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Electro-optic effect in mixture of 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 cholesteryl nonanoate (CN), Cetyl-dimethyl-ethylammonium bromide (CDEAB) and Ethylene glycol (EG). Mixtures of these molecules exhibits a liquid crystalline cholesteric, SmA, SmC, SmE and SmB 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

Liquid crystals are an attractive model system for studying mesophase ordering and phase transitions. The phase behavior of liquid crystal is strongly influenced by disorder and impurities and it is easily handled allowing for unique control of the important physical, optical and electrical parameters.

Recently, the attention has been given to binary mixtures of liquid crystals and compatible (i.e. miscible), low-molecular weight, and solvent as a system in which the intermolecular potential responsible for the liquid crystal order can be modified. The studies of liquid crystal and solvent systems have focused exclusively on the isotropic to smectic, nematic and cholesteric phase transitions as a function of solvent type and concentration. The liquid crystalline phase behavior can also be altered by using external electric and magnetic fields. Some of researcher done a large amount of work: in order to study the effect of electric fields on the optical properties of some liquid crystalline materials[1-18]. Later: the potential applications of these effects have been explored for display devices. At lower frequency region effect of electric field on the temperature dependent liquid crystalline phase causes some pattern such as grid, chevron and dynamic scattering mode patterns. The system of these patterns is of interest for developing electronic devices, and it is of special interest to study these non-equilibrium phenomena from the stand point fluid mechanics.

In the present investigation, our aim is to study the multi-component system of the compounds namely, cholesteryl nonanoate (CN), Cetyl-dimethyl-ethylammonium bromide (CDEAB) and Ethylene glycol (EG), which exhibits cholesteric, SmA, SmC, SmE and SmB phases, respectively at different temperatures. These phases were observed using microscopic technique and then also study the effect of electro-optical phase transition behavior of the given liquid crystalline materials. Optical anisotropy has also been discussed.

MATERIALS AND METHODS

In the present investigation, we have used the multi-component system of the materials namely; cholesteryl nonanoate (CN), Cetyl-dimethyl-ethylammonium bromide (CDEAB) and these are obtained from M/s Eastman Organic Chemicals, USA. The chemicals are purified twice with benzene. Ethylene glycol was supplied from Kodak, Ltd., Kodak House. Mumbai, India. Mixtures of different concentrations of CN in (CDEAB+EG) were prepared and were mixed thoroughly. These mixtures of different concentrations 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 Leitz-polarizing microscope in conjunction with hot stage. The samples were sandwiched between the slide and cover slip and were sealed for microscopic observations.

Refractive index has been measured using Abbe's Refractometer. A polarizer has been introduced in Abbe's refractometer to block the extraordinary ray, which clears the contrast of the boundary line at view of Refractometer and hence to calculate birefringence Δn. Abbe's Refractometer temperature is controlled by circulating heated oil using JULABO F-25, refrigerated circulator. The temperature was measured by placing a thermocouple in close vicinity of the sample with an accuracy of 0.1^0C.

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 ^{0}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 eye-piece 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[15]. 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 ^{0}C using polarizing microscope in conjunction with a hot stage.

OPTICAL TEXTURE STUDIES

The molecular orientations of the optical textures exhibited by the samples were observed and recorded using the Leitz-polarizing microscope and specially constructed hot stage. The specimen was taken in the form of thin film and sandwiched between the slide and cover glass. The concentrations from 30% to 70% of binary mixture of CN in (CDEAB+EG) have been considered for the experimental studies. When the specimen of 40% CN in (CDEAB+EG) is cooled from its isotropic phase and hence it exhibits cholesteric, SmA, SmC, SmE and SmB 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 as shown in Figure 1(a). 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(b). On further cooling the specimen, unstable SmA phase changes over to schlieren texture of SmC phase and it as shown in Figure 1(c). Sequentially on cooling the specimen, SmC phase changes over to zig-zag type herring-bone pattern SmE phase and then it slowly changes over to paramorphotic texture of SmB phase, in which the molecules are arranged in hexagonal close-packed structure, which remains stable at room temperature[19].

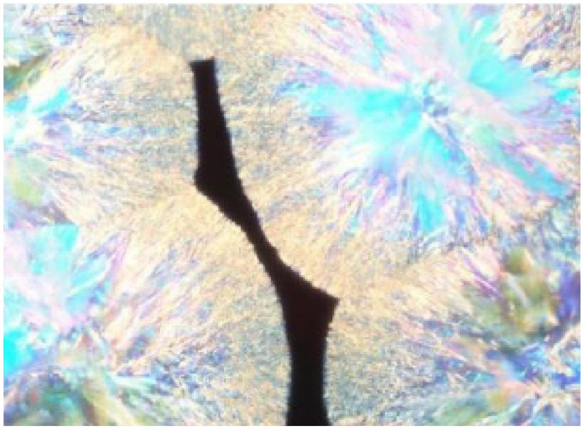

Figure 1(a) : Spherulitic texture of cholesteric phase at temperature (250X)

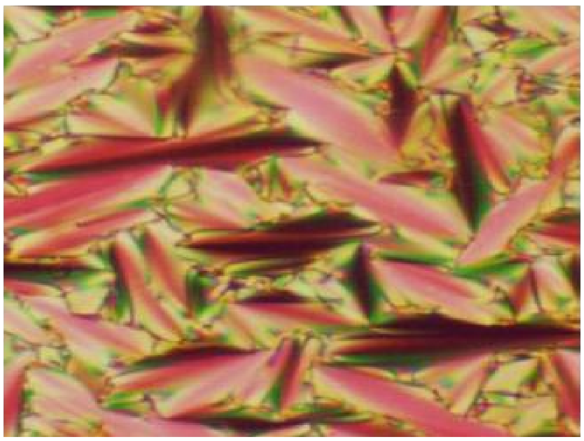

Figure 1(b) : Focal conic fan shaped texture of SmA phase at temperature (250X)

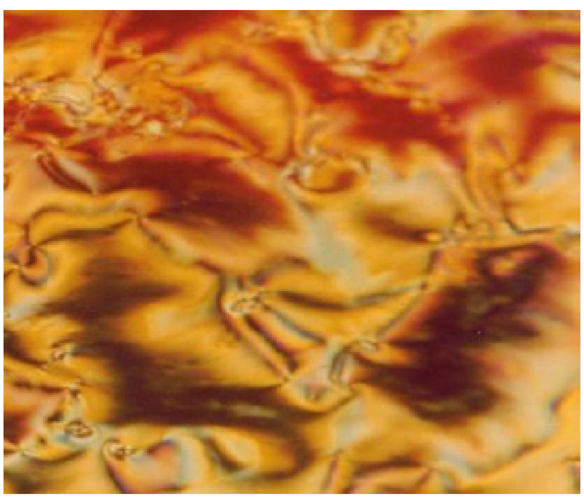

Figure 1(c) : Schlieren texture of SmC phase at temperature (250X)

OPTICAL ANISOTROPIC STUDIES

Liquid crystals are found to exhibit two principal refractive indices, the ordinary refractive index n_o, and the extraordinary refractive index n_e. The ordinary refractive index n_o is observed with a light wave where the electric vector oscillates perpendicular to the optic axis. The extraordinary refractive index n_e is observed for a linearly polarized light wave where the electric vector is vibrating parallel to the optic axis. The optic axis of uniaxial mesophases is given by the director.

The optical anisotropy, or birefringence, is wavelength and temperature dependent and defined by the equation

$$\Delta n = n_e - n_o = n_{\|} - n_{\perp}$$

where, $n_{\|}$ and $n_{\perp}$ are the components parallel and perpendicular to the director, respectively. The Results of this investigation are supported by the optical studies. The refractive indices for extraordinary ray (n_e) and ordinary ray (n_o) of the mixture were measured at different temperatures for the different concentrations using Abbe Refractometer. The variations of birefringence as a function of temperature for 40% CN in (CDEAB+EG) are shown in Figure 2. The values of electrical susceptibility for 40% CN in (CDEAB+EG) have been calculated using Neugebauer relation[20] at different temperatures. The variation of electrical susceptibility as a function of temperature for the mixture is shown in Figure 3. From the figure, it can be observed that wherever there is phase transition, the value of electrical susceptibility changes appreciably, which indicates that the changes correspond to various different smectic modifications. Further, with increase in the concentration of CN, the value of electrical susceptibility decreases with temperature, because the effective optical anisotropy associated with the molecules of CN also decreases.

OPTICAL TRANSMITTANCE STUDIES

The temperature variation of optical transmittance for the mixture of 40% of CN in (CDEAB+EG) is shown in Figure 4. This clearly illustrates that, the value of optical transmittance increases slowly with increase in temperature from 50^0C to 140^0C, while the sequence of phase appear from crystalline

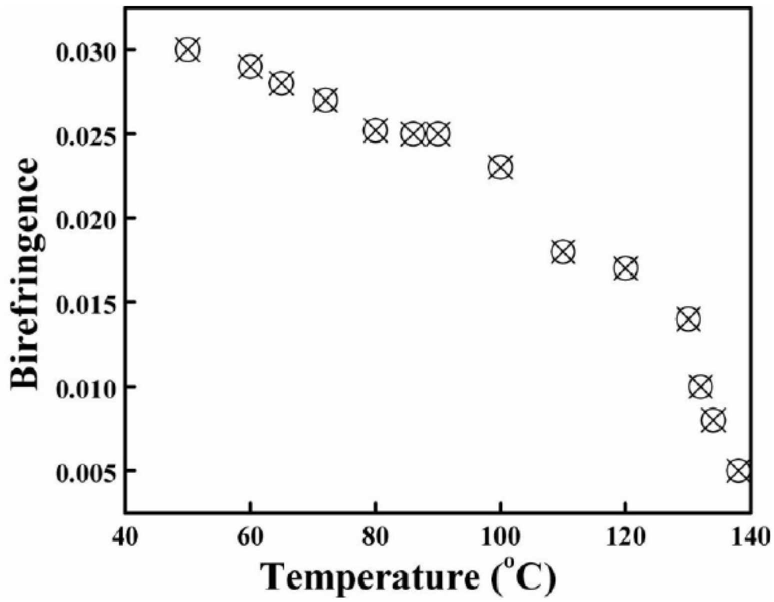

Figure 2 : Temperature variations of birefringence for the mixture of 40% of CN in (CDEAB+EG)

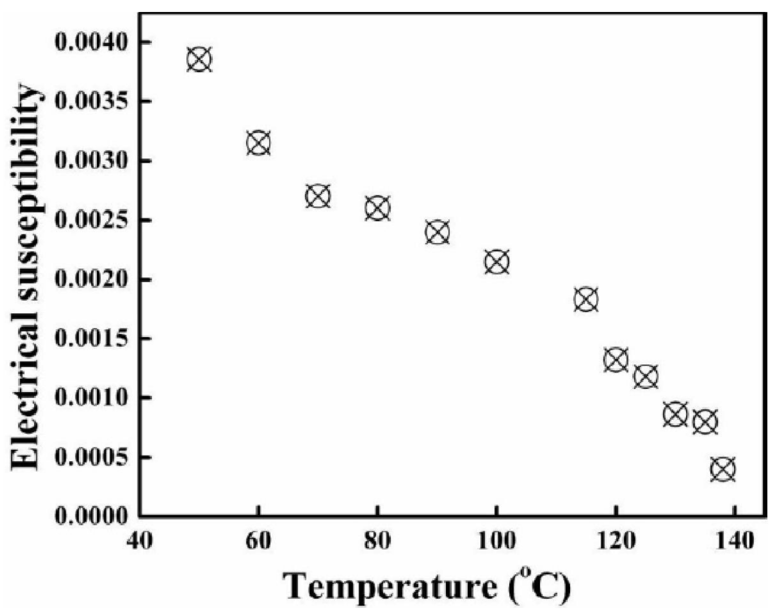

Figure 3 : Temperature variation of electrical susceptibility for the mixture of 40% of CN in(CDEAB+EG)

region to near isotropic region and suddenly some changes are observed in the value of optical transmittance from 130^{0}C to 140^{0}C[21].

The optical transmittance is continuous at the SmB-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 the SmA and cho phases. The divergence of the optical transmittance can be related to the first-order or second order transition. Here in the region of SmA and cho phases, the optical transmittance shows a steep decrease and it is very close to isotropic phase which is the characteristics 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 40% CN in (CDEAB+EG)

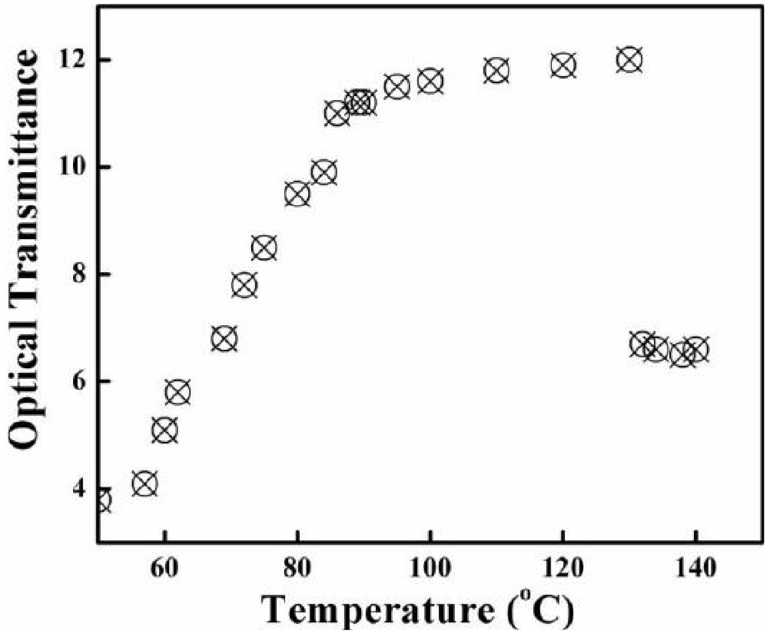

Figure 4 : The temperature variations of optical transmittance for the mixture of 40% of CN in(CDEAB+EG)

at constant temperature 56^{0}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 22.05 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 5(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 5(a), it follows that: an extremely regular hexagonal grid pattern is formed when the external electric field is applied. One of

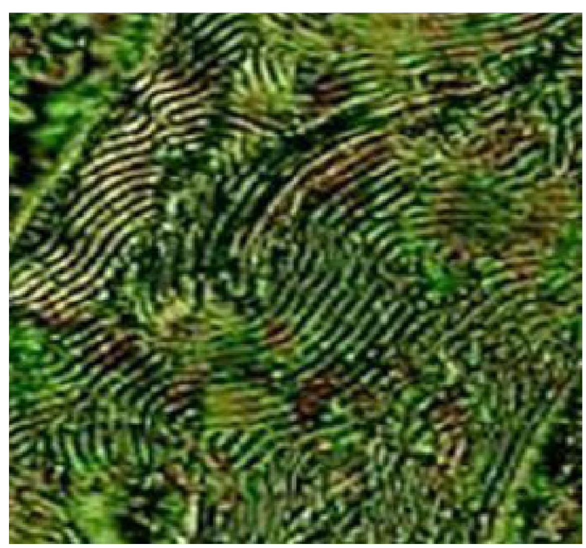

Figure 5(a) : Stripped pattern electro-optical texture

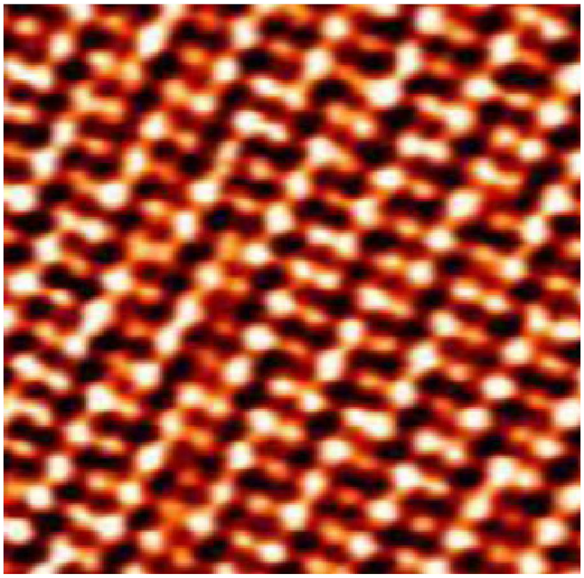

Figure 5(b) : Hexagonal grid pattern electro-optical texture

the regions is that: the formation of hexagonal grid pattern is the electronic charge injected by the applying external electric field[16, 22-23].

CONCLUSION

Microscopic investigation of the multi-component system of CN in (CDEAB+EG) shows the existence of cholesteric, SmA, SmC, SmE and SmB phases for all concentrations of given mixture. The drastic changes in the optical anisotropic measurements with variation of temperature unambiguously correspond to polymorphic smectic phases, respectively at different concentrations. The experimentally measured optical transmittance has been discussed based on the phase transition behavior of different temperature. Under the applied electric field at constant temperature unambiguously correspond to optical purity of the liquid crystalline phases. The various aspects of frequency effects on the given mixture show different directions of molecular reorientations exhibit a flow patterns formed such as stripped pattern chevron textures and hexagonal grid pattern textures, and hence these textures microscopically have been observed.

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