JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Optical Anisotropy of Dispersive Power Studies on Re-entrant Smectic-A Phase of Liquid Crystals

T.N. Govindaiah
Post-Graduate Department of Physics,

Government College (Autonomous), Mandya-571401, India.

ABSTRACT

The gist of our study focuses on specific properties-thermal and optical of a system comprising the binary system of 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB) and 4-hexyl-4-biphenylcarbonitrile (6CB) mesogens exhibits a very interesting unusual re-entrant smectic-A with the addition of induced chiral smectic phases sequentially when the specimen cooled from its isotropic phase respectively at different temperatures. Experimentally measured temperature and wavelength dependent optical anisotropy of refractive indices has been discussed. X-ray studies are helps us to understand the aggregated nano crystalline size of the liquid crystalline phase. Dispersive power has also bee discussed with the help of different combinations of wavelengths.

Keywords: Optical studies: wavelength dependent Refractive indices: Re-entrant smectic: X-Ray studies: Dispersive power:

INTRODUCTION

To understand the relationship between liquid crystals chemical structures and mesomorphic properties, there has been extensive research on the different types of molecules such as: organic compounds, drug and dyes of these molecules. Mesophase stability and temperature range are predominantly results of their molecular shape, i.e., slight changes in the molecular geometry lead to major shifts in the mesomorphic behavior [1, 2].

Liquid crystals (LC) are important for fundamental research and for their applicability in display technology. Liquid crystals are best known for their application in displays; besides it they are widely used in liquid crystal thermometers, tunable micro-lenses, light modulators, switchable devices and light shutters [3, 4].

In the present investigation, we have been consider two compounds namely; 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB) and 4-hexyl-4-biphenylcarbonitrile (6CB). Mixture of these molecules exhibits a re-entrant smectic-A phases with an induced chiral smectic phases sequentially when the specimen is cooled from its isotropic melt. They were observed using microscopic technique and also been verified from the results of optical anisotropic techniques. X-ray studies are helps us to understand the size of the aggregated molecules. Colour combinations of dispersive power values have also been discussed.

EXPERIMENTAL STUDIES

In the present work: we have been considered two compounds namely, 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB) and 4-hexyl-4-biphenylcarbonitrile (6CB). For the experimental studies; here we have chosen a 47% of CPHB molecules mixed with 53% of 6CB. The given concentrations of these molecules were kept in desiccators for a long time. The samples were subjected to several cycles of heating, stirring, and centrifuging to ensure homogeneity. The phase transition temperatures of these concentrations were measured with the help of Gippon-Japan polarizing microscope in conjunction with a hot stage. The samples were sandwiched between the slide and cover slip and were sealed for microscopic observations. Refractive indices in the optical region were determined at different temperatures using multi-wavelength Abbe-refractometer (Atago: DR-M4) including constantly circulating constant bath and six interference color filters. The X-ray diffraction patterns were obtained using SHIMADZU -XRD-6000. diffractometer.

RESULTS AND DISCUSSIONS

LIQUID CRYSTALLINE PROPERTIES

The hot-stage Gippon-Japan-polarizing microscope was used to observe the stability of molecular orientation of unusual re-entrant smectic-A phase of liquid crystalline mesophases, the sequence of unusual phase were exhibited by the sample of binary mixture of thermotropic/lyotropic liquid crystals: 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB) and 4-hexyl-4-biphenylcarbonitrile (6CB). The given concentrations of asymmetric molecules are exhibits striped pattern focal conic domains of re-entrant SmA phase and then this phase produces a schlieren texture with disclinations and point defects-boojums (with four brushes of extinction) [5], these are the characteristics of characteristic of the Sm**C** phase, when the sample is cooled from the re-entrant SmA phase. Microscopic observations of schlieren texture of SmC phase as shown in Figure 1. Remarkably it shows that: the sequence of phase transition from re-entrant smectic-A to smectic-C phases are caused by an increase tilt angle of chiral molecules as the temperature is lowered in the SmC phase. The existence of chiral molecules in smectic phase form a layered structure, the thickness of each layer being typically of the order 20-30 Å. X-ray studies have shown that the molecular centers are packed randomly within the layers. The molecules are tilted from the layer normal by an angle. Eventually this phase changes over to the crystalline SmB phase and this phase remains stable at room temperature [6-8].

OPTICAL ANISOTROPY OF WAVELENGTH DEPENDENT REFRACTIVE INDICES

Liquid crystal is a complex molecular system: in which that involving a short and long-range molecular interactions. Several models have been attempted to address the wavelength and temperature dependencies of the liquid crystal refractive indices [**9, 10**]. Refractive indices of a liquid crystal are fundamentally interesting and practically useful parameters. Measurements of liquid crystal refractive indices play an important role for validating the physical models and the device design. Here we use a multi-wavelengths Abbe-refractometer to measure the optical anisotropy of re-entrant smectic-A (Sm_{RE}) and chral smectic-C phases of liquid crystalline refractive indices for Blue, Green, yellow and Red colors of wave lengths λ=486 (Blue), 546(Green), 589(Yellow) and 633(Red). The refractive indices for extraordinary ray (n_e) and ordinary ray (n_o) of the given ternary mixture were measured at different temperatures for different wavelengths. The temperature variations of different colors of wavelength-dependent refractive indices are as shown in figure 2. From the fig, it is very clear: extraordinary ray (n_e) and ordinary ray (n_o) are the functions of wavelength and temperature. The frequency of the light wave remains unchanged, irrespective of the medium. Whereas the wavelength of light wave changes based on refraction. The wavelength effect shows: according to our experimental data, the value of refractive indices decreases with increasing the colors of wavelength. Wavelength and temperature are important factors for affecting the liquid crystal refractive indices. For an instance: in order to achieve a full-color display of wavelength corresponds to Blue, Green, yellow and Red. The wavelength-dependent refractive indices of mixture of these asymmetric molecules occupied an order to optimize the cell design. Usually the operating temperature changes an optical anisotropy of refractive indices of liquid crystalline materials changes. Accordingly thermodynamic effect is particularly important for projection displays and liquid crystal on silicon for micro-display applications. From the figure, it can also be observed that: wherever there is anisotropic liquid crystalline phase transition, the values of optical-birefringence changes appreciably, which indicates that the changes correspond to existence of re-entrant smectic-A, chiral smectic-C and smectic-B phases. The multi-wavelength refractive index studies help us to develop photonic applications.

X-RAY DIFFRACTION STUDIES

X-ray studies are an important tool for determining the structural investigation of liquid crystalline material. Following figure (3) shows the powder XRD pattern for binary mixture of CPHB and 6CB and they were recorded by using SHIMADZU -XRD-6000 diffractometer. This shows six largest peaks of different 2θ values. Broadening of the peaks is in the XRD pattern refers to a micro structural nano crystallite size. Thus, the given binary mixture, crystalline size of the molecules was calculated by using Deby Scherrer´s equation [11]. That are supported by full width at half maximum (FWHM), which is 35.6314, 62.8414 and 57.2832.

$$L = \frac{0.694\lambda}{\beta cos\ \theta}$$

Where ($\lambda = 0.167$ A°) it's the wavelength of X-ray which is used, β is the peak width of half maximum in radian and θ is angle diffraction of Bragg´s in degree. Here It has been found that: the phase transition temperature increases as we move from crystalline phase to amorphous region, which clearly illustrates that: micro structural nano crystallite sizes of molecules in liquid crystalline materials are decrease with increasing the temperature. From study, the nano crystallite size of CPHB and 6CB molecules are approximately (59.5) nm, (31.8) nm and (39.3) nm. The studies are helps us to understand the nano order of molecules in the given phase increases with decreasing towards room temperature. The existence of orientational chiral tilted smectic-C phase of molecules are slowly move towards the crystalline phase with the formations of hexagonal close packed smectic-B phase and hence it clearly shows that, micro structural nano sggregated crystalline size of asymmetric molecules are big enough to indicates that: the molecular ordering [12] of layer structure increases with decreasing the temperature.

DISPERSIVE POWER O LIQUID CRYSTALLINE MATERIALS

The ratio of angular dispersion between two colours to the deviation produced by the small angled prism which houses the material is called the dispersive power of the material for this colour.

Dispersive power $$\omega_s = \frac{\delta_y - \delta_r}{\delta}$$ ----- (1)

where n_y = average refractive index <n> of the material for yellow light, n_r = average refractive index <n> of the material for red light, n = refractive index <n> of the material for the mean light, and

$$n = \frac{n_y + n_r}{2} \qquad \text{(Approximately)}$$

Then

$$\delta_y = (n_y - 1)^* A, \qquad \delta_r = (n_r - 1)^* A$$

and

$$\delta = (n - 1)^* A,$$

where A is the angle of the prism which is very small in this case. Substituting these in Equation (1), the dispersive power of the material for this colour is

$$\omega = \frac{n_y - n_r}{n - 1}$$

Or

$$\omega_s = \frac{dn}{n - 1}$$

Where $$dn = \frac{n_y + n_r}{2}$$ ----- (2)

Using Equation (1), the dispersive power value ω is estimated for the binary mixture of CPHB and 6CB liquid crystalline materials for different colours. The temperature variations of dispersive power for different colors of wavelength are as shown in figure 3. From the figure it is very clear that: for different combinations of wavelength colours such as: λ=486 (Blue), 546(Green), 589(Yellow) and 633(Red), these are slightly changes in dispersive power values. Change in temperature, which causes to changes in the values of dispersive power corresponding to the colour combinations of different wavelengths. Estimated dispersive power values are in the given molecules with the variation with temperature is similar to that obtained in the case of water [13] and quartz [14].

CONCLUSIONS

Optical microscopic investigations of binary mixture of (CPHB) and (6CB) molecules show the existence of re-entrant smectic-A phases with an induced chiral smectic phases such as SmC and SmB phases for given concentrations respectively at different temperatures. The experimentally measured wavelength dependent optical anisotropy of refractive index has been discussed. X-ray studies lend support to understand the aggregated molecular structure and mesophase order. An estimated value of dispersive power tells us to understand the colour contrast of display with different wavelengths.

REFERENCES

[1] S. Sudhakar, T. Narasimhaswamy and K.Srinivasan, Liq. Cryst. 2000:27:1525-1532.

[2] G.-Y. Yeap, F. Osman and C.T. Imrie. Liq. Cryst. 2015:42:543-554.

[3] W. Haase, F. Podgornov, J. Opt. Tech. 2001: 68: 677

[4] A. Jakli, L.C. Chien, Liq. Cryst. 2002: 29: 377

[5] M. Kleman and O. D. Lavrentovich. 2003. Soft matter physics An Introduction. New York: Springer-Verlag; page. 361.

[6] T. N. Govindaiah, H. R, Sreepad and Nagappa. Mol. Cyst. Liq. Cryst. 2014: 592: 82-90.

[7] T. N. Govindaiah, Nagappa, P. M. Sathyanarayana, J .Mahadeva and H. R, Sreepad. Mol. Cryst. Liq. Cryst. 2011: 548: 120-125.

[8] T. N. Govindaiah, Nagappa, P. M. Sathyanarayana, J .Mahadeva and H. R, Sreepad. Mol. Cryst. Liq. Cryst. 2011: 548(1): 55-60.

[9] E. M. Averyanov. Liq. Cryst. 1987: 2(4): 491-504.

[10] W. H. de Jeu. 1980. Physical Properties of Liquid Crystalline Materials (Gordon and Breach, New York).

[11] P. R. Parmar, M. H. Mangrola, , B. H. Parmar and V. G. Josh. Edu Global Quest (Quarterly). 2012: 1(1): 33-39.

[12] T. N. Govindaiah. Mol. Cryst. Liq. Cryst. 2016: 625: 99-105.

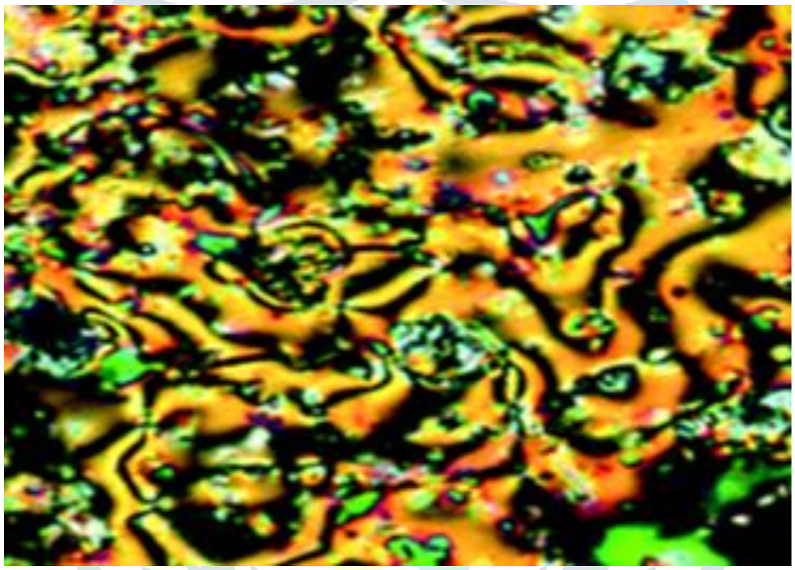
[13] A. N. Bashkatov and E. A. Genina. Proc SPIE. 2003: 5068: 393-395.

[14] P. Hlubina and D. Ciprian Opti Comm. 2011: 284: 2683–2686.

[15] L. Jun, G.Baird, Y-H. Lin, H. Ren and S. T. Wu. J. Soc. Inf. Disp. 2005; 13:1017-1026.

Figure Captions

Figure 1 Microphotographs obtained in between the crossed polars,



Schlieren texture of SmC phase at temperature.

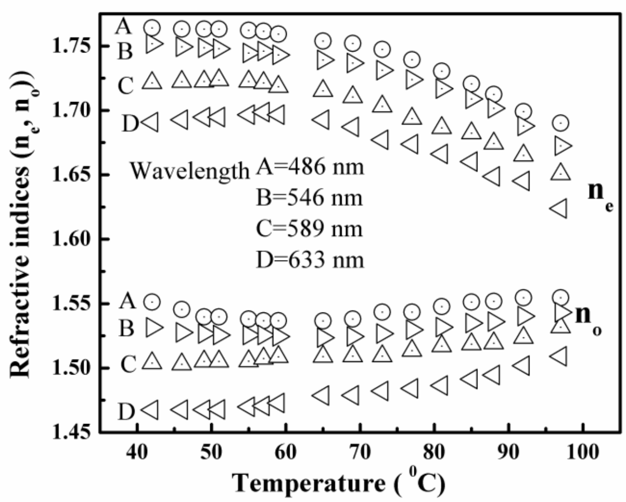


Figure 2. Temperature variations of wavelength dependent Refractive indices for the mixture of CPHB and 6CB.

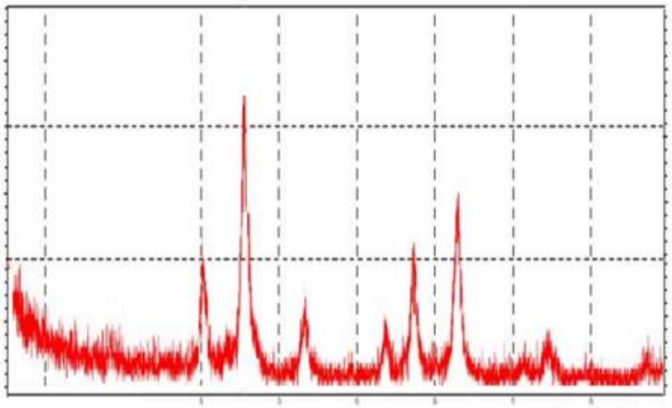


Figure 3. XRD traces obtained for the binary mixture of CPHB and 6CB.

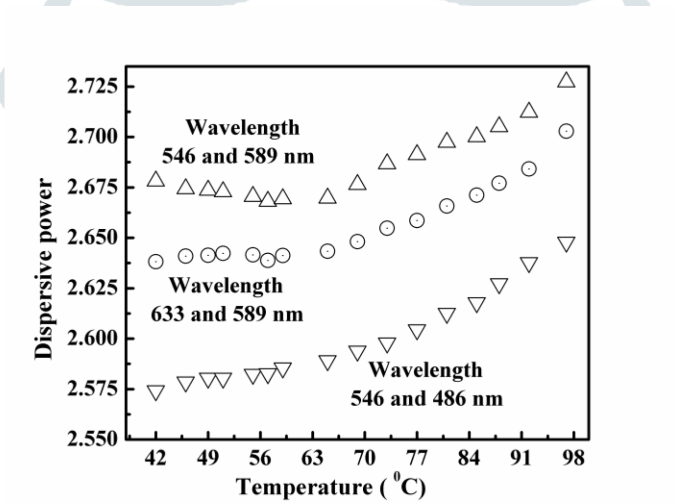


Figure 4. Temperature variations of dispersive power for the mixture of CPHB and 6CB.