

# Conductivity Measurements and Thermodynamical Response of Optical-Birefringence of Reentrant Smectic Phase of Liquid Crystalline Materials

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**ABSTRACT:** The multi-component system of *p*-*n*-Decyloxybenzoic acid (10OBAC), 4, 4'-di-*n*-heptyl-azobenzene (7AB7) and cholesteryl nanonate (CN), exhibits liquid crystalline mesophases, like cholesteric and induced smectic phases, such as SmA, SmC, ReSmA, SmC\* and SmE phases sequentially when the specimen is cooled from its isotropic phase. These phases have been observed by using microscopic and optical anisotropic technique. The electrical conductivity has been discussed based on the phase transition behavior of different temperature. Thermodynamical response of birefringence of reentrant smectic-A (ReSmA) has also been discussed to understand the stability of liquid crystalline phase, chemical structure and molecular dynamics of the given mixture.

**KEYWORDS:** optical textures; optical anisotropy; electrical conductivity; thermodynamical studies:

## I. INTRODUCTION

Comprehensive studies on the mesomorphic behavior of mixtures of non mesogenic compounds have been well investigated. Binary/ternary mixtures of some non-mesogenic compounds exhibit lyotropic and thermotropic mesophases. Generally, the chemical structure is the most salient feature of molecules forming lyotropic mesophases in the presents of solvent. It is quite interesting to investigate the molecular self assembly of lyotropic mesophases formed by organic solvent system. [1-3].

## II. LITERATURE SURVEY

In the present study, we have considered the multi-component system namely, *p*-*n*-Decyloxybenzoic acid (10OBAC), 4,4'-di-*n*-heptyl-azobenzene (7AB7) and cholesteryl nanonate (CN). Different liquid crystalline phases such as cholesteric, SmA, SmC, ReSmA, SmC\* and SmE phases were observed by using optical microscopic technique and hence they have been verified from the results of optical anisotropic techniques. The thermodynamical response of birefringence of reentrant smectic-A (ReSmA) has been discussed.

E.g. Soft soil, Guardrail, Steep Slope

## III. METHODOLOGY

In the present investigation, we have considered multi-component system of liquid crystalline materials namely: *p*-*n*-Decyloxybenzoic acid (10OBAC), 4, 4'-di-*n*-heptyl-azobenzene (7AB7) and cholesteryl nanonate (CN). Mixture of different concentrations of 10OBAC in 7AB7+CN was 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 Leitz-polarizing microscope in conjunction with a hot stage. The

melting points of purified samples are in good agreement with the reported value. Refractive indices of these mixtures were measured at different temperatures employing the technique described in our earlier paper [4]. The electrical conductivity measurements for given mixture at different temperatures were carried out using digital LCR meter and a proportional temperature control unit.

#### IV. SIMULATION RESULTS

##### OPTICAL TEXTURE STUDIES

For the purpose of optical texture studies, the given mixtures of the samples was sandwiched between a slide and a cover glass and then the optical textures were observed using a Leitz polarizing microscope in conjunction with a hot stage. When given mixtures shows the existence of different liquid crystalline induced phases such as cholesteric, SmA, SmC, ReSmA, SmC\* and SmE phases: that have been obtained at different concentrations of given multi-component systems are at different temperatures sequentially when they cooled from their isotropic melt. The mixture with different concentrations ranging from 5% to 50% of 10OBAC in 7AB7+CN has been considered for the experimental studies. When the specimen of 35 % of 10OBAC in 7AB7+CN is cooled from their isotropic liquid phase, it exhibits I-Cho-SmA-SmC-ReSmA-SmC\*-SmE-K phases sequentially. While the sample is cooled from isotropic liquid phase, the genesis of nucleation starts in the form of small bubbles growing radially, which form a fingerprint pattern of cholesteric phase with large values of pitch [5-7], is shown in Figure 1(a). On further cooling the specimen, the cholesteric phases are slowly changed over to a well-defined focal conic fan-shaped texture, which is the characteristic of SmA phase and is shown in Figure 1(b). The SmA phase is unstable and then changes over to the schlieren texture of SmC phase as shown in Figure 1(c), and then this phase is also not energetically stable, which changes over to ReSmA [8] phase. On further cooling the specimen, this phase changes over to SmC\* phase, which exhibits radial fringes on the fans of focal conic textures, they are the characteristic of chiral SmC\* phase, sequentially this phase changes over to SmE phase and then this phase remains stable till at room temperature.

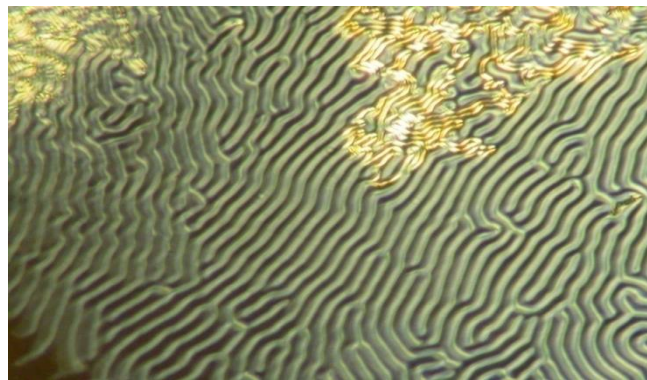


Figure 1(a). Fingerprint pattern of cholesteric phase at temperature 112 °C (250X).

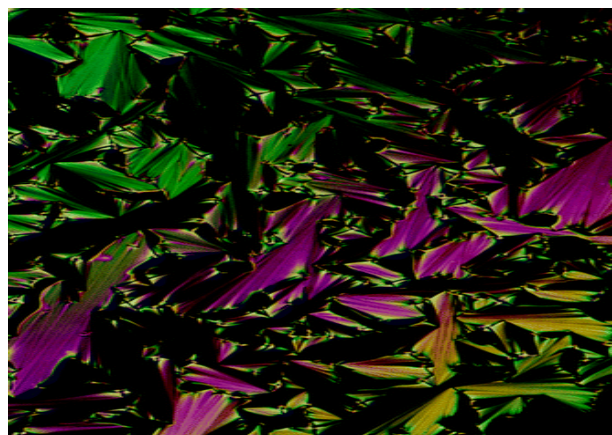


Figure 1(b). Focal conic fan shaped texture of SmA phase at temperature 93 °C (250X).

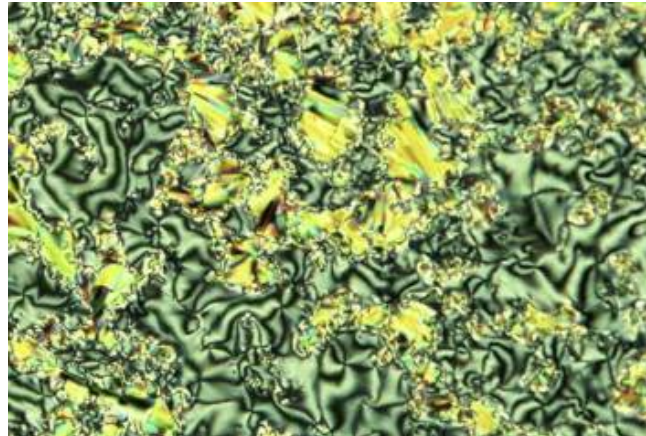


Figure 1(c). Schlieren texture of SmC phase at temperature 75 °C (250X).

## OPTICAL ANISOTROPY

Results of this investigation are further supported by the optical studies. The refractive indices for extraordinary ray ( $n_e$ ) and ordinary ray ( $n_o$ ) of the given mixtures were measured for the different concentrations and at different temperatures using Abbe Refractometer. The value of  $n_e$  is greater than  $n_o$ , indicating that the material is uniaxial positive. The values of electrical susceptibility for the sample of 35 % of 10OBAC in 7AB7+CN have been calculated using Neugebauer relation [9, 10,] at different temperatures. The variation of electrical susceptibility as a function of temperature of the given ternary mixture is shown in Figure 2. From the figure, it can be observed that: wherever there is transition between isotropic and liquid crystalline phase, the value of electrical susceptibility changes appreciably, which indicates that the changes correspond to cholesteric and induced reentrant smectic modifications. Further, with increase in the concentrations of 10OBAC, the value of electrical susceptibility decreases with temperature because the effective optical anisotropy associated with the molecules of 10OBAC also decreases.

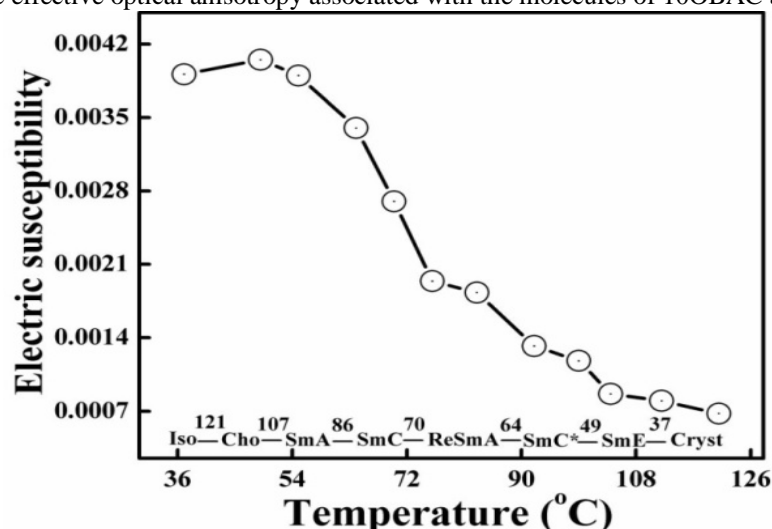


Figure 2. Temperature variation of electrical susceptibility for the mixture of 35 % of 10OBAC in 7AB7+CN.

## CONDUCTIVITY MEASUREMENTS

Electrical-conductivity measurements help in getting better idea on the phase behavior with temperature. An abrupt increase or decrease of electrical-conductivity with temperature relates to the phase transition behavior of lyotropic, thermotropic and chromonic systems. The temperature variations of electrical conductivity are as shown in

Figure 3. From this figure some changes are observed in the value of electrical conductivity temperature ranging from 45°C to 127°C, while the specimen cooling from its isotropic phase for the mixture of 35% of 7AB7 and CN. From the microscopic observation: the sequence of liquid crystalline phase changes from Cho–SmA–SmC–ReSmA–SmC\*–SmE phases respectively at different temperatures. Here it has been found that the electrical conductivity goes on increasing as the temperature decreases. This suggests that aggregated molecular size starts growing towards lower temperatures and then the system becomes more ordered [11-15].

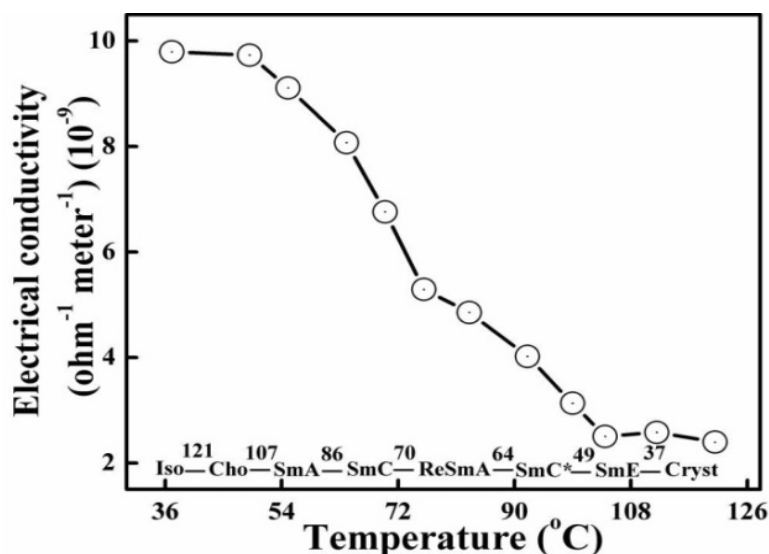


Figure 3. Temperature variation of electrical-conductivity  $\sigma$  ( $\times 10^{-9} \Omega^{-1} \text{m}^{-1}$ ) for the mixture of 35 % of 10OBAC in 7AB7+CN.

### THEMODYNAMICAL RESPONSE OF OPTICAL-BIREFRINGENCE

Studies on multi-component system of liquid crystalline materials are more important not only from the viewpoint of their technological applications but also from that of fundamental studies in the field of molecular interactions [16]. Thermodynamical response of birefringence is a very important role to understand the stability of liquid crystalline phase, chemical structure and molecular orientations of liquid crystals [17, 18]. Temperature dependent molecular orientations of liquid crystalline phases have been considered in many technological applications. The applied applications of these technologies are based 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 they individually or together may be responsible for increasing or decreasing the thermal stability of liquid crystalline phase [19]. Thermodynamical response of birefringence for reentrant smectic-A ((ReSmA) phase at different concentrations of multi-component system of liquid crystalline materials are estimated using Boltzmann distribution laws. If we draw a graph of variations of thermodynamical response of birefringence for reentrant smectic-A ((ReSmA) phase as a function of mole fractions for the sample of 10OBAC in 7AB7+CN at constant temperature 65 °C is presented in Figure 4, which clearly shows, the degree of micro molecular separations are one of the parameters to controlling a physical properties of given different liquid crystalline materials [20]. In this context the existence of birefringence for reentrant smectic-A ((ReSmA) can be varied either through chemical modification or through physical modification and hence they are depends on nature of additives molecules. From the figure: we have been clearly observed that, statistically how the molecular orientations of birefringence for reentrant smectic-A ((ReSmA) phase is thermodynamically changes at different concentrations in order to show the thermal stability of liquid crystalline phase. Here if at constant temperature: the birefringence of given molecules are fractionally varies as increasing the concentrations of the additive molecules. In this study: it is very interesting to observe a spin temperature. Due to this gradient temperature: on the surface area of liquid crystalline reentrant smectic-A phase, the values of birefringence of the given molecules are thermodynamically varies with one mole fraction to the others. If an increasing the mole fractions for the sample of 10OBAC in 7AB7+CN; the value of thermodynamical



response of birefringence is restrained and then it varies from concentrations to concentrations and hence it also changes the intermolecular energy of given molecules with spin temperature, because the effective intermolecular interactions of anisotropic energy associated with the molecules of 10OBAC increases with the additive ones. The molecular ordering or thermodynamical stability of reentrant smectic-A at given constant temperature: the intermolecular interactions of anisotropic energy are responsible for the charges of carbon and adjacent hydrogen molecules: and hence it shows the correct electrostatic potentials, which are reproduced by different partial charge distributions. If an increasing the mole fractions for the samples of 10OBAC in 7AB7+CN, it shows small variation of electrostatic potentials and which they around the molecule. In spite of these uncertainties, the full sets of partial charges are very essentials as it can provide a detailed insight into the molecular arrangements of the mesophase.

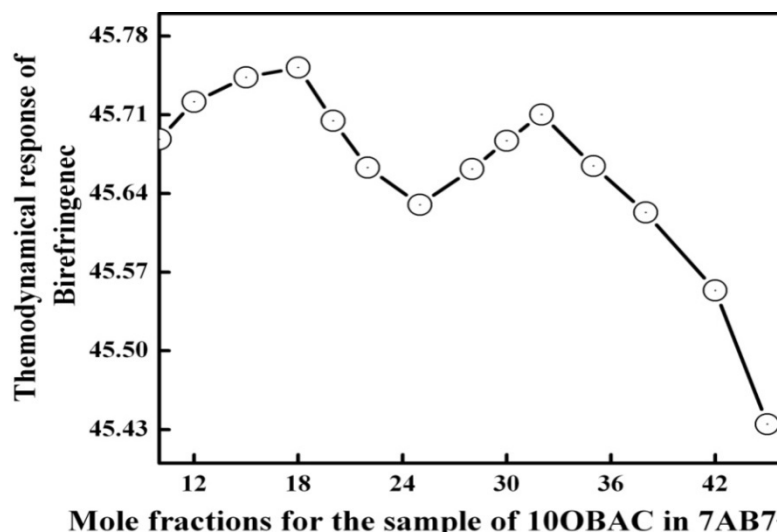


Figure 4. Thermodynamical response of optical-birefringence as a function of mole fraction for The sample of 10OBAC in 7AB7+CN.

## V. CONCLUSION

Microscopic investigation of the binary/ternary mixture of 10OBAC in 7AB7+CN shows the existence of Iso→Cho→SmA→SmC→ReSmA→SmC\*→SmE→Cryst phases for all concentrations of given mixture. The drastic changes in values of optical anisotropic measurements with variation of temperature unambiguously correspond to cholestric and induced reentrant smectic, respectively at different concentrations. Electrical conductivity measurements have also done to understand the molecular orientations and stability of the liquid crystalline phases and then we Thermodynamical response of birefringence of reentrant smectic-A (ReSmA) phase have also been discussed to understand: statistically how it thermodynamically changes at different concentrations in order to show the thermal stability, phase stability, chemical structure and molecular dynamics of given mixture of liquid crystalline materials.

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