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Optical Anisotropy of Birefringence and Optical Retardation Studies on Chromonic Phases of Nematic and Columnar Biphasic Regions of Liquid Crystalline Materials

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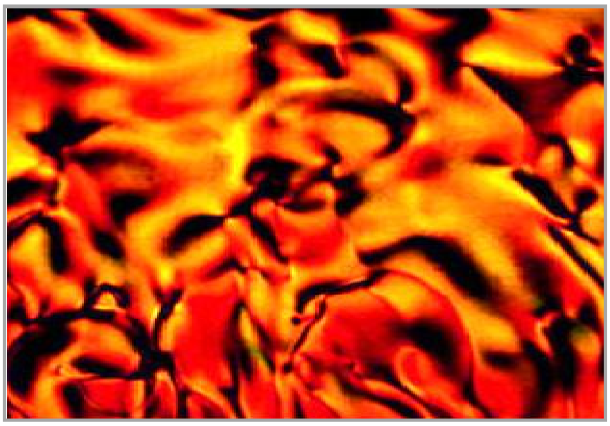
ABSTRACT

The crux of our study focuses on specific properties- thermal and optical of a system comprising of binary component system, namely: 4-n-(nonyloxybenzoic) acid (NOBA).and abietic acid. Mixture of these molecules shows the co-existent biphasic regions of nematic (N+I) and columnar smectic (C + I) phases: sequentially when the specimen is cooled from its isotropic phase respectively at different temperatures. The paper throws light on experimentally measured temperature-dependent liquid crystalline refractive index. The study also concentrates on thermoynamical response of optical birefringence and phase retardation of chromonic liquid crystallinephases.

Graphical Abstract:



Microphotographs obtained in between the crossed polars.

Keywords: Chromonics, Optical anisotropy, Thermodynamical studies, Optical retardation.

INTRODUCTION

Liquid crystals are thermodynamically stable state of matter. Which exist between three dimensionally ordered crystal and completely disordered isotropic liquid. One of the important factor required for an organic compound to exhibit a liquid crystalline phase is the shape or geometric anisotropy of constituent molecules. Liquid crystals have imperfect long range orientational order and/or positional order. Thus they have some properties of liquids and have anisotropic properties of crystals like birefringence. Now: recent studies shows the combination of self-ordering, ease of alignment, sensitivity to change the conditions of additives, coupled with their optical and electro-optical properties, that makes the possible range of sophisticated devices, which including polarizer's, optical compensators, light-harvesting devices and micro patterned materials and the fact that they are water-based: hence if they suggests a future role in biosensors for medical diagnosis [**1-4**].

In the present work, we have considered the mixture of 4-n-(nonyloxybenzoic) acid (NOBA).and abietic acid. The co-existent biphasic regions of nematic (N+I) and columnar smectic (C + I) phases have been observed using optical microscopic technique and they have been also verified from the results of optical anisotropic techniques. Thermodynamical response of optical-birefringence of the molecules has been discussed to understand the stability of chromonic phase, chemical structure and molecular dynamics of the binary mixture of liquid crystalline materials. Optical retardation studies have also been discussed.

MATERIALS AND METHODS

In the present study, we used the materials, namely, 4-n-(nonyloxybenzoic) acid (NOBA).and abietic acid. Mixtures of different concentrations of 4-n-(nonyloxybenzoic) acid (NOBA).and abietic acid were prepared and they were mixed thoroughly. The mixtures of these concentrations were kept in desiccators for 6 h. The samples were subjected to several cycles of heating, stirring and centrifuging to ensure homogeneity. Phase transition temperatures of these mixtures were measured with the help of Gippon-Japan-polarizing microscope in conjunction with 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 [**5**].

RESULTS AND DISCUSSION

1) **Optical Texture Studies:** The molecular orientation of optical textures exhibited by the samples was observed and recorded using Gippon-Japan-polarizing microscope and specially constructed hot stage. The specimen was taken in the form of thin film and sandwiched between slide and cover glass. All concentrations of NOBA, the abietic acid molecules have a strong tendency to stack into aggregates. A larger number of aggregated molecules are producing a poly-disperse system [**6-8**], the system of such molecules that can arrange themselves into ordered co-existent biphasic regions of nematic (N+I) and columnar smectic (C+I) phases at different temperature and at different concentrations, while the chosen molecules are slowly cooled from its isotropic phase. The different concentration of NOBA molecules are in abietic acid shows the existence of co-existent biphasic regions of nematic (N+I) and columnar smectic (C+I) phases respectively at different temperature. Themicroscopically observed co-existent biphasic regions of nematic (N+I) phase has shown in figure 1.The existence of co-existent biphasic regions of optical textures of chromonic molecules does not form micelles, but it shows any appreciable surface activity. However: the presence of NOBA molecules, abietic acid are tend to aggregate into stacks due to both weak Vander Waals interactions betweenthe cores and the hydrophobic effect [**9, 10**]. Usually the concentrations of given NOBA molecules increases, if there observed a degree of orientation and aggregated molecular size increases. If the molecular concentrations of NOBA are high enough, the mechanism of aggregated molecular sizes of chromonic liquid crystals are analogous to the worm-like micelles, that can formed by a surfactant molecules are in the solutions. The size of the aggregated molecules grows definitely, if the entropy increases when the

number of aggregates decreases. The stability of these chromonic phases depends on both temperature and concentration.

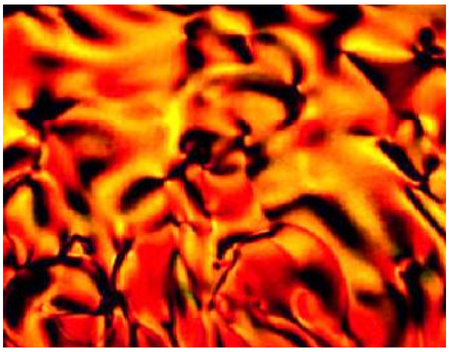


Figure 1. Microphotographs showing, Co-existent biphasic region of nematic (N + I) phase.

Themodynamical Studies on Optical-Birefringence: Studies on different concentrations of chromonic liquid crystalline materials are more important not only the technological applications but also the fundamental studies in the field of molecular interactions [**11**]. Thermodynamical responses are very important role to understand the phase stability, chemical structure and molecular dynamics of chromonic liquid crystals [**12, 13**]. Temperature dependent molecular orientations of chromonic phase of liquid crystals have been considered in many of technological applications. The application of these technologies woks on the properties of molecular structure and intermolecular interactions. The intermolecular forces such as van der Waals interaction, hydrogen bonds, electron donor interactions and steric repulsive interactions are individually or together may be responsible for increasing or decreasing the thermal stability of liquid crystalline phase [**14**].

Thermodynamical variations of co-existence biphasic region of chromonic phases at different concentrations of given binary mixtures of liquid crystalline materials are estimated using Boltzmann distribution laws. Draw a graph of variations of thermodynamical response of optical-birefringence as a function of mole fraction for the sample of NOBA in abietic acid at constant temperature 70°C is presented in figure 2, which clearly shows, the degree of separations microphase which is one of the parameters to controlling a physical properties of chromonic phase of liquid crystalline materials [**15**]. In this context the existence of optical-birefringence can be varied infinitesimally small either through chemical modification or through physical modification and hence it depends on nature of additivity of the molecules. The figure clearly illustrates that, statistically how the birefringence of molecules are thermodynamically changes at different concentrations in order to show the thermal stability of chromonic liquid crystalline phase. Here we noticed that: at constant temperature, given molecules are fractionally varies as increasing the concentrations of additive molecules. In this study it is very interesting to observe the spin temperature. Due to temperature gradient: on the surface area of (N+I) phase, the degrees of freedom of molecules are thermodynamically varies with one mole fraction to other mole fractions. If an increasing the mole fractions for the sample of NOBA in abietic acid; thermodynamical response of optical-birefringence of the molecular orientations are fractionally increases/decreases, i.e., fluctuate the molecules with spin temperature, because the effective intermolecular interactions are associated with the molecules of NOBA increases with the additive ones. The molecular ordering or the thermal phase stability of (N+I) phase at a constant temperature: the effective optical -anisotropic energies are responsible for the charges of carbons and the adjacent hydrogen molecules. The chemical interaction of these molecules shows an electrostatic potential, in which there re-produced by different partial charge distributions.In spite of these uncertainties, the full sets of partial charges are very useful, as it can provide a detailed insight into the molecular arrangement in co-existent biphasic regions of nematic (N+I) phase and which they reproduce the electrostatic potential.

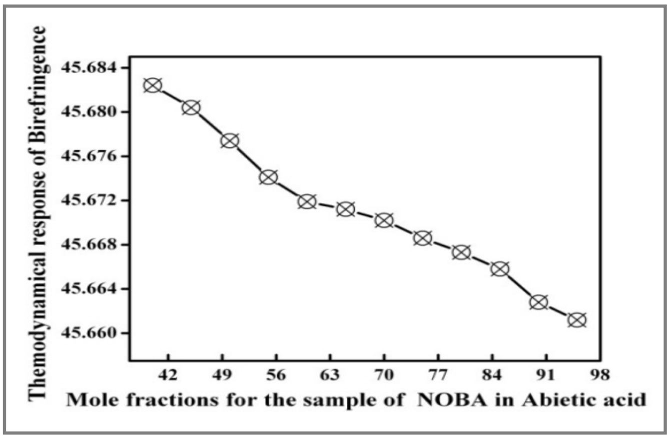


Figure 2. Variations of thermodynamically response of birefringence as function of mole fractions for the sample of NOBA in abietic acid.

Optical Phase Retardation: The precise determination of optical phase retardation studies on optical-birefringence of certain liquid crystalline materials play an important role in various fields of research. Photonic switching operation in the free space is an example. Switching operations of the device rely on the separation of polarization or the deflection of light beams: by means of liquid crystal cells whose birefringence is controlled electrically. Many techniques have been used for measuring the birefringence of liquid crystalline materials [**16, 17**]. Anisotropy of birefringence is responsible for the appearance of interference colors in liquid crystal display operating with plane-polarized light. Here: the index of refraction, such as extraordinary and ordinary rays traveled through a medium with different velocities: that gives rise to the colored appearance of liquid crystalline materials. Any of the liquid crystals: with positive birefringence, e-axis is the slow axis and o-axis is the fast axis. In this context: the optical axis is not parallel to the surface of the liquid crystalline phases; the extraordinary refractive index has to be replaced by the angle between the direction of propagation and the optical axis. The optical retardation is a wavelength dependent, so that the positive and destructive interferences are occurs at different wavelengths. Thus the results are in the suppression of some part of visible spectrum, that there will be a non-white color. Moreover, the birefringence is also wavelength and temperature dependent, because the refractive indices also vary with these parameters [**18**].

Optical retardation values of binary mixture of NOBA and abietic acid molecules were estimated at optical birefringence for different concentrations and at different thickness of chromonic liquid crystalline materials. In this study: the variation of optical retardation with birefringence has been observed. The variations of birefringence are fully dependent on thickness and shape of molecular aggregation in addition to their dependence on orientational order. However, we notice that: the optical retardation varies with mole percent and thickens of NOBA molecules. Variation of optical retardation as function of temperature dependent optical birefringence in the present case is as shown in figure 3. Mixtures of different concentrations of NOBA molecules with abietic acid show the variations of optical birefringence and hence it is observed that: the values of optical retardation increases with increasing the birefringence at different thickness of the given molecules. However, it is remarkably observed that: the nature of molecular aggregation of optical retardation varies significantly towards on cooling, that may appear due to the transformations of co-existent biphasic regions of nematic (N+I) phase to columnar smectic (C + I) phases. Here the variations of optical retardation are expected to be due to changes in the dimension of discs along with changes in the orientational order of the molecules.

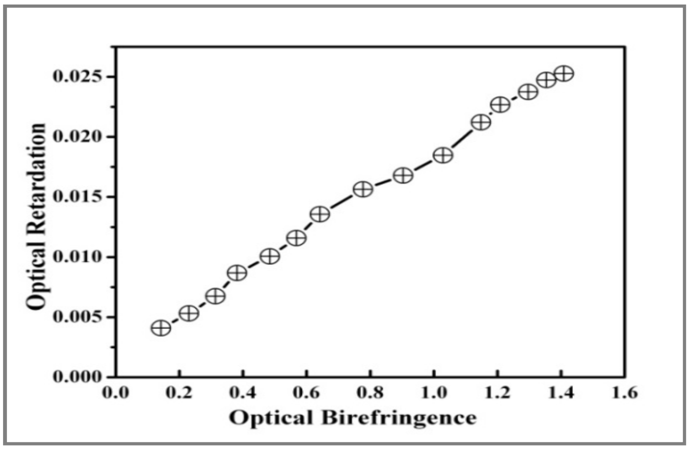


Figure 3. The variation of optical retardation as function of optical birefringence for a sample of NOBA in abietic acid.

APPLICATION

The studies of these parameters are helps to shows microscopically observed molecular self-assembly of co-existent biphasic regions of nematic and columnar smectic phases are changes with variations of temperature. The biphasic regions of nematic phases are the least ordered and widely used phase of the liquid crystals. Nematic liquid crystal and antimicrobial properties of other composites have received a lot of concentration and deep attention in the recent days for the reason of electro-optic applications.

CONCLUSION

Optical microscopic investigations of binary mixture of NOBA and abietic acid molecules clearly show the molecular ordering of co-existent biphasic regions of nematic (N+I) and columnar smectic (C+I) phases for different concentrations of binary mixture of given molecules respectively at different temperatures. Observation from the various studies of these unconventional sequences are clearly indicates the mixture exhibits a lyotropic chromonic liquid crystalline nature. At lower concentrations of NOBA, the molecular orientations are not aligned and they start aligning as the concentration increases at higher temperatures. Thermodynamic response of optical birefringence have also been discussed to understand statistically how the birefringence is thermodynamically changes at different concentrations in order to show the thermal stability, phase stability, chemical structure and molecular dynamics of binary system of liquid crystalline phase. The temperature variation of birefringence across chromonic phases of N+I and C + I are more predominant than other transitions. Changes in optical retardation value are more expected to be due to changes in the aggregated molecular dimension of the discs along with changes in the orientational order of the given binary molecules.

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