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RESEARCH ARTICLE

DISPERSION OF LIGHT IN CHOLESTERIC LIQUID CRYSTAL AND MIXTURES AT 303^0K

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ABSTRACT

In the present work, the dispersion of light at 303^0K in Cholesteric liquid crystal(CLC), Polymer dispersed CLCs and nanopowder dispersed CLC as well as PDCLCs is studied using multiple wavelength refractometer. The variation of the refractive index of a medium with wavelength constitutes the phenomenon of dispersion. In Cholesteric Liquid Crystals a twist is superimposed on the usual parallel arrangement of molecular associations. A Polymer-dispersed Cholesteric liquid crystal (PDCLC) film is polymer film with embedded CLC droplets. The Ferroelectric nanoparticles dispersed at a low concentration in a CLC induce realignment of neighbouring Liquid crystal molecules. We observed that the dispersion increases in the mixtures of CLCs than in the pure CLC. Doping CLC with monomer or low concentration of ferroelectric nano – powder can thus modify the characteristics of CLCs, which plays an important role in the designing of new materials.The value of dispersion reaches maximum for PDCLC 1: CLC+M1.These are the promising material for various electro-optical devices, where light modulation is required.

INTRODUCTION

Liquid crystals are compounds that display order in the liquid state above the melting temperature and below the mesogenic isotropic temperature. Cholestaric liquid crystals exhibit selective reflection and giant optical activity that can easily be regulated by electric field and temperature. Polymer dispersed liquid crystal (PDLC) systems are promising novel materials for their potential applications as reflective displays, electrically controllable light shutters, and holographic gratings (Doane *et al.,* 1986; Kawakita *et al.,* 1999; Sutherland *et al.,* 1994; Drazic, 1995; Tanaka *et al.,* 1995; Crawford *et al.,* 1996; Amundson, 1996). Micron-sized liquid crystal droplets dispersed in a polymer matrix produce significant light scatterings in the visible spectral region. (Doane *et al.,* 1986; Fergason, 1985). The refractive index mismatch between the liquid crystal droplets and the host polymer is the physical mechanism responsible for such light scattering in the voltage-off state. At the voltage-on state, the droplets are reoriented along the field direction. The ordinary refractive index of the LC matches the index of the polymer. As a result, little scattering takes place and most of the light is transmitted. One advantage of this type of electro-optical modulation is that it does not require polarized light (i.e. no polarizer is needed). Therefore, optical efficiency is greatly enhanced. Recently, nanoparticals have been doped into Liquid Crystals and studied for improvement in electro-optic and optical properties such as enhanced photoluminescence, higher polarization, fast response time, low operating voltage, and improved conductivity (Prakash *et al.,* 2008; Kumar *et al.,* 2009; Tong and Zhao, 2007; Lee, *et al.,* 2002; Balandin *et al.,* 2000; Lee *et al.,* 2010; Pandey *et al.,* 2011; Podgornov *et al.,* 2009; Chaudhary *et al.,* 2012; Malik *et al.,* 2012). The nanoparticales share their intrinsic properties with the liquid crystal matrix due to the alignment and anchoring with the liquid crystal.

Suspension of nanopartical in a cholesteric liquid crystal enhances dielectric anisotropy and is sensitive to the sign of an applied electric field. Because small domains with different director configurations are formed, the system of liquid crystal doped with nanoparticles shows strong light scattering. By applying electric field, the liquid crystal molecules reorient and the scattering state can be switched to the transparent one. In the present work we have studied the dispersion of light for CLC and five mixtures at 303^0 K. We measured the ordinary refractive indices of Cholesteric liquid crystal and mixtures for different wavelengths at the temperature interval of 5^0 K.

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MATERIALS

1) The CLC in the present study

Cholesteryl Myristate is a thermotropic liquid crystal whose properties change with the change in temperature.

Molecular formula: $C_{41}H_{72}O_2$, Melting Point: 84 °C

2) The monomer M_1

Ethylene Glycol Dimethacrylate (EGDMA) is a water-insoluble diffunctional methacrylic monomer employed as a cross-linking agent or a low viscosity reactive diluent.

3) The monomer M_2

2-ethyl hexyl acrylate (2eha) is an acrylate monomer. It is a clear liquid which is not soluble in water and completely soluble in alcohols and ethers. It is easily miscible with other organic solvents and is readily polymerized with monomer molecules to create polymer chains.

4) The ferroelectric nano – powder NP

The particles of ferroelectric nano-powder BaTiO3 are slightly anisotropic and their size is less than100nm.

METHODS

1) Both the monomers were dispersed separately in Cholesteryl Myristate (CLC) by encapsulation method to form Polymer dispersed Cholesteric Liquid Crystals (PDCLCS). The PDCLC formed contained 10% of monomer with 90% of CLC.
2) BaTiO3 is mixed with Oleic acid and Heptane in appropriate proportion by weight and then this mixture was doped with Cholesteryl Myristate by ultra-sonication method.The ultra-sonicaton ensures homogeneous distribution of nano – powder in Cholesteric liquid crystal. The mixture was kept in vacuum for six hours for complete evaporation of heptane. The resulting sample contains the small concentration (~1%) of BaTiO3 nano – particles. Similar procedure was adopted for dispersing BaTiO3 in PDCLCs.

List of samples

1) CLC: Cholesteryl Myristate Mixtures:
2) PDCLC 1: CLC+M1: Cholesteryl Myristate +EGDMA
3) PDCLC 2: CLC+M2: Cholesteryl Myristate +2eha
4) CLC +NP: Cholesteryl Myristate +BaTiO3
5) PDCLC 1+NP: Cholesteryl Myristate +EGDMA+BaTiO3
6) PDCLC 2+NP: Cholesteryl Myristate +2eha+BaTiO3

Measurement of Refractive Index

We measured the ordinary refractive indices of Cholesteric liquid crystal and mixtures. The refractive indices for ordinary ray were measured in the visible spectral region using a multiwavelength Abbe Refractometer (DSR-λ by SCHMIDT+HAENSCH) for wavelengths 404.7, 435.8, 486.1, 546.1, 587.6, 589.3, 635.8, 656.3, 706.5 in nm. The accuracy of the Abbe Refractometer is up to fifth decimal. For a given wavelength, we measured ordinary refractive indices of CLC, PDCLC1, PDCLC2, CLC+NP, PDCLC1+NP, PDCLC2+NP from 303^0 K to 353^0 K with the intervals of 5^0K.

RESULTS AND DISCUSSION

The measurements of the ordinary refractive indices for sample CLC+NP are presented in the Table 1.

Similar measurements were taken for CLC, PDCLC1, PDCLC2, PDCLC1+NP, PDCLC2+NP. The graphs of refractive index versus temperature for various wavelengths are plotted for all the samples. The graph for PDCLC1 is given in figure 1. Figure 1 indicates that the values of RI vary with temperature, wavelength and the material used. All the mixtures show similar pattern as CLC. The values of RI decrease with increase in temperature.

The relation between refractive index (n) and wavelength (λ) is given by two-constant Cauchy equation;

$$n = A + \frac{B}{\lambda^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{Equation 1}$$

The constants A, B can be obtained by fitting the experimental results at any two wavelengths. From equation 1 the refractive index decreases as the wavelength increases.

Figure 2 shows graph of RI vs wavelength at 303^0K.

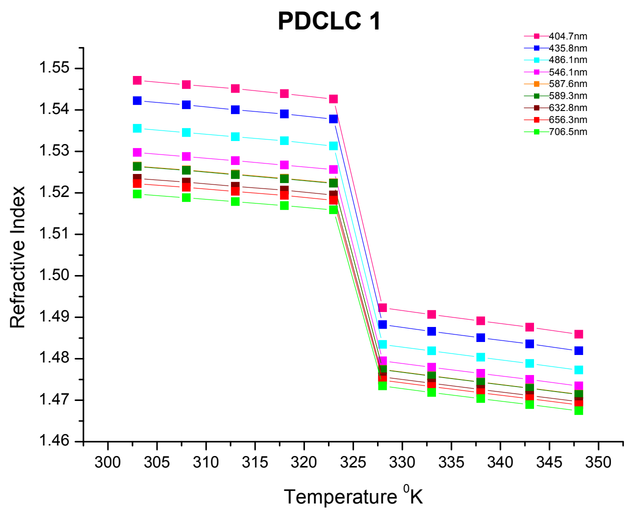

Figure 1.RI vs Temperature for PDLC1

The graph indicates that RI decreases with increase in wavelength. This is in accordance with equation 1.

Dispersion

Differentiating equation 1, we get dispersion which is variation of RI with wavelength,

$$\frac{dn}{d\lambda} = -\frac{2B}{\lambda^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \text{Equation 2}$$

This shows that dispersion $\frac{dn}{d\lambda}$varies approximately as the inverse cube of the wavelength.
Dispersion is often measured in terms of the coefficient of dispersion.

$$\text{Coefficient of dispersion} = n_F - n_C \ldots\ldots\ldots\ldots \quad \text{Equation 3.0}$$

Since refractive index and wavelength are not linearly related, use of a single number to quantify dispersion is rather misleading.

Table 1. Measurement of Ordinary RI for CLC+NP

WL-nm→	404.7	435.8	486.1	546.1	587.6	589.3	632.8	656.3	706.5
Temp°C↓	RI ↓	RI ↓	RI ↓	RI ↓	RI ↓	RI ↓	RI ↓	RI ↓	RI ↓
303	1.53762	1.53427	1.52903	1.52421	1.52187	1.52178	1.51936	1.51791	1.51631
308	1.53592	1.53273	1.52772	1.52308	1.52068	1.52059	1.51817	1.51683	1.51519
313	1.53456	1.53145	1.52662	1.52184	1.51947	1.51938	1.51707	1.51572	1.51416
318	1.53296	1.52996	1.52530	1.52050	1.51826	1.51818	1.51602	1.51464	1.51303
323	1.53114	1.52837	1.52370	1.51909	1.51684	1.51676	1.51450	1.51316	1.51186
328	1.52456	1.52477	1.52149	1.51746	1.51562	1.51555	1.51332	1.51189	1.51072
333	1.48966	1.48556	1.48094	1.47721	1.47526	1.47519	1.47357	1.47286	1.47160
338	1.48831	1.48428	1.47954	1.47585	1.47393	1.47385	1.47220	1.47146	1.47019
343	1.48709	1.48308	1.47831	1.47454	1.47264	1.47257	1.47095	1.47021	1.46886
348	1.49467	1.48916	1.48296	1.47708	1.47447	1.47439	1.47241	1.47128	1.46970
353	1.49326	1.48963	1.48531	1.48160	1.47965	1.47957	1.47789	1.47709	1.47573

Table 2. Dispersion in relation to RI for CLC, CLC+NP, PDCLC1, PDCLC2, PDCLC1+NP, PDCLC2+NP at 303^{0}K

	CLC	CLC+NP	PDCLC1	PDCLC2	PDCLC1+NP	PDCLC2+NP
Fitting const. A	1.5136646	1.5059026	1.5066781	1.52884245	1.5188292	1.5146049
Fitting const. B μm^2	0.00501308	0.00519472	0.0068246	0.0056091	0.00627462	0.00650133
Coeff. of dispersion	0.01021	0.01112	0.01333	0.01218	0.01278	0.01260
Dispersive power	0.0193334	0.0213116	0.025326	0.0223244	0.0237829	0.23567
Abbe number	51.7238	46.92266	39.484621	44.4939	42.046948	42.431746

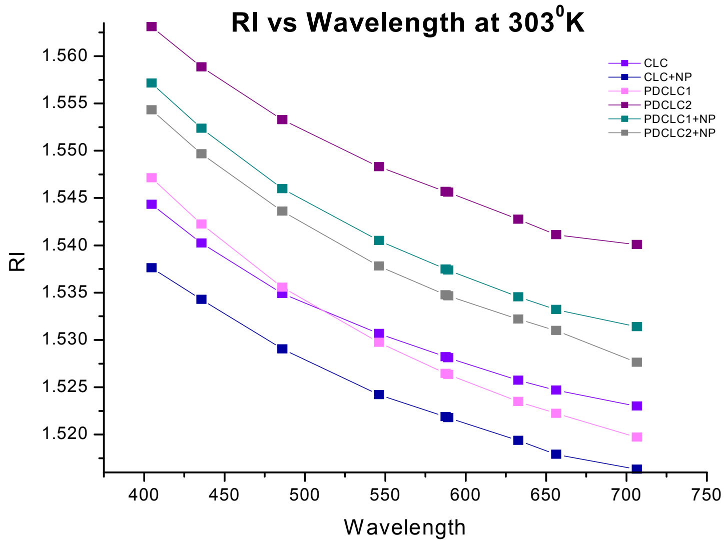

Figure 2.RI vs Wavelength at 303^{0}K

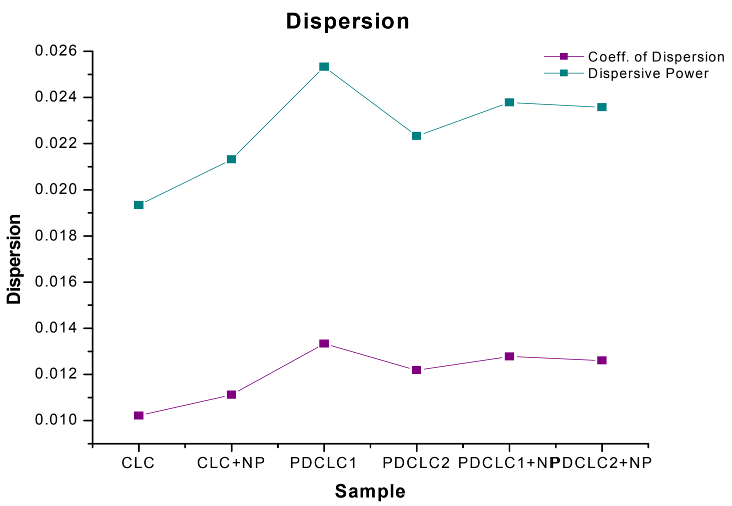

Figure 3.Dispersion vs Sample

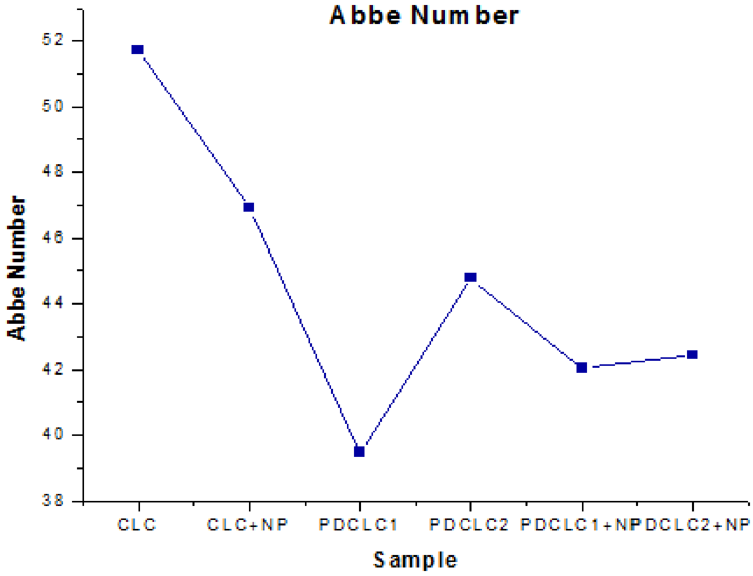

Figure 4.Abbe Number vs Sample

Another common measure of dispersion is the dispersive power.

Dispersive Power $= \frac{n_F - n_C}{n_D - 1}$ …………………… Equation 3.1

The dispersion is also measured by a standard parameter known as Abbe's number or V number. The high values of V_D indicate low dispersion of the material and vice-versa.

$V_D = \frac{n_D - 1}{n_F - n_C}$…………………………………… Equation 3.2

In equation 3.0, 3.1 and 3.2, n_D, n_F and n_C are the refractive indices at the wavelengths of the spectral lines589.3nm, 486.1nm, 656.3nm respectively.

Since many devices prefer to operate around room temperature, the dispersion for CLC and mixtures is calculated at 303^0K using equation 3, 3.1 and 3.2.

The Table 2 indicates the values of fitting constants A, B, coefficient of dispersion, dispersive power and Abbe number at 303^0K for CLC, CLC+NP, PDCLC1, PDCLC2, PDCLC1+NP, PDCLC2+NP using equations 1, 3.0, 3.1 and 3.2 respectively. The dependence of RI on wavelengths varies with the constituent molecules in the sample.

The figure 3 gives variation of measures of dispersion i.e. Coefficient of dispersion and dispersive power with samples at 303^0K. Coefficient of dispersion as well as dispersive power show increase in values in the mixtures of CLC. It means dispersion increases in the doped CLC than in the pure CLC. The value reaches maximum for PDCLC1. The value is nearly same for both PDCLCs doped with nanopowder. The figure 4 gives the variation of Abbe Number with samples at 303^0k. Low value of the Abbe number indicates more dispersion. From the graph it is clear that dispersion is maximum in PDCLC1.Also, dispersion increases in the doped CLC than in the pure CLC. In CLC linear component of light experiences change in RI because of the twist of the layer along the director. By doping monomer or nanopowder in CLC the position, orientation or shape of the molecules is changed. The pitch and the distance between the successive layers also change in the mixtures. High degree of transparency is achieved in electro-optical modulation because of the reorientation of the directors in the CLC droplets in the matrix along the field direction. It's effective RI is equal to the ordinary RI which is similar to RI of the polymer. By addition of nanopowder in PDCLC increases the amount of droplets and decrease in the droplet size. This helps in lowering of interaction forces between particles. This enhances the dispersion.

Conclusion

In the present paper we measured the ordinary refractive index of light by varying material, wavelength and temperature. Using these values of ordinary refractive index, we studied dispersion of light at 303^0K in Cholesteric liquid crystal, Polymer dispersed CLCs and nanopowder dispersed CLC as well as PDCLCs. We observed that the value of dispersion of light is more in doped CLCs than in pure CLC. This indicates that the modulation of light in the material can be controlled by introducing microscopic structural changes in it.This also indicates that low concentration of ferroelectric nano – powder or monomer can modify the characteristics of CLC which plays an important role in the designing of new materials. The value of dispersion is nearly same for both PDCLCs doped with nanopowder. Dispersion is maximum for PDCLC1 among all the mixtures. This is a promising material for various electro-optical devices, where light modulation is required.

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