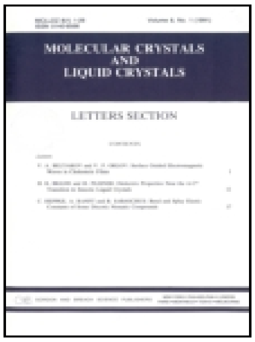

Molecular Crystals and Liquid Crystals

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Optical and electro-optical studies on liquid crystalline materials

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ABSTRACT
In the present work, our investigation is to study on the optical and electrical properties of multi-component system of cholesteryloleate (CO), sodium oleate (Naol), and Glacial acetic acid (GAA). Mixtures of these molecules exhibits cholesteric, SmA, SmC, and SmG phases sequentially when the specimen cooled from its isotropic phase. These phases have been characterized by using microscopic technique. The temperature variations of optical transmittance have been discussed. Temperature dependent electro-optical phase transition behaviors of the given molecules have been discussed.

KEYWORDS
Molecular orientation; optical textures; optical transmittance; Electro-optical studies

Introduction

Lyotropicnematics, generally formed by solution of amphiphile materials, water and co-surfactants, they are anisotropic mesophases of matter and very sensitive to external magnetic fields [1–3]. These mesophases are sorted into three types: optically uniaxial nematic–calamitic (N_C) and nematic–discotic (N_D) mesophases and optically biaxial (Nbx) mesophase. These mesophases exhibit both long-range orientational order and short-range translational order based on the formation of miceller aggregates [4]. NMR experiments [5, 6] investigated that N_C and N_D mesophases have rod-like and disk-like miceller shapes, respectively [7]. Now recent studies shows the combination of self-ordering, ease of alignment, sensitivity to change the conditions of additives, coupled with their optical properties and electro-optical properties, makes possible a range of sophisticated devices, including polarizer's, optical compensators, light-harvesting devices and micro-patterned materials and the fact that they are water-based, suggests a future role in biosensors for medical diagnosis.[8–12].

In the present investigation, our aim is to study the mixture of multi-components, namely, cholesteryloleate (CO), sodium oleate (Naol) and Glacial acetic acid (GAA), which exhibits cholesteric and smectic phases, such as SmA, SmC, and SmG phases, respectively, at different temperatures. They were observed using microscopic technique and also have been verified from the results of optical anisotropic techniques. The temperature dependent optical transmittance and electro-optical studies have also been discussed.

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gmcl.

Materials and methods

In the present investigation, we have studied the multi-components systems, namely, cholesteryloleate (CO), sodium oleate (Naol) and these are obtained from M/s Eastman Organic Chemicals, USA. The chemicals are purified twice with benzene. Glacial acetic (GAA) was supplied from Kodak, Ltd., Kodak House. Mumbai, India. Mixtures of different concentrations of CO in (Naol+GAA) were prepared and were mixed thoroughly. The mixtures of different concentrations of the samples were kept in desiccators for a long time. The samples were subjected to several cycles of heating, stirring, and centrifuging to ensure homogeneity. The optical textures of these concentrations were measured with the help of a Leitz-polarizing microscope in conjunction with a hot stage. The samples were sandwiched between the slide and cover slip and were sealed for microscopic observations.

For the Optical Transmittance Measurement the sample was in to the standard sample holder pre treated for planar alignment having 5μm spacer by heating it 10°C above the clearing point of the sample and then introducing the sample at one end of the holder it was filled in the sample holder by the capillary action and sample holder was slowly cooled up to the room temperature. Now sample holder is placed between two crossed polarizer 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 has been directly measured by attached digital multi-meter.

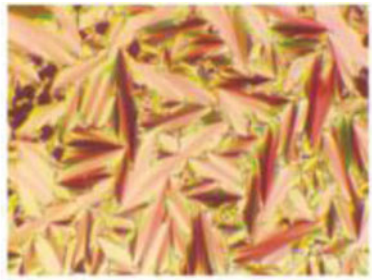
Electro optical measurements were carried out by the usual experimental setup of Williams [13]. It consists of tin oxide coated transparent conducting glass plate and the sample sandwiched between these two glass plates. Teflon spacers having thickness of $d = 39 \pm 1\ \mu m$ were used and observations were made at 56°C using polarizing microscope in conjunction with a hot stage.

Optical texture studies

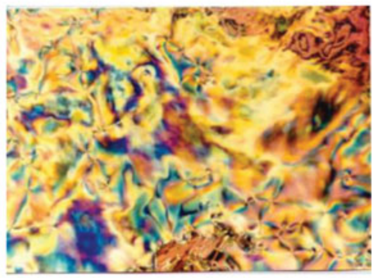
Molecular orientations of optical textures exhibited by the samples were observed and recorded using the Leitz-polarizing microscope in conjunction with hot stage. The specimen was taken in the form of thin film and sandwiched between the slide and cover glass. The concentrations from 10% to 80% of ternary mixture of CO in (Naol+GAA) have been considered for the experimental studies. When the specimen of 50% CO in (Naol+GAA) is cooled from its isotropic melt and hence it exhibits cholesteric, SmA, SmC, and SmG phases sequentially. While the sample is cooled from its isotropic phase, the genesis of nucleation starts in the form of small bubbles growing radially, which are identified as spherulitic textures of cholesteric phase. On further cooling the specimen, the texture slowly transform to focal conic fan texture of SmA phase in which the molecules are arranged in layers and the texture is as shown in Figure 1(a). On further cooling the specimen, the unstable SmA phase changes over to schlieren texture of SmC phase and it as shown in Figure 1(b). Sequentially on cooling the specimen, SmC phase slowly changes over to SmG phase and then it remains stable at room temperature [14].

Optical transmittance studies

Temperature variation of optical transmittance for the mixture of 50% CO in (Naol+GAA) is shown in Figure 2. This clearly illustrates that, the value of optical transmittance increases



a)



b)

Figure 1. Microphotographs obtained in between the crossed polars, (a) Focal conic fan shaped texture of SmA phase at temperature (2507×). (b) Schlieren texture of SmC phase at temperature (250×).

slowly with increase in temperature from 35°C to 120°C, while the sequence of phase appear from crystalline region to near isotropic region and suddenly some changes are observed in the value of optical transmittance from 100°C to 120°C [15].

The optical transmittance is continuous at the SmG-SmC, SmC-SmA, and SmA-Cho transition. Here it can be noted that, the molecular orientation of this transition is not (stable) energetic. The optical transmittance decreases while increasing the temperature and it diverges on approaching SmA and Cho phases. The divergence of optical transmittance can be related to the first-order or second order transition. Here in the region of SmA and Cho

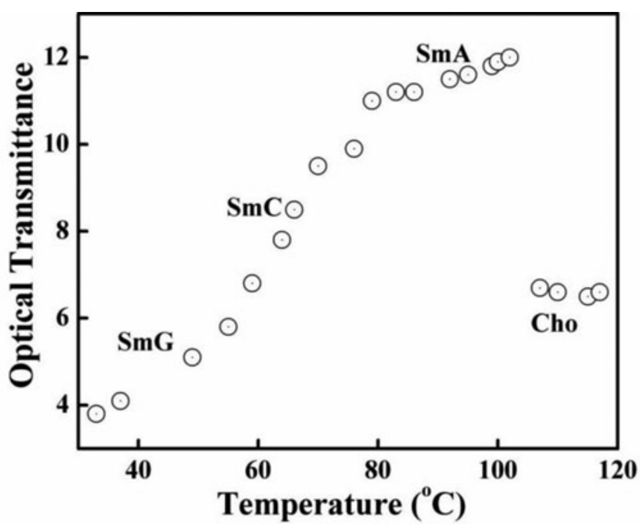


Figure 2. The temperature variations of optical transmittance for the mixture of 50% CO in (Naol+GAA).

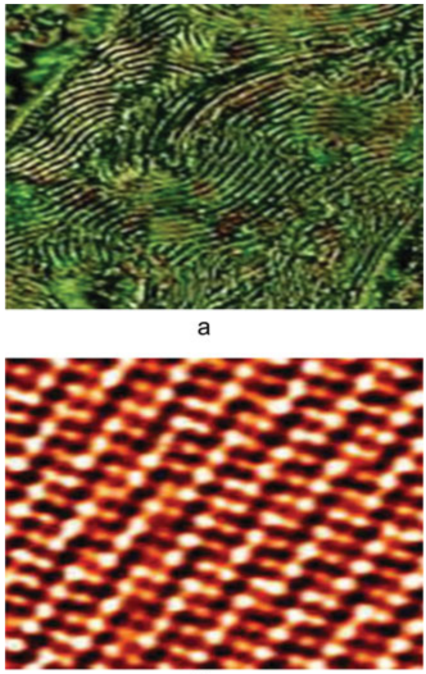


Figure 3. (a). Stripped pattern electro-optical texture. (b). Hexagonal grid pattern electro-optical texture.

phases, the optical transmittance shows a steep decrease and it is very close to isotropic phase: which is the characteristic of first-order transitions of Cho and SmA phases, respectively, at different temperatures.

Electro-optical studies

Electro-optical measurements are a very important tool in getting better idea on the phase behavior with electric field at constant temperature. In this experimental study we have been considered the sample for the mixture of 50% CO in (Naol+GAA) at constant temperature 58°C. When the applied voltage increases: the molecular arrangements of liquid crystalline phase start to fluctuate and begin to grow; hence it deforms gradually the original position. Remarkably it has been observed that, if at constant temperature, the various aspects of low frequency effects on the given mixture show the different directions of molecular re-orientations exhibited a flow patterns formed: such as stripped pattern and chevron textures: the formations of zig-zag domains are characteristic of chevron textures: the forming time of these patterns depends on the applied electric field. If there we observed the significant differences in the electro-mechanical responses of these textures. The stripe of textures does not have a linear electromechanical effect at low fields; only at higher fields does the mechanical vibration have a component of the frequency of the field. This indicates that the spontaneous polarization has rotated and is no longer parallel to the electric fields. In contrast to the director re-orientations, the layer structure is unchanged by the application of the field. Sequentially we have to increase the applied voltage above 22.20 V, the observed pattern becomes dynamic scattering mode-like and it has been appearing like irregularity of molecular re-orientations of liquid crystalline phase. The new disordered regions are arises probably due to the molecules not being confirmed to the orientations in the X, Z plane. If the voltage is kept constant for some time, a completely stationary and regular two-dimensional hexagonal grid pattern is observed. The stripped pattern and hexagonal grid pattern textures are as shown in Figure 3(a–b). The hexagonal grid pattern deforms gradually with increasing frequency and at some stage it becomes indistinguishable from the chevron texture. However, the hexagonal grid pattern is rather stationary and is formed in a short time at 250Hz, 23V. From the Figure 3(a), it follows that: an extremely regular hexagonal grid pattern is formed when the external electric field is applied. One of the regions is that: the formation of hexagonal grid pattern is the electronic charge injected by the applying external electric field [16–18].

Conclusion

Microscopic investigation of the multi-component system of CO in (Naol+GAA) shows existence of cholesteric, SmA, SmC, and SmG phases for all concentrations of the given mixture. The drastic changes in optical anisotropic measurements values unambiguously correspond to different liquid crystalline phases: respectively, at different concentrations and temperature. The experimentally measured optical transmittance has been discussed based on the order of phase transition of different liquid crystalline phases. Under the applied electric field at constant temperature unambiguously corresponds to optical purity of liquid crystalline phases. The various aspects of frequency effects on given mixture show different directions of molecular re-orientations: which exhibit a flow patterns formations such as stripped pattern chevron textures and hexagonal grid pattern textures and hence these textures microscopically have been observed.

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