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Broad temperature range blue phases in polymer dispersed cholesteric liquid crystals

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ABSTRACT

'Blue phases' (BP) in liquid crystal are three-dimensional cubic defect structures normally observed in chiral liquid crystals. These phases exist for very short duration of temperature from 0.5°C to2°C. It is because of this restriction their practical usability is limited which is proved both theoretically and experimentally. There are three well-known thermodynamically stable blue phases, BP III, BP II and BP I. BP III is amorphous with a local cubic lattice structure in the director field, whereas BP II and BP I have a fluid three-dimensional periodic structure in the director field with simple cubic and body-centred cubic symmetry, respectively[1]. We have made polymer dispersed cholesteric liquid crystals (PDCLCs) with different concentrations of nematic and cholesteric liquid crystals in our lab using thermally induced phase separation method. We are reporting presence of broad temperature range blue phases in PDCLCs. Their presence is confirmed by various techniques viz. fabry parot scattering studies (FPSS), optical polarising microscope (OPM) and differential thermal analysis (DTA). We propose that the unusual behaviour of these blue phase materials is due to the addition of polymer to the cholesteric liquid crystals making them polymer dispersed cholesteric liquid crystals (PDCLCs)[2].

KEYWORDS

Blue phases;
Chiral nematic;
Polymer dispersed cholestric liquid crystal;
Optical polarizing microscopy;
Differential thermal analysis;
Fabry perot scattering studies.

INTRODUCTION

A mesophase with a three-dimensional spatial distribution of helical director axes leading to frustrated structures with defects arranged on a lattice with cubic symmetry and lattice constants of the order of the wavelength of visible light is called a blue phase (BP). The name "blue phase" derives historically from the optical Bragg reflection of blue light. Also because of larger lattice constants, BPs can reflect visible light of longer wavelengths. A BP is optically isotropic and exhibits a Bragg reflection of circularly polarized light[3]. These phases exist over a small temperature range between isotropic and chiral nematic (N*) thermotropic phases. Blue phases are generally observed on cooling from the isotropic phase to the chiral nematic phase.

Blue phases results from the competition between the chiral forces and the desire for molecules to pack in

ways such that they fill space uniformly. Theoretical and experimental work on BP have demonstrated that cholesteric liquid crystals of short pitch can form up to three distinct blue phases between the chiral nematic and isotropic phases[4,5]. They are named blue phase I (BPI), blue phase II (BPII), and blue phase III (BPIII) in order of ascending temperature. BPI and BPII have body-centered cubic and simple cubic symmetry respectively. BPIII is seemingly amorphous with a still unknown local structure[6].

Neat blue phases have only existed over a narrow temperature range a few degrees celsius wide and this has limited their practical applicability. Several attempts have been made to widen the temperature interval of the blue phases, notably by polymer stabilization[7,8]. The most recent report describes the stabilization of the three-dimensional cubic lattice in a defect confined polymer matrix[9]. Hence we tried to analyze the PDCLCs to see the effect of polymer and cholesteric materials together in PDCLCs.

PDCLC samples contain polymers and cholesteric liquid crystals. These materials because of their unique properties are very useful in display industry. PDCLCs consist of liquid crystal droplets (Nematic and Cholestric) that are dispersed in a solid polymer matrix. Among the factors influencing the properties of the PDCLC material are the size and morphology (shape) of the droplets, the types of polymer and liquid crystals used and cooling and heating rates in production in case of thermally induced preparation method.

EXPERIMENTAL

A series of PDCLC films were made using mixtures of a prepolymer PN393, supplied by Nematel Germany and nematic liquid-crystal TL205, supplied by E. Merck Darmstadt. PN393 is a mixture of acrylate monomers that forms a cross-linked network. TL205 is a mixture of halogenated bi- and tri-phenyls with aliphatic tails of lengths two to five carbons. Nematic liquid crystal, cholesteric liquid crystal and the prepolymer are mixed in the desired ratio by stirring at room temperature until the mixture is homogeneous. Thermally induced phase separation method is used to make PDCLCs. We concentrated our studies on 20% monomer solutions and used 80% mixture of TL205 and cholesteryl pelargonate in different proportions. The PDCLC mixtures with following proportions have been investigated.

1) 80(90N+10CP)+20P **2)** 80(80N+20CP)+20P
3) 80(70N+30CP)+20P **4)** 80(60N+40CP)+20P
5) 80(50N+50CP)+20P **6)** 80(30N+70CP)+20P
7) 80(10N+90CP)+20P

where all numbers are in percentages (%), N-TL205, CP-Cholesteryl Pelargonate, P- PN393.

The above PDCLC mixtures have been investigated using the FPSS[10-12]. A low power (2mw) He-Ne laser is used as the optical source. A fabry-perot etalon coupled to a spectrometer telescope forms the rest of the experimental set-up. An indigenous electric heater heated the PDCLC sample. The angular diameters of the rings were measured at various temperatures using a remote sensing infra-red thermometer having a resolution of 0.1^0C. The graphical mappings of the angular diameter of the fabry-perot rings Vs. temperature shows an abrupt variation (20' to 25' with a spectrometer of least count=0.5') at the mesophase transition temperatures of PDCLCs. DTA (Metler Toledo FP90) was also used to investigate phase transitions in PDCLCs. The optical textures using OPM (Olympus BX51, Japan) revealed the presence of extended blue phases in PDCLCs[13].

RESULTS AND DISCUSSIONS

Phase transition behaviour of PDCLC samples were investigated by FPSS, DTA and OPM. We have succeeded in lowering (normally BP's are observed at a temperature which is very close to the isotropic temperature) the blue phase temperatures in PDCLCs as well as in increasing the temperature range over which the blue phases are visible. We are able to view the blue phase textures from a temperature of

(i) 62^0C to 38°C i.e. over a range of 24^0C for the sample 80%(60%N+40%CP)+20%P, whose isotropic temperature is 76.7^0C

(ii) 73.6^0C to 56°C i.e. over a range of 17.6^0C for the sample 80%(50%N+50%CP)+20%P, whose isotropic temperature is 75.6^0C and

(iii) 61^0C to 33°C i.e. over a temperature range of 28^0C for the sample 80%(10%N+90%CP) +20%P, whose isotropic temperature is 72.1^0C.

Please note that these temperatures are well below the isotropic temperatures.

TABLE 1 gives the phase transition temperatures (PTTs) for the various concentrations of the PDCLC samples. These results are obtained using FPSS technique. For each of the samples, the experiment was repeated for five heating/cooling cycles to check for the consistency.

TABLE 1 : Showing PTTSs of samples

No	Sample (numbers are concentration in %)	Concentration of Cholesteryl Pelargonatethe Cholesteryl(in ^{0}C) while cooling Pelargonate(CP)	Phase transition temperatures (in ^{0}C) while cooling
1	80(90N+10CP)+20P	10	*81.8, 70.3, 60.5, 39.8, 33.8
2	80(80N+20CP)+20P	20	*79.8, 70.5, 58.9, 46, 39.8, 33.8.
3	80(70N+30CP)+20P	30	*78, 70.4, 62, 53, 46, 42, 34.
4	80(60N+40CP)+20P	40	*76.7, 62, 38, 32.4, 30
5	80(50N+50CP)+20P	50	*75.6, 73.6, 56, 46, 38.8, 33.6
6	80(30N+70CP)+20P	70	*73.8, 61.5,56, 52.8, 43.2, 36.8
7	80(10N+90CP)+20P	90	*72.1, 61, 33, 32.8

"*"Indicate isotropic temperature i.e. clearing temperature for the sample.

The graphical mappings (Figure 1) of the Angular Diameter of the rings Vs PTTs show an abrupt variation (20' to 25' with a spectrometer of least count=30") at the mesophase transition temperatures. Only one graph has been inserted, similar graphs were plotted for all the samples.

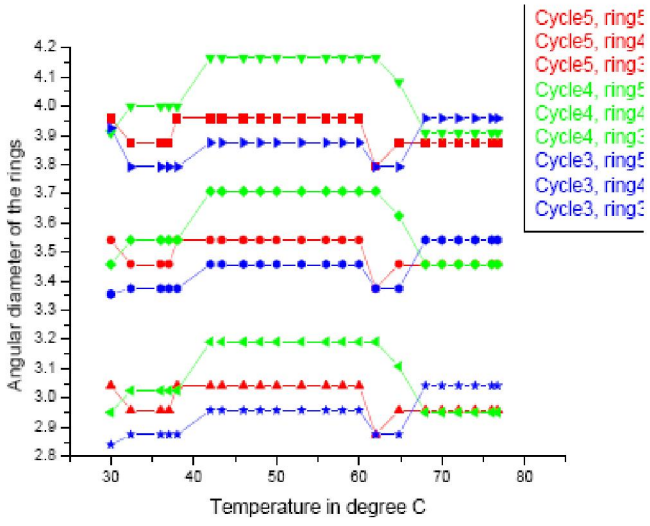

Figure 1: Shows the graphical mappings of angular diameter versus temperature showing the mesophase transition temperatures

Figure 2 : Shows OPM result for 80%(60%N+40%CP) +20%P sample, where blue phase is extended from a temperature of 62^{0}C.

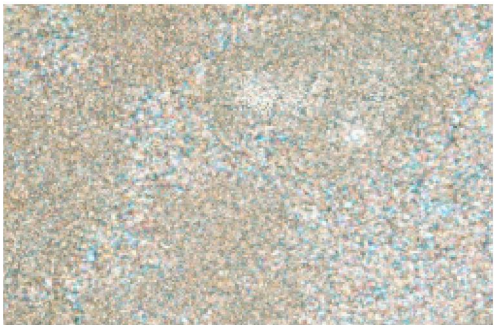

Figure 3 : Shows OPM result for 80%(60%N+40%CP) +20%P sample, where blue phase is extended from a temperature of 38^{0}C.

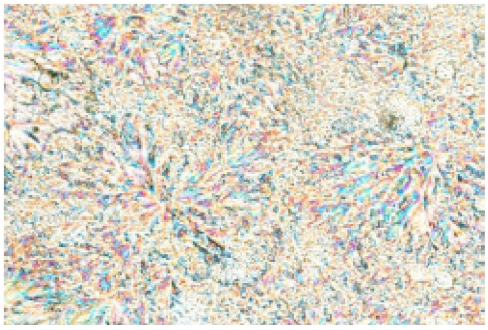

Figure 4 : Shows OPM result for 80%(50%N+50%CP) +20%P sample, where blue phase is extended from a temperature of 73.6^{0}C.

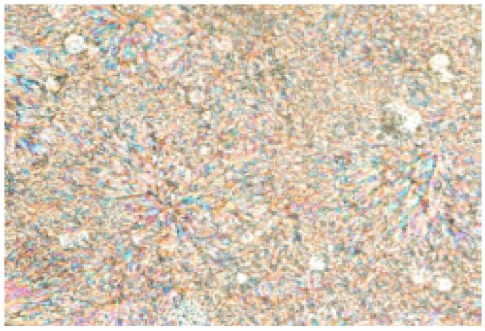

Figure 5 : Shows OPM result for 80%(50%N+50%CP) +20%P sample, where blue phase is extended from a temperature of 56^{0}C.

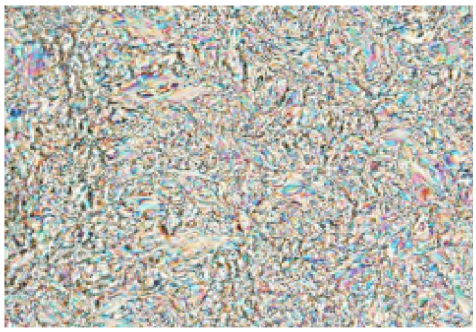

Figure 6 : Shows OPM result for 80%(10%N+90%CP) +20%P sample, where blue phase is extended from a temperature of 61^{0}C.

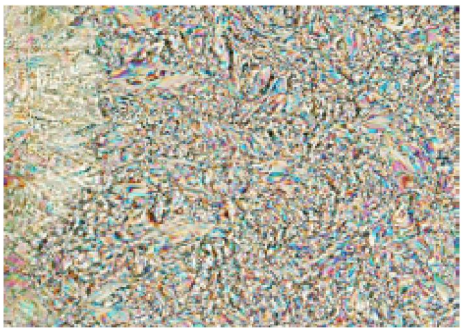

Figure 7 : Shows OPM result for 80%(10%N+90%CP) +20%P sample, where blue phase is extended from a temperature of 33^{0}C.

CONCLUSIONS

The technique of thermally induced phase separation was successfully used to make PDCLC samples with various concentrations of the liquid crystal. The properties of PDCLC materials have been improved by creating different types of mixtures. We were able to observe blue phases over the wide temperature range for different PDCLC samples. It was also observed that these blue phases are highly stable over the given temperature range. The reason being that liquid crystal molecules are chiral, hence their twisted structure competes with spatially uniform liquid crystalline orders, resulting in a variety of modulated liquid crystal phases, such as the cholesteric blue phase[14]. In case of PDCLCs, it is the combination of polymer and the chiral LC which restricted the deformation of the blue-phase lattice. Hence no colour switching was observed. Recently compounds possessing an axis or a plane of chirality have been reported[15-18]. PDCLC materials with a wide temperature range of a blue phase at lower temperatures have never been obtained before.

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REFERENCES

[1] P.P.Crooker; in 'Chirality in Liquid Crystals' (Eds H.-S.Kitzerow, C.Bahr,) Springer, New York, ChemPort, 186-222 **(2001)**.
[2] http://plc.cwru.edu/tutorial/enhanced/files/pdlc/prep/prep.htm.
[3] M.Baron; IUPAC, Pure and Applied Chemistry, **73**, 845–895 **(2001)**.
[4] H.Stegemeyer, T.H.Blu¨mel, K.Hiltrop, H.Onusseit, F.Porsch; Liq.Cryst., **1**, 3 **(1986)**.
[5] P.P.Crooker; Liq.Cryst., **5**, 751 **(1989)**.
[6] P.Jame´e, G.Pitsi, M.H.Li, H.-T.Nguyen, G.Sigaud; J.Thoen, PRE, The American Physical Society, **62**, 3687 **(2000)**.
[7] H.-S.Kitzerow, et al.; Liq.Cryst., Chem Port, **14**, 911-916 **(1993)**.
[8] C.Bohley, T.Schart; Proc SPIE, Chem Port, **5184**, 202-208 **(2003)**.
[9] H.Kikuchi, M.Yokota, Y.Hisakado, H.Yang, T.Kajiyama; Nature Mater, Chem Port, **1**, 64-69 **(2002)**.
[10] S.J.Gupta; Journal of Optics, India, **29(2)**, 53-62 **(2000)**.
[11] S.J.Gupta; Indian Journal of Pure and Applied Physics, **37**, 620 **(1999)**.
[12] S.J.Gupta, R.A.Gharde, A.R.Tripathi; Procs. of SPIE, Photonics West, **4970**, 89-100 **(2003)**.
[13] Harry J.Coles, Mikhail N.Pivnenko; Liquid Crystal 'Blue Phases' with a Wide Temperature Range.
[14] Erato Yokoyama; Nano-Structured Liquid Crystal Project, JST, 5-9-9 Tokodai, Tsukuba, Japan, 300-2635.
[15] G.Solladie, R.Zimmermann; Angew.Chem, Int.Ed. Engl., **24**, 4062 **(1985)**.
[16] R.Lunkwitz, C.Tschierske, A.Langhoff, F.Gießelmann, P.Zugenmaier; J.Mater.Chem., **7**, 1713 **(1997)**.
[17] K.Yang, R.F.Lemieux; Mol.Cryst.Liq.Cryst, **260**, 247 **(1995)**.
[18] L.Ziminski, J.Malthete; J.Chem.Soc., Chem. Commun., 1495 **(1990)**.