7*	31.5,37.7,45.6,52, 63.8, 75*	1.7
80(50N+50CP) +20P	38.8, 46, 56.5, 60.8, 62.4, 75.2*	38, 46, 55, 61.5, 73.1*	2.1
80(30N+70CP) +20P	36.8, 43.2, 52.5, 61.5, 73.6*	38, 41.5, 51.6, 60.3, 71.2*	2.4
80(10N+90CP) +20P	36.5, 46.3, 53.5, 56,69.5, 72.5*	36, 45.1, 54.5, 69.8*	2.7

It is clear from the TABLE 1 and TABLE 2 that the concentration of the cholesteric material (CP) significantly affects the number of PTTs and the clearing point of the PDCLC samples. It is also observed that the PTTs while heating and cooling shows hysteresis effect.

Figure 1 shows the FPSS graph for the sample containing 80%(60%N+40%CP)+20%P composition. An abrupt variation (20' to 25' with a spectrometer of least count=30'') at the mesophase transition temperatures is clearly visible in the graph.

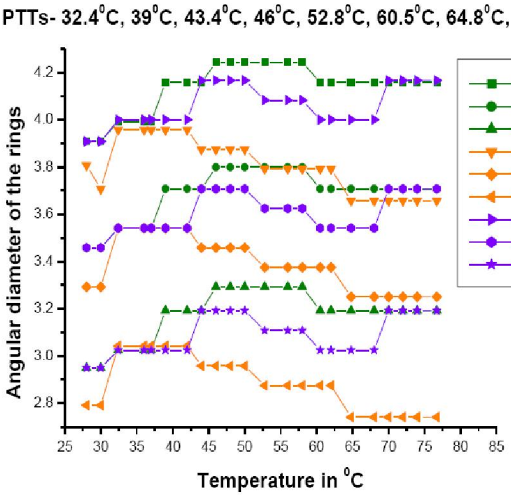

Figure 1 : FPSS graphs for 80%(60%N+40%CP)+20%P sample

Figure 2 shows graphical representation of the Variation of Clearing Point[13] (Heating) with concentration of the Cholesteric liquid crystals present in the 80 % mixture of the TL205 and CP to which 20% polymer is added to make PDCLC.

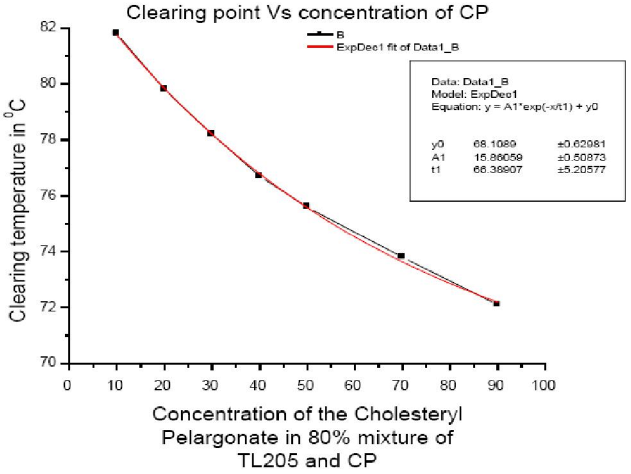

Figure 2 : Graphical representation of the variation of clearing point with concentration of CP

Figure 3 shows Hysteresis loop for various concentration of CP at 1^{0}C rate of change of temperature.

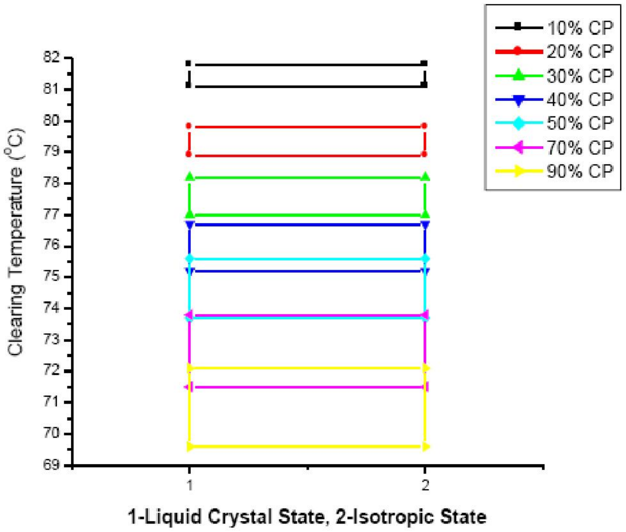

Figure 3 : Hysteresis loop for various concentration of CP at 1^{0}C per minute rate of change of temperature

Figure 4 shows Hysteresis loop for various concentration of CP at 2^{0}C rate of change of temperature.

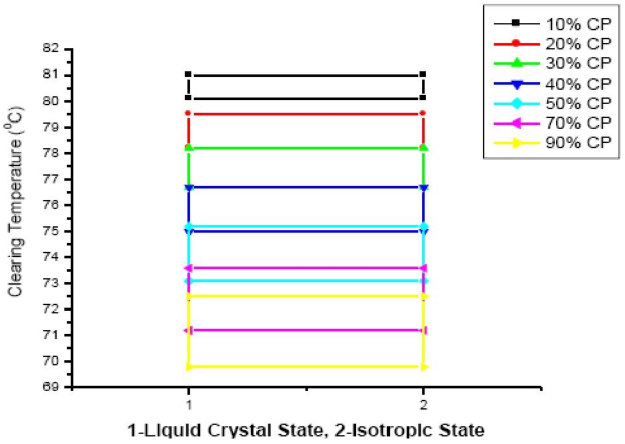

Figure 4 : Hysteresis loop for various concentration of CP at 2^{0}C per minute rate of change of temperature

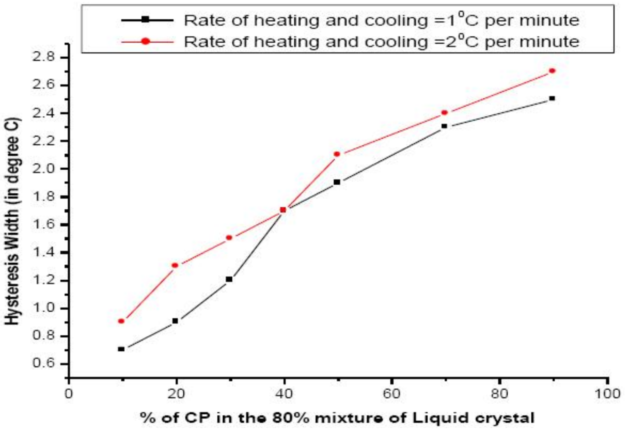

Figure 5 : Graphical representation of the variation of hysteresis width with concentration of CP

Figure 5 shows graphical representation of the Variation of Hysteresis[14] width while heating and cooling with the concentration of CP in the 80% mixture of TL205 and CP.

CONCLUSIONS

It is clear from the experimental results that the concentration of cholesteric material (CP) significantly affects thermal response of the sample such as the number of PTTs and clearing temperature (CT) of the PDCLC samples. CT decreases exponentially with increasing concentration of chiral dopant that also points at the variation in the homogeneity of the samples[15].

Concentration of the Cholesteric material plays an important role in the variation of the width of the hysteresis curve. The thermal hysteresis width shown by the samples depends on the heating and cooling rate that is clear from figure 5. More important is the fact that these temperature effects are completely reversible. Normally for switching effects to be observed very high field is required, here we are able to see the switching properties by very small variation in the temperature. More important is the fact that in the liquid crystal state under cross polarizer's we are able to see beautiful colour textures and as soon as it goes to isotropic state the view becomes black completely blocking the light and visa-versa.

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