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Optical Anisotropy of Chromonic Phases of Liquid Crystalline Materials

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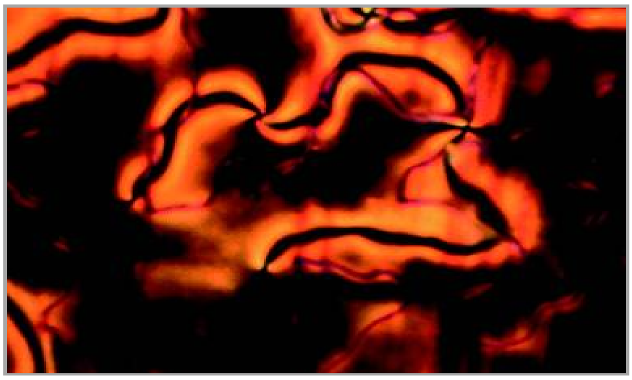
ABSTRACT

The crux of our study focuses on specific properties- thermal and optical of a system comprising of multiple component system, namely: curcumin, sodium dodecyl sulfate (SDS), and glacial acetic acid (GAA). Mixture of these molecules shows the existence of co-existent biphasic regions of nematic (N + I) and lyotropic nematic (N) 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 at varied wavelength. The study also concentrates on the temperature variations of optical transmittance of chromonic liquid crystalline phases.

Graphical Abstract



Microphotographs obtained in between the crossed polars.

Keywords: Ternary mixture, Optical anisotropy, Optical transmittance, Temperature-dependent Wavelength.

INTRODUCTION

Liquid crystal signifies a state of aggregation that is intermediate between the crystalline solid and the amorphous liquid. These share the anisotropic nature such as refractive index, birefringence, susceptibility, dielectric, magnetic and electrical properties [1, 2]. These are sensitive to temperature, and hence it possesses order and mobility at microscopic and macroscopic levels [3]. Specifically the temperature effect is vital for projection of displays. Refractive indices of liquid crystals are fundamentally interesting and practically useful parameters. Most liquid crystal light modulators, e.g., flat panel display devices, utilize the electric-field-induced refractive index change. In addition to the molecular constituents, the wavelengths andtemperature are the two most important factors affecting the liquid crystal refractive indices:for instance, to achieve a full-color display.

In the present work, our intention is to study the multi-component system, namely:curcumin, sodium dodecyl sulfate (SDS) and glacial acetic acid (GAA), which shows the existence of chromonicnature of the co-existent biphasic region of nematic (N+I) and lyotropic nematic (N) respectively at different temperatures. Using the microscopic technique these phases have been recorded. Optical and thermal studies were conducted to understand the optical anisotropy of the sample [4].

MATERIALS AND METHODS

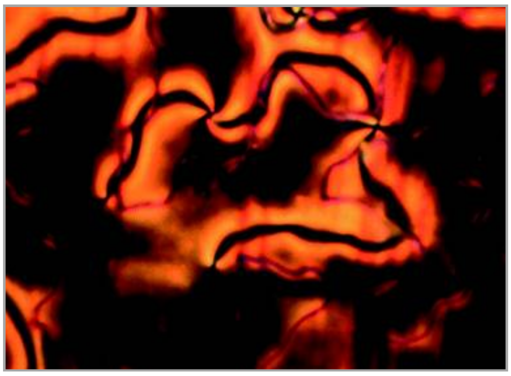
In the present study, we use the molecular compounds, namely:curcumin, sodium dodecyl sulfate (SDS) and glacial acetic acid (GAA). Using benzene as a solvent it was subjected to purification twice by adopting the method of re- crystallization. For our experimental studies, we have considered the ternary system of curcumin molecules are at 30% of concentration and 30% concentration of SDS molecules mixed with 40% concentrations of GAA. To ensure homogeneity the ratio of given mixtures in desiccators is kept in exposures to many cycles of heating, stirring and centrifuging. Transition temperatures of given concentrations were measured using a Gippon-Japan polarizing microscope in conjunction with a hot stage. For microscopic observations the samples take their place on slide. 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.

For the optical transmittance measurement: the sample was into the standard sample holder pre-treated for planar alignment having 5μm spacer by heating it ten-degree centigrade above the clearing point of the compound and then introducing the experimental sample at one end of the holder it was filled in the sample holder by the capillary action and sample holder was slowly cooled down to the room temperature. Now sample holder is placed between two crossed polarizer's of polarizing microscope model CENSICO (7626) fitted with a hot stage and light intensity coming through the eyepiece has been measured by light-dependent resistance (LDR). The resistance value of LDR corresponding to varying light intensity due to temperature variation of the sample is proportional to the inverse of optical transmittance and it was directly measured by a digital multi-meter attached to it.

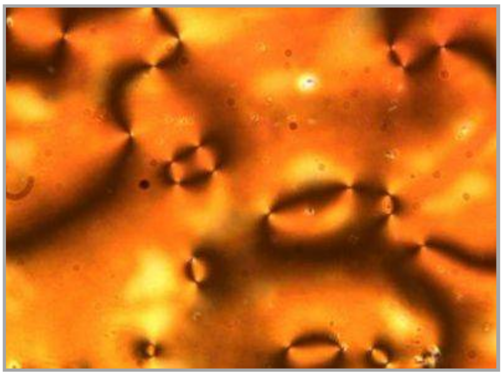
RESULTS AND DISCUSSION

Optical Texture Studies: Molecular optical textures were observed and recorded using the Gippon Japan-polarizing microscope and specially constructed hot stage. The specimen was taken in the form of thin-film is sandwiched between the slide and cover glass. For our experimental studies: the ternary mixture (Curcumin in (SDS+GAA)) of given moleculesare slowly cooled from its isotropic melt, the genesis of nucleation starts in the form of molecular orientations, which grows and segregates the molecules, which are identified as chromonic nature of the co-existent biphasic region of nematic (N+I) phase and is as shown in figure 1 (a). On further cooling, the N+I phase changes over to the lyotropic nematic (N) phase as shown in figure 1 (b); it remains up to room temperature. Here it is found that the molecular segregation increases towards the room temperature. In the lyotropic nematic N phase, the molecules are stacked to form long columnar aggregates that align parallely. There is no long-range positional order among the columns.

Chromonic phases of liquid crystals hold great promise to applications as optical materials and devices in technology, some of the potential applications such as biosensors [5-7], polarizing films [8-10], optical retardation plates, [11, 12] and micro-patterned polarizing elements for stereoscopic displays [13-16].



(a).Co-existent biphasic region of nematic (N + I) phase.



(b). Schlieren texture of lyotropicnematic (N) phase.

Figure 1. Microphotographs obtained in between the crossed polars,

Studies on Refractive Indices: Liquid crystal is a complex molecular system involving short and long-range molecular interactions. Several models have attempted to address the wavelength and temperature dependencies of the liquid crystal refractive indices [17, 18]. Here we use a multi-wavelengths Abbe-refractometer to measure the liquid crystal refractive indices for red, blue, and green (RGB) colors of wave lengths λ=486 (Blue), 546 (Green),and 656 (Red) nm. 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 red, blue, and green 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 wavelength effect shows: according to our experimental data, the value of refractive indices decreases with increasing the colors of wavelength. From the figure, it can also be observed that: wherever there is anisotropic liquid crystalline phase transition, the values of birefringence changes appreciably, which indicates that the changes correspond to co-existent biphasic region of nematic (N+I) phase to lyotropic nematic (N).

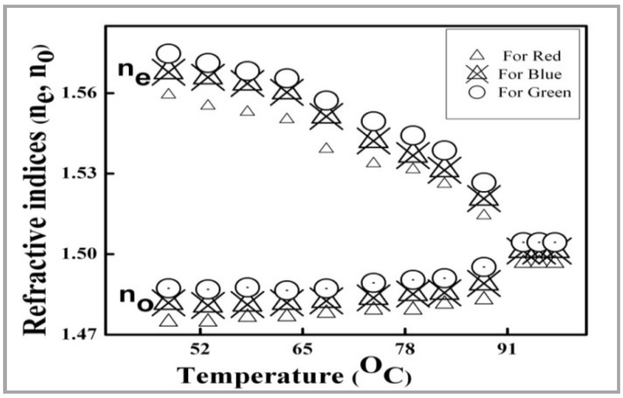


Figure 2. Temperature variations of refractive indices for different wave lengths of given sample.

Optical Transmittance Studies: Figure 3 shows temperature variation of optical transmittance is shown in. The figure shows the value of optical transmittance increases slowly with an increase in temperature from 48°C to 62°C, the sequence of phase changes appear from crystalline to near isotropic phase, region where suddenly some changes become visible in the value of optical transmittance from 68°C to 92°C [19, 20]. The optical transmittance is continuous at the crystalline phase to Nematic (N) phase, Nematic (N) phase to co-existent biphasic region of nematic (N + I) phase transition. Here we noted that, the molecular orientations of different liquid crystalline phase transition are not energetic. The optical transmittance decreases with increasing the temperature, and it diverges on approaching nematic (N) phase and co-existent biphasic region of nematic (N + I) phases. The divergence of optical transmittance can be related to the first-order or second-order transition. Here in the region of nematic (N) and co-existent biphasic region of nematic (N + I) phases, the optical transmittance shows a steep decrease and it is very nearer to isotropic region: it is one of the important points to observe the phase transition by detecting the enthalpy change associated with it and also by measuring the level of enthalpy changes: from this enthalpy studies we can able to learn the type of the phase transition [21], which is the characteristic of first-order transitions of co-existent biphasic region of nematic (N+I) and Nematic (N) phases respectively at different temperatures.

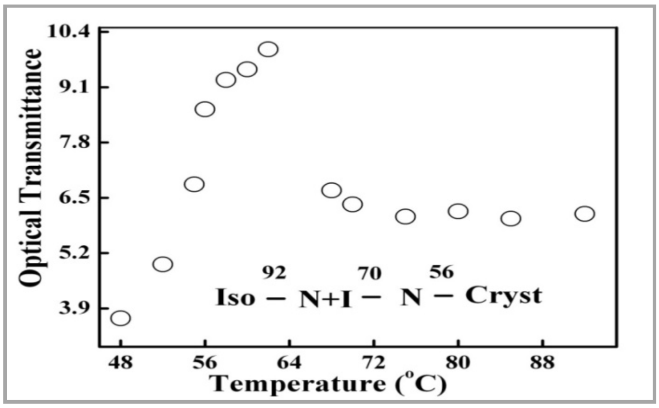


Figure 3. Temperature variation of optical transmittance for the given sample.

APPLICATION

This study shows how microscopic technique and optical anisotropy of binary mixtures of chromonic phases of liquid crystalline materials changes with variations of temperature.

CONCLUSION

Optical microscopic investigations of ternary mixture of Curcumin molecule mixed with SDS+GAA molecules and is shows an molecular order in the form of co-existent biphasic regions of nematic (N+I) and schlieren texture of lyotropic nematic (N) phases sequentially when the cooling of the specimen occurs from its isotropic phase. The temperature and wavelength-dependent experimentally measured refractive indices are unambiguously corresponding to chromonic phases: Temperature and wave lengths play a significant role in affecting optical-anisotropy of refractive indices, birefringence, and it is helpful to understand full-colors display of three primary colors red, green, and blue. The experimentally measured optical transmittance has been discussed based on the order of phase transition of different liquid crystalline phases.

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