Electro-optical and UV Absorbance Study of Polymer Doped Ferroelectric Liquid Crystal

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Abstract

In this study UV absorption, textures and electro-optical study have been performed for pure ferroelectric liquid crystal (FLC) and its three different concentrations, i.e., 1%, 3% and 5% of polymer in pure FLC. I observed that there is higher value of UV absorption for polymer doped system in comparison to the pure system. The higher value of spontaneous polarization and faster response has been observed for polymer doped system compared to the pure FLC system. The important electro-optical parameters like spontaneous polarization, response time and tilt angle have been calculated and plotted with variation of applied voltage. The tilt angle is an intrinsic property of an FLC material, which is hardly affected by the presence of dye molecules and hence studies showing such observations are rare. The electro-optical study suggests that there exists an optimum concentration of polymer for which I have found highest spontaneous polarization and least response time.

Keywords: Electro-optical parameters, Ferroelectric liquid crystal, Polymer.

I. Introduction

Ferroelectric Liquid Crystals (FLCs) are finding interesting applications in a variety of fields like optics, material science and bioscience [1-8]. In spite of some drawbacks, Ferroelectric liquid crystal (FLC) became a good option for commercial video applications such as fast response and wide viewing angle. They have been attracted considerable attention from both fundamental and applied view [8-12]. These materials are technologically important due to their considerable characteristics such as high optical contrast, good switching response. The incorporation of different types of guest materials into the host material (FLC) is very practical method for manipulating the properties of host material. Polymer doped liquid crystals (PDLC) represent an exciting class of functional materials retaining the useful electro-optical properties of LCs and adding further unique power abilities and functionalities. PDLC provide wide range of applications such as privacy windows, reflecting display devices and dynamic holography. Dispersion of various dyes into FLCs has shown tremendous results due to the unique properties of polymer. In order to improve dielectric characteristics of liquid crystal materials, doping of polymer in FLC has been introduced [10-12]. The doping of polymer in pure FLC modifies or improves the electro-optical properties of pure FLC [10,11]. The polymer doped FLC are not only of fundamental importance but it is also useful in different devices applications such as development of less energy consuming displays like mobile communication tool. Due to this reason use of polymer seems attractive in such displays [10]. The UV study [10-12] along with electro-optical properties of FLC material doped with different concentration of polymer has been investigated.

II. Experimental Details

The sample cells for the present study consisted of highly conducted (H" 10W/n) indium tin oxide (ITO) coated glass plates. The ITO patterns which were square of dimension of 5 mm are used as electrodes. Such patterns were achieved by photolithographic techniques [10-14]. The thickness between two glass plates was uniformly maintained 10 µm. The planar alignment on the patterned glass plates was obtained by using conventional rubbed polyimide techniques. A commercially mixture Felix 16/100 has been used as host

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material purchased from Clariant Chemicals Co Ltd., Germany. The phase transition sequence of this FLC sample was given as follows [14]:

$$\text{Cryst.} \xrightarrow{-20^0C} \text{SmC*} \xrightarrow{72^0C} \text{SmA} \xrightarrow{82^0C} \text{N*} \xrightarrow{90\text{-}94^0C} \text{Iso.}$$

The polymer used for doping is Poly (3,32 ,4,42 -benzophenonetetracarboxylic dianhydride-alt-3,6-diaminoacridine hemisulfate) has been used as guest material purchased from Sigma Aldrich India. The structure of this polymer has been shown in Figure 1.

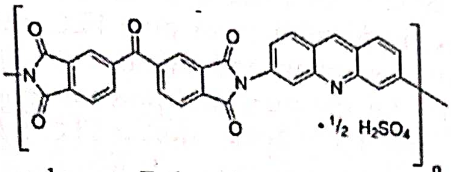


Figure 1. Molecular structure of polymer Poly (3,32 ,4,42 -benzophenonetetracarboxylic dianhydride-alt-3, 6- diaminoacridine hemisulfate)

The three concentrations of polymer has been prepared by doping of polymer 1% wt./wt., 3% wt./wt. and 5% wt./wt. of pure FLC in pure FLC and we call these as mixture 1, mixture 2 and mixture 3 in the whole paper for discussion.

The UV visible absorption study has been performed UV-VIS spectrophotometre (Elico SL210) for a wavelength interval 300-600 nm. The spontaneous polarization measurement has been carried out by well known polarization reversal current method [12-14]. The optical response of FLC was performed by square wave method by using a 5 mW He-Ne laser of wavelength 633 nm. The optical response was recorded by photo detector Instec PD02-L1.The triangular and square wave signal (10 Hz frequency and 20 Volt peak to peak) were applied using a function generator (Tektronix AFG-3021B) for the measurement of spontaneous polarization and response time. The electrical and optical response of pure and polymer doped mixtures has been recorded by Textronic TDS-2024C. The output waveform was now used to determine the response time. The response time of FLCs was evaluated using

$$\iota = t_{90}"t_{10}/1.8$$

Here, t_{90} and t_{10} are the time taken by the output waveform to reach 90% and 10% of the maximum of the output waveform. The alignment of all the mixtures has been checked by Radical polarizing microscope. In this method, a square wave of frequency 1 Hz and amplitude 20 V peak to peak is applied to the sample cell.

The electrical and electro-optical response of all the mixtures at room temperature and 10 volt peak to peak has been shown in Figure 2(A) and 2(B). The tilt angle measurement at different voltage has been studied at room temperature (35°C) by applying (10^4 $Vcm^{"1}$) square wave of both polarities at 0.2 Hz to the planar aligned sample cell. The tilt angle was obtained by setting the two extinction position of the sample. The tilt angle is half of the angle between the two extinction positions.

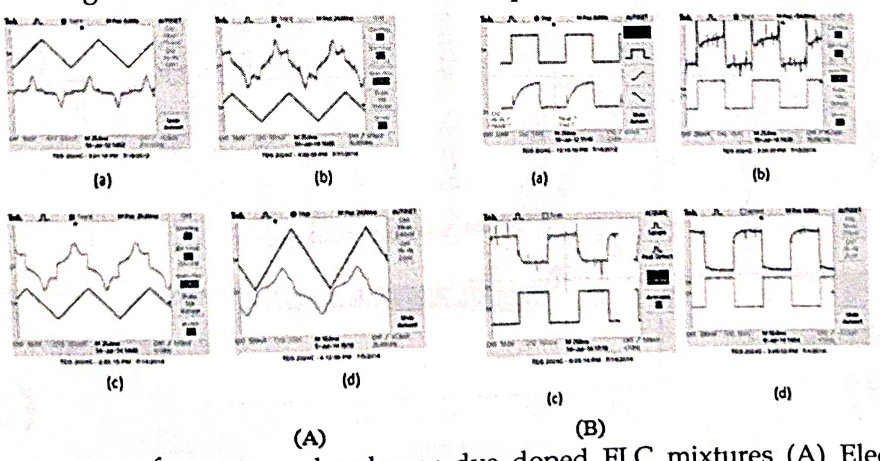
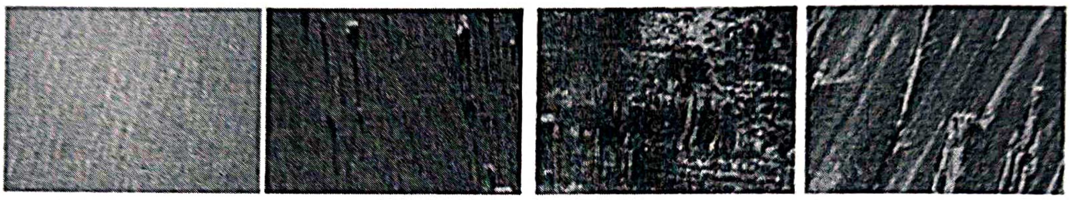


Figure 2. Response curve for pure and polymer dye doped FLC mixtures (A) Electrical Response (B) Optical Response, In both figures (a) Pure (b) Mixture 1 (c) Mixture 2 (d) Mixture.

III. Results and Discussion

The electrical switching behaviour of all the mixtures have been confirmed by optical polarizing microscopic study at 10X magnification through crossed polarizer interfaced with camera. The photographs have been taken for all the mixtures in SmC* phase at room temperature. When there is no field the textures are shown in figure 3(a) as field is increased from 0V, the helical axis of molecule or director get disturbed and get oriented more or less parallel along the electrode as shown in Figure 3(b).

The UV visible absorption study has been carried out to observe absorbance of white light by pure FLC and polymer doped FLC mixtures. I have made solution of pure FLC, mixture 1, mixture 2 and mixture 3 in toluene and we kept normality 1N for absorption and fluorescence study. The absorbance in arbitrary unit on the wavelength scale in nanometre for the pure and polymer doped has been plotted in Figure 4. From Figure 4 I see that absorbance is higher for polymer doped FLC mixtures in comparison to the pure FLC. In polymer doped FLC mixtures we see that absorbance is highest for mixture 2 in comparison to the other two mixtures. From Figure I see that anomaly increase of absorption for mixture 3 at wavelengths more than 350 nm is due to reason that after mixture 2 polymer saturates and absorption shows this trend.



(A) (B) (C) (D)

Figure 3(a). Optical Photographs in SmC* Phase at room temperature with no field (A) Pure FLC (B) Mixture 1 (C) Mixture 2 (D) Mixture 3.

(A) (B) (C) (D)

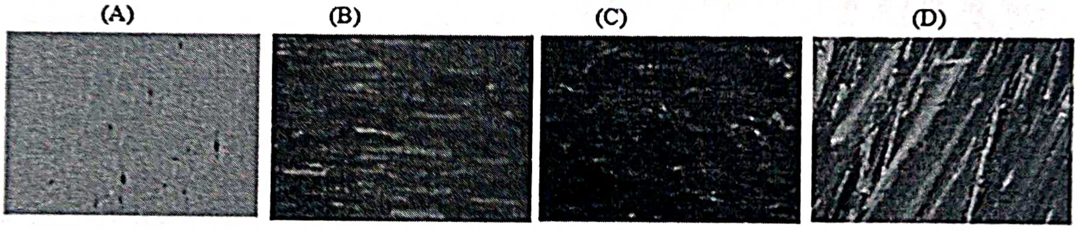


Figure 3(b). Optical Photographs in SmC* Phase at room temperature with field of 5V (A) Pure FLC (B) Mixture 1 (C) Mixture 2 (D) Mixture 3.

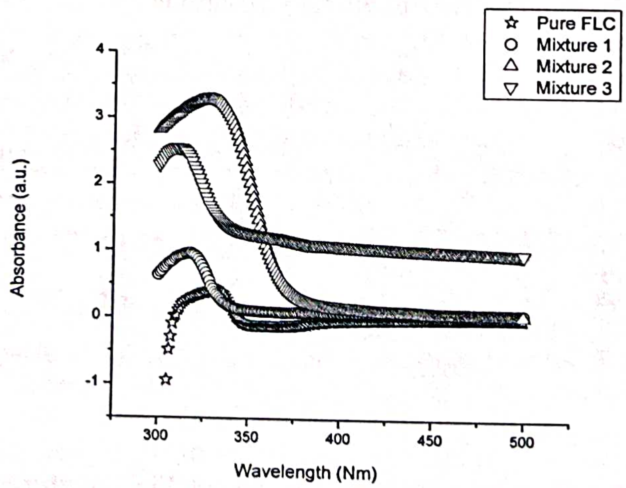


Figure 4. Wavelength variation of absorbance for pure and polymer doped FLC mixtures.

Kundu *et al.* observed a significant improvement in the tilt angle of an FLC by mixing a suitable amount of non-mesogenic polar molecules [15]. Figure 5 shows the variation of tilt angle (è), spontaneous polarization and response time with temperature for the pure and polymer composite. It can be seen that from Figure 5(a) tilt angle decreases with increase in temperature. The value of è increases with increasing polymer concentration. For the pure sample, the only interaction is between FLC molecules. When the polymer is doped into the FLC, two more interactions occur in addition to FLC-FLC molecule interaction, which are as follows:

1. FLC-polymer interaction.
2. polymer- polymerinteraction.

The increment in tilt angle of polymer doped FLC could be understood as a consequence of the polymer - polymer interaction. The FLC-polymer interaction does not have much effect on the decrement of tilt angle as the polymer lying near to the FLC molecule generate same effect on it from all the sides which in turn gets nullified. Therefore, the second interaction dominates over the first interaction. It has been anticipated that FLC molecules around the polymer molecules get more tilted because of the favourable attraction between the two nearby polymer molecules. Therefore, the value of tilt angle for mixture 1 and mixture 2 increases. For mixture 3, the decrease in tilt angle is not as prominent as that for mixture 1 and mixture 2 which point towards the condition near to the saturation concentration of polymer molecules in the pure FLC system. Therefore, merely a small decrement in the tilt angle for mixture 2 has been observed.

From Figure 5(b) I see that spontaneous polarization increases for polymer doped mixtures in comparison to the pure FLC. The modifications in the spontaneous polarization value of FLC material when doped with different concentrations of polymer could be understood by taking into account this reason. The value of spontaneous polarization is directly coupled with the tilt angle of the FLC molecule. Tilt angle is the primary and preferred order parameter whereas spontaneous polarization is the secondary order parameter for SmC* phase. It is clear from Figure 5 (a) that the value of tilt angle has been increased for the dye doped system; therefore, the increment in the value of P_s value can be attributed to the increasing of tilt angle. Thus, reduction in the value of spontaneous polarization has been observed for the dye doped system.

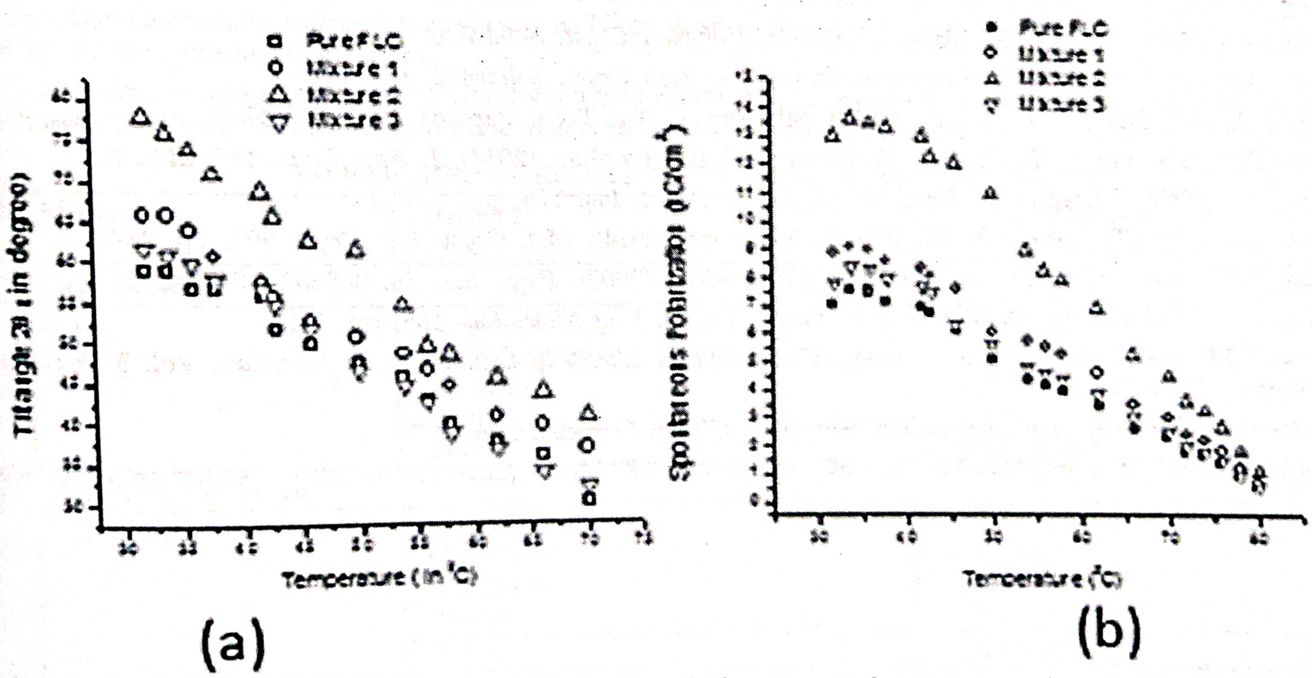


Figure 5. Temperature dependence variation of electro-optical parameters for pure and polymer doped FLC mixtures (a) Tilt Angle (b) Spontaneous Polarization

IV. Conclusion

Polymer doped system has been explored using UV absorption, texture and electro-optical study. I observed in this study that UV absorption is higher for polymer doped system in compared to the pure system. The optical textures show that as field is increased from 0 volt the axis of helical get disturbed and oriented less or more towards the electrodes. The mixture 2 has highest spontaneous polarization, and least response time in comparison to all other mixtures, after this concentration of dye there is no practical importance. The electro-optical study suggests that mixture 2 is an optimum concentration polymer in pure FLC, therefore, after this mixture there is saturation or slight changes in the value of electro-optical material parameters. The enhancement in spontaneous polarization for polymer doped system is an indication of better alignment because the presence of polymer molecules induces higher spontaneous polarization of FLC molecules.

Conflict of Interest

The article is original and has been written by the stated author who is all aware of its content and approve its submission. This article has neither been published previously nor under consideration for publication elsewhere. No conflict of interest exists, or if such conflict exists, the exact nature of the conflict must be declared and if accepted, the article will not be published elsewhere in the same form, in any language, without the written consent of the publisher.

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