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CAUCHY'S COEFFICIENTS AND DISPERSIVE POWER STUDIES ON RE-ENTRANT NEMATIC AND SMECTIC-A PHASE OF LIQUID CRYSTALS

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ABSTRACT We report the results of our study focuses on specific properties-thermal and optical of a system comprising the ternary system of the compounds namely: 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB), 4-cyano-4-n-pentyl-cyclohexanephenyl (5PCH) and cholesteryl acetate (CA) mesogens exhibits a very interesting unusual re-entrant nematic and re-entrant smectic-A with an additionally 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. With the help of experimentally measured data of refractive indices Cauchy's coefficients and dispersive power has been discussed for blue and green colour combinations of wavelengths.

KEYWORDS : Optical texture studies: wavelength dependent Refractive indices: Dispersive power: Cauchy's Co-efficients:

INTRODUCTION

Liquid crystal has been used extensively for direct view and projection displays, tunable photonics, and nonlinear optics [1-3]. Most of the liquid crystal devices use the electric-thermal, or optical-field-induced refractive index change to modulate light. Liquid crystal refractive indices are determined mainly by the molecular structure, wavelength, and temperature. Several models, such as the single-band model, three band model and extended Cauchy model, have been developed to describe the wavelength-dependent liquid crystal refractive indices. The three-band model is particularly useful for understanding the origins of the refractive indices of single Liquid crystal compounds, while the extended Cauchy model is more appropriate for liquid crystal mixtures. As the wavelength increases, both n_e refractive index for the extraordinary ray and n_o refractive index for the ordinary ray decrease and then gradually saturate in the near-infrared region.

Temperature also plays an important role in affecting the liquid crystal refractive indices. As the temperature increases, n_e behaves differently from n_o. The derivative of n_e(i.e., ∂^{ne}/∂_T)always negative. However, $\partial^{n^o}/\partial_T$ changes from negative to positive as the temperature exceeds the crossover temperature. For elevated temperature operation of a liquid crystal device, temperature-dependent refractive indices need to be modeled accurately. Some semi-empirical models [4-5] have been developed for describing the temperature effect on the liquid crystal refractive indices. However, a comprehensive model would be much more desirable.

In the present investigation, we have been consider three compounds namely; 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB), 4-cyano-4-n-pentyl-cyclohexanephenyl (5PCH) and cholesteryl acetate (CA). Mixture of these molecules exhibits a very interesting re-entrant nematic and re-entrant smectic-A phases with an additionally induced chiral smectic phases sequentially when the specimen is cooled from its isotropic melt. The unusual sequence of these phases were observed using microscopic technique and also been verified from the results of optical anisotropic techniques. Optical anisotropy of Cauchy coefficients and dispersive power of given ternary mixture of liquid crystalline molecules has been discussed [6].

EXPERIMENTAL STUDIES

In the present work: we have been considered two compounds namely, 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB), 4-cyano-4-n-pentyl-cyclohexanephenyl (5PCH) and cholesteryl acetate (CA). For the experimental studies; here we have chosen a 55% of CPHB molecules mixed with 25% of 5PCH and 20% of CA. 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 they 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 [7-9].

LIQUID CRYSTALLINE PROPERTIES

The hot-stage Gippon-Japan-polarizing microscope was used to observe the stability of molecular orientation of unusual re-entrant nematic and re-entrant smectic-A phase of liquid crystalline mesophases, the sequence of this type of unusual phases were exhibited by the sample of ternary mixture of thermotropic liquid crystals: 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB), 4-cyano-4-n-pentyl-cyclohexanephenyl (5PCH) and cholesteryl acetate (CA). The given concentrations of cyano group of symmetric molecules are additionally added with the small concentration of cholesteryl molecules are exhibits an very interesting unusual sequence of re-entrant nematic and focal conic domains of re-entrant SmA phases with an induced chiral smectic-C* phases are obtained by sequentially on cooling the specimen from its isotropic melt. The existence of microscopic observations of nematic, smectic-A and smectic-C* phase are as shown in figure 1(a, b and c)[10, 11].

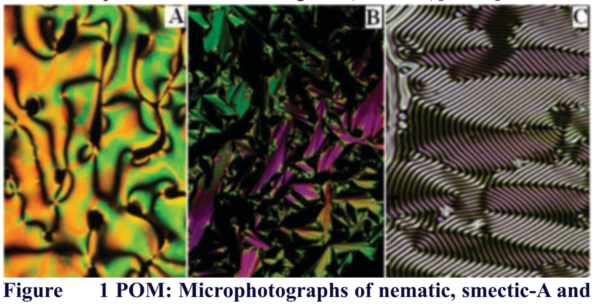

Figure 1 POM: Microphotographs of nematic, smectic-A and smectic-C* phases.

OPTICAL ANISOTROPY OF WAVELENGTH DEPENDENT REFRACTIVE INDICES

The complex molecular systems such as organic molecules, drugs, dyes and nucleic acids are of liquid crystals: that involving a short and long-range molecular interaction. Many of the models are used to address the wavelength and temperature dependencies of the liquid crystal refractive indices [12, 13]. 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 liquid crystal refractive indices for Blue and Green colors of wave lengths λ= 486 (Blue) and 546 (Green) nm. The refractive indices for extraordinary ray (ne) and ordinary ray (no) of the given ternary mixture were measured for the color of wavelengths λ= 486 (Blue) and 546 (Green) nm at different temperatures. The temperature variations of blue and green colors of wavelength-dependent refractive indices are as shown in figure 2. From the fig, it is very clear: extraordinary ray (ne) and ordinary ray (no) 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. The wavelength and refractive indices of cyano group and cholesteryl molecules are segregated optimize the cell design of full colour display. The temperature 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 birefringence changes appreciably[14], which indicates that the changes correspond to existence of re-entrant nematic and re-entrant smectic-A phases with an induced chiral smectic-C* phases. The multi-wavelength refractive index studies help us to develop photonic applications.

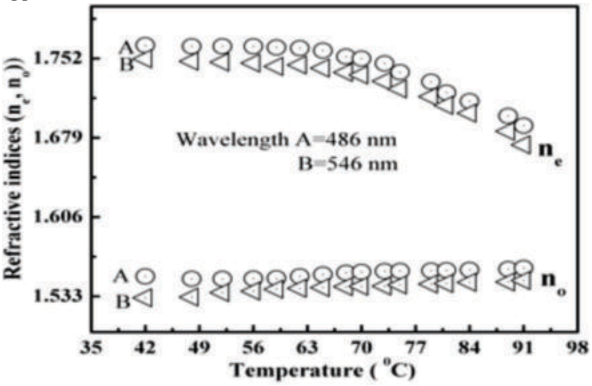

Figure 2. Temperature variations of wavelength dependent Refractive indices for the ternary mixture of CPHB, 5PCH and CA molecules.

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 the following colour.

$$\text{Dispersive power} \qquad \omega_s = \frac{\delta_B - \delta_G}{\delta} \text{ ----- (1)}$$

where n_B = average refractive index <n> of the material for blue light, n_G = average refractive index <n> of the material for green light, n = refractive index <n> of the material for the mean light, and

$$n = \frac{n_B + n_G}{2} \qquad \text{(Approximately)}$$

Then

$$\delta_B = (n_B - 1)^* A, \qquad \delta_G = (n_G - 1)^* A$$

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 following colour is

$$\omega = \frac{n_B - n_G}{n - 1}$$

Or

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

$$\text{Where } dn = \frac{n_B + n_G}{2} \qquad \text{----- (2)}$$

Using Equation (1), the dispersive power value ω is estimated for the ternary mixture of 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB), 4-cyano-4-n-pentyl-cyclohexanephenyl (5PCH) and cholesteryl acetate (CA) liquid crystalline materials for different two colours such as Blue and Green colours. The temperature variations of dispersive power for Blue and Green, colours of wavelength are as shown in figure 3.

From the figure it has been that: two colour combinations of wavelength such as: λ=486 (Blue), 546(Green), these are slightly changes in dispersive power values. Change in temperature, which causes to changes in the values of dispersive power corresponding to the above wavelengths. The dispersive power values are in the given cyano group of derivatives and cholesteryl molecules shows variation with temperature: which are similar to that obtained in the case of water [15] and quartz [16].

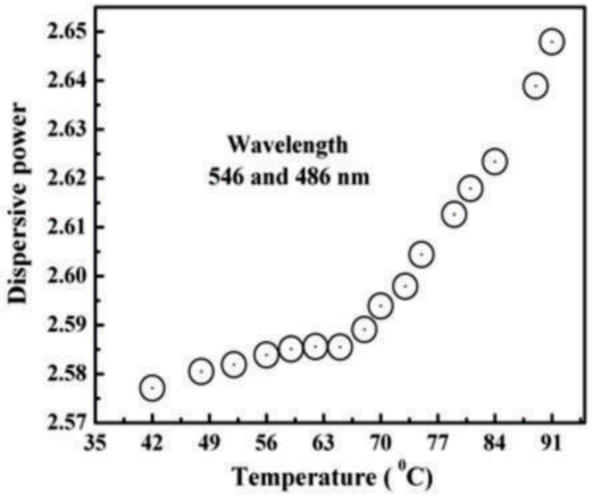

Figure 3. Temperature variations of dispersive power for the ternary mixture of CPHB, 5PCH and CA molecules.

Cauchy Coefficient Of Liquid Crystalline Materials:

Cauchy formula is an empirical relation between refractive index and wavelength of light for particular transparent material. The most general form of Cauchy's equation is

$$n(\lambda) = A + \frac{B}{\lambda^2}$$

Where n is refractive index, λ is wavelength. A and B is co-efficients: that can be determined for given material for measured refractive index at known wavelength.

The original Cauchy equations are used to describing the wavelength and temperature-dependent refractive indices of anisotropic liquid crystals. The original Cauchy equation was intended for the isotropic gases and liquids [17, 18]. Cauchy equations are not only applied to single liquid crystal materials, but we derive a two-coefficient Cauchy model for the refractive indices of low birefringence liquid crystalline mixtures. The given ternary mixture of given molecules 4-heptyl-benzoic acid 4-cyano-phenyl ester (CPHB), 4-cyano-4-n-pentyl-cyclohexanephenyl (5PCH) and cholesteryl acetate (CA) are shows the derivation for two-coefficient Cauchy equations.

$$n(B) = A + \frac{B}{\lambda_B^2} \qquad \text{-----} (1)$$

$$n(G) = A + \frac{B}{\lambda_G^2} \qquad \text{-----} (2)$$

where $n^{(B)}$ average refractive index <n> of the liquid crystalline material for blue light, $n^{(G)=}$ average refractive index <n> of the liquid crystalline material for Green light. Simplifying the equation 1 and 2. We get clear solutions for the blue and green colours of different wavelength.

$$B = (n_B - n_G)\frac{\lambda_B^2 \ \lambda_G^2}{\lambda_G^2 - \lambda_B^2} \qquad \text{-----} (3)$$

The obtained Cauchy's co-efficient B values are substituted to either equation 1 or 2. Equation gives the Cauchy's co-efficient of A values, which are completely the temperature and wavelength dependence of ternary mixtures of CPHB, 5PCH and cholesteryl molecules. The experimentally measured optical anisotropy of refractive index at any two colours of wavelengths then the two Cauchy coefficients A and B can be obtained. Any structural molecular interactions of ternary mixture of given liquid crystals, the equation 3 holds equally well for low birefringence of liquid crystalline mixtures. The estimated Cauchy Coefficients listed in Table 1. The optical transmission of Cauchy's Co-efficients of cyano group derivative and cholesteryl molecules depends on the scattering properties of nano-sized droplets and their distribution in space. The scattering of light in blue and green colors of wavelength induced by nano-sized nematic droplets is much more significant than that from the director's fluctuation. This feature is particularly important for the elevated temperature operation of liquid crystal devices.

Table 1: Obtained Cauchy coefficients A and B for ternary

mixtures of CPHB, 5PCH and cholesteryl molecules at different temperatures.

Temp (0C)	A	B (nm2)
42	1.6577	18.3052
48	1.6561	17.3956
52	1.6562	15.5764
56	1.6564	15.4628
59	1.6568	15.6902
62	1.6564	15.0080
65	1.6562	16.1449
68	1.6542	15.5764
70	1.6532	16.1449
73	1.6417	16.9408
75	1.6478	16.0313
79	1.6435	14.7806
81	1.6387	13.5299
84	1.6349	12.7341
89	1.6285	14.7806
91	1.6245	16.5998

CONCLUSION

Optical microscopic investigations of ternary mixture of CPHB, 5PCH and CA molecules show the existence of very interesting unusual re-entrant nematic and re-entrant smectic-A phases for given concentrations respectively at different temperatures. The experimentally measured wavelength dependent optical anisotropy of refractive index has been discussed. With the help of experimentally measured data of refractive indices: Cauchy's coefficients and dispersive power has been discussed for blue and green colour combinations of wavelengths.

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