Thermoelectric Effects on Optical Properties of The Polymer Dispersed Liquid Crystal Films

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ABSTRACT

Recently, has been studied the electro-optical properties of the polymer dispersed liquid crystal (PDLC) systems because it has unique properties use in smart windows technology. The selection of material is important for performance and application of polymer dispersed liquid crystal devices. The choosing of the materials are based on the physical properties of each constituent materials like refractive matching/ mismatching of Liquid Crystals and polymers, their purity, chemical and photo stability, mutual miscibility etc. The size, shape, and arrangement of these microscopic structures are (droplet) synthetic chemistry of the both constituent molecules. In this present work has been used commercially available nematic liquid crystal ZLI-3239 and UV curable polymer (NOA-71) was used as matrix element. This polymer is clear, colorless, liquid photopolymer that is cured under UV light. The main idea of this research is mixing both the liquid crystal and the polymer in liquid state which both having almost same viscosity to form single liquid phase followed by phase separation processes to separate liquid crystal from the polymer. The polymer is provided sit for liquid crystal which has arrangement of microscopic structures droplet in different sizes. This research showing effect of the temperature and electrical field on the liquid crystal which has direct influence on the optical properties of polymer dispersed liquid crystal film.

Keywords: PDLC, Smart Windows

INTRODUCTION

This research showing the electro-optical properties of the polymer dispersed liquid crystal (PDLC) systems because it has unique properties use in smart windows technology. The selection of material is important for performance and application of polymer dispersed liquid crystal devices. The choosing of the materials are based on the physical properties of each constituent materials like refractive matching/ mismatching of Liquid Crystals and polymers, their purity, chemical and photo stability, mutual miscibility etc. the main idea of this research is mixing both the liquid crystal and the polymer which can be done through different method like **(PIPS)** refer to polymerization-induced phase separation, **(TIPS)** refer to thermally-induced phase separation processes and **(SIPS)** refer to solvent-induced phase separation processes. In the (**PIPS**) the liquid crystal is mixed with low molecular-weight monomers or oligomers which act as a solvent for the liquid crystal. Polymerization is induced through the application of heat, light, or radiation. The growing polymers chains phase separate from the liquid crystal to form a matrix surrounding discrete liquid crystalline domains. But in **(TIPS**) the liquid crystal is mixed with a Thermoplastic polymer melt at high temperatures. Cooling the mixture the mixture both solidifies the polymer and induces phase separation of the liquid crystal. Finally in **(SIPS)** the polymer and liquid crystal are mixed with an organic solvent to form a single-phase mixture. Evaporation of the solvent causes phase separation of the polymer and liquid crystalline phases. In this research the thermally induced phase separation **(TIPS)** has been used. Each of mixing

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method between the polymer which generally matrix phase and liquid crystal depended on physical and chemical properties of each constituent. The synthesis of the film has been done by capillary action with thickness 4, 5 and 10 µm as describe in cell preparation later. The liquid crystal drop let phase has isotropic optical properties depended on amount of electrical field that applied. In addition to the electrical effect on the behavior of liquid crystal, the liquid crystal showing also isotropic optical properties as function of temperature. [1,2,3]

Experimental

The first step is selection of the materials, in this research the materials have been chosen are NOA-71 as polymer matrix from PDH UK [4] and commercially available nematic liquid crystal ZLI-3239 from Norland, NJ, USA. [5] Both constituents having almost same viscosity 200 (CPS) and 188 (CPS) at 25 ℃ for polymer and liquid crystal respectively, this led to form homogenous single phase when it's mixed together. The homogenous single phase has injected into cell or using the capillary action depended on the thickness of the PDLC film.

The cell preparation is consist of two glass substrates which are coated with indium tin oxide (ITO) conductive film. The (ITO) film is high transparent to light with resistivity about (140-180 ohm-m). The conducting sides of glass substrates which coated with (ITO) are joined together and the space gab between the substrates is maintained with help of the mylar spacer of different thickness like 4, 5 and 10 µm. Then the two substrate glass sealed with adhesion used in the lateral sides of the glass plates (figure 1). The single homogenous phase which consists of mixing liquid crystal and polymer by weight ratio 1:1 is filled into space gab between the glass plates by capillary action. [6,7]

The second step is how to separate the homogenous single phase into two phases by using the phase separation methods. In this case the polymer which has been selected is thermoset polymer (NOA-71) can be cured by expose the polymer to the UV light at room temperature for hour. The polymer transformed from viscos liquid to the solid film with liquid crystal droplet inside in liquid state. The UV light increase crosslink in the polymer chain which led to solidify while it has no effect on the liquid crystal. [8-10].

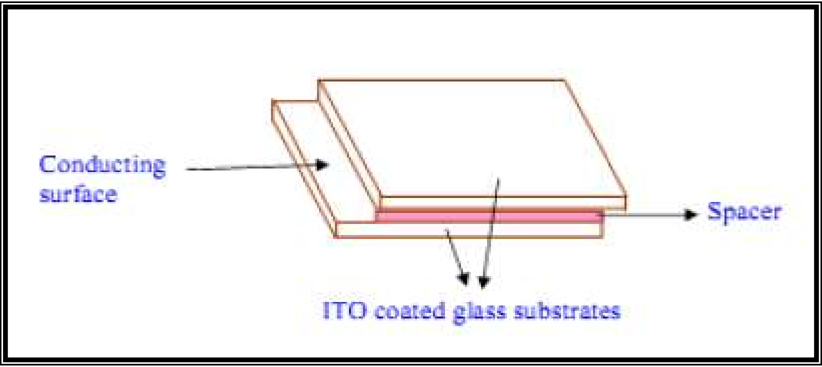


Figure (1). Showing the cell preparation. [11]

Finally the wires are connected to the conducting surface by using indium or silver paste. In this research the soldering with indium has been used. These wires connected the power supply AC with frequency range (50 Hz to 1MHz) but in this case low frequency has been used to study the elect optical properties of the cell at different voltage and temperature by examined under polarize microscope. The temperature is controlled by Linkam temperature programmer cum hot stage (Model TP94 and THMS 600) with temperature range (-50 to 300)℃. The electric field was applied to the sample through Scien-tech function generator (Model ST 4060), Philips function generator (Model FG8002). The microscopic optical textures were captured through the charge coupling device (CCD) digital camera (Olympus DP 12 JAPAN) fitted on polarizing microscope and interfaced to a computer. A block diagram of the experimental set-up for the examination of optical textures, electro-optic properties and other parameters of liquid crystal is shown in (figure 2).

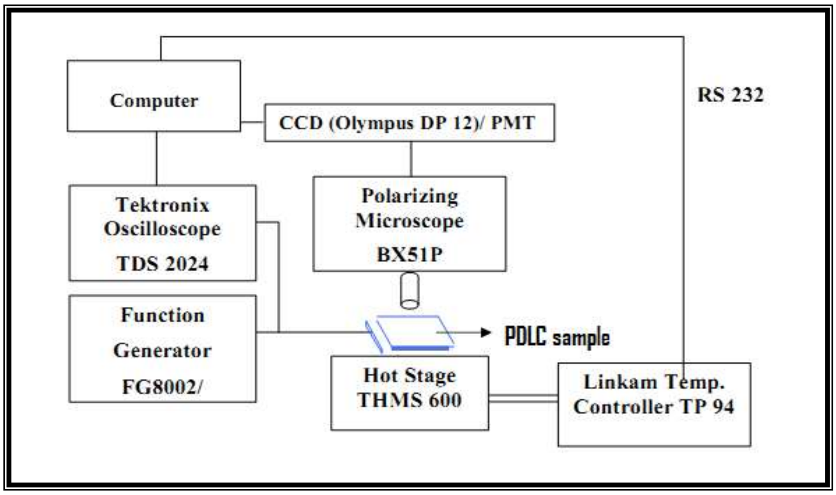


Figure (2). Block diagram of the experimental set-up

Result and Discussion

The droplet morphology

After the cell preparation is completed, the droplet morphology has been examined under polarize microscope at different temperature and different electrical field. It was seen that the liquid crystal droplet size in rang between (10-15 µm) and have spherical shape and uniform distribution as shown in the (figure 3). The molecular orientations of the liquid crystal can be described by combination of several other configurations [bipolar, axial, radial and concentric which appear simultaneously. But bipolar configuration is the dominant one. [12,13]

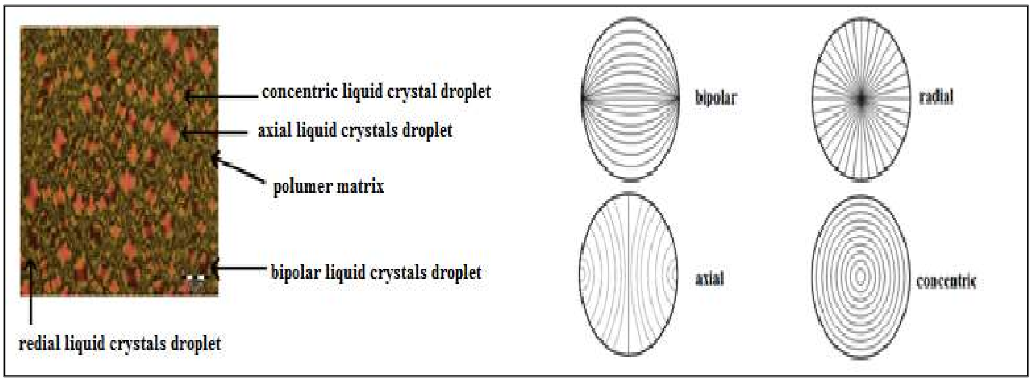


Figure (3). Represented polymer dispersed liquid crystal of NOA-71 and liquid crystal ZLI-3239 examined under polarized microscopy.

The shape, location and size of the black spots presented in the figure above give clear idea about which type of configuration presented. In concentric the black spots are small and it location at the surface of the drop let while it has bright core. But in axial the black spots presented as two spots symmetric edges. In other hand bipolar the black spots showing continuous inhomogeneous curve lie in the center of the droplet. Finally the radial showing single spot at the center with small edge (like cross).

It's was seen that the liquid crystal droplets mainly have a bipolar configuration and their bipolar axes are randomly distributed into polymer matrix. In this configuration the director field is anchored parallel at the interface. The director field possess cylindrical symmetry, with the symmetry axis defined by two point defects which lie at the opposite ends of the droplet. Most polymers tend to induce a parallel alignment of the nematics so that bipolar droplets most often found in polymer dispersed liquid crystal films. [14, 15]

The effect of electric field

The orientation of the optical bipolar which corresponding to the average nematic director alignment which showing randomly orientation from droplet to droplet without applied any voltage across the cell. These randomly form of the bipolar droplet causing scattering in the light that passed through the cell given opaque view (milky). The amount of scattered light is depended on a four major parameter light beam, operation conditions, component characteristics and the polymer dispersed liquid crystal configuration. The light beam consist of (wavelength, incidence angle, polarization state), the operating conditions including (temperature, value and waveform of the applied electric or magnetic field), the component characteristics (polymer and liquid crystal refractive indices and dielectric constants, liquid crystal elastic constants) and finally the polymer dispersed liquid crystal configuration (droplet shape, size, uniformity and distribution). When the voltage is applied across the film, the bulk distortion of the LC droplet has reduced with increasing the voltage until the fill alignment reached. The rotation of bipolar axes is associated with the individual droplets which gives alignment of the liquid crystal molecular in the perpendicular to conducting surface of cell. This change in the bipolar axes led to increasing the transparency of the cell as function of voltage as seen in the figure 4. [16,17]

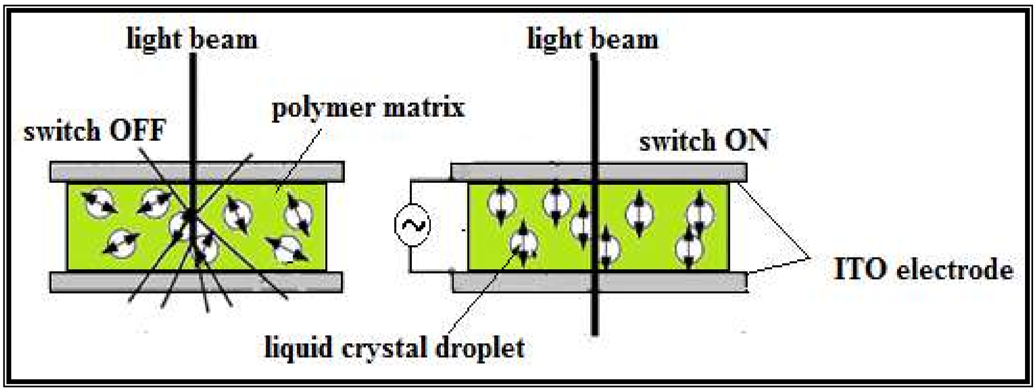
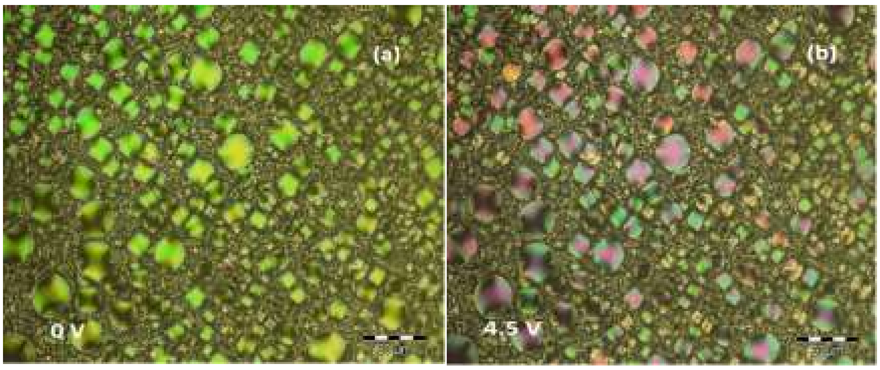


Figure (4). Schematic represented of the polymer dispersed liquid crystal a light shutter in the switch OFF (left) and when a low frequency electric field is applied across it (switch ON, right). Double arrows are a schematic representation of the droplet director. [17]



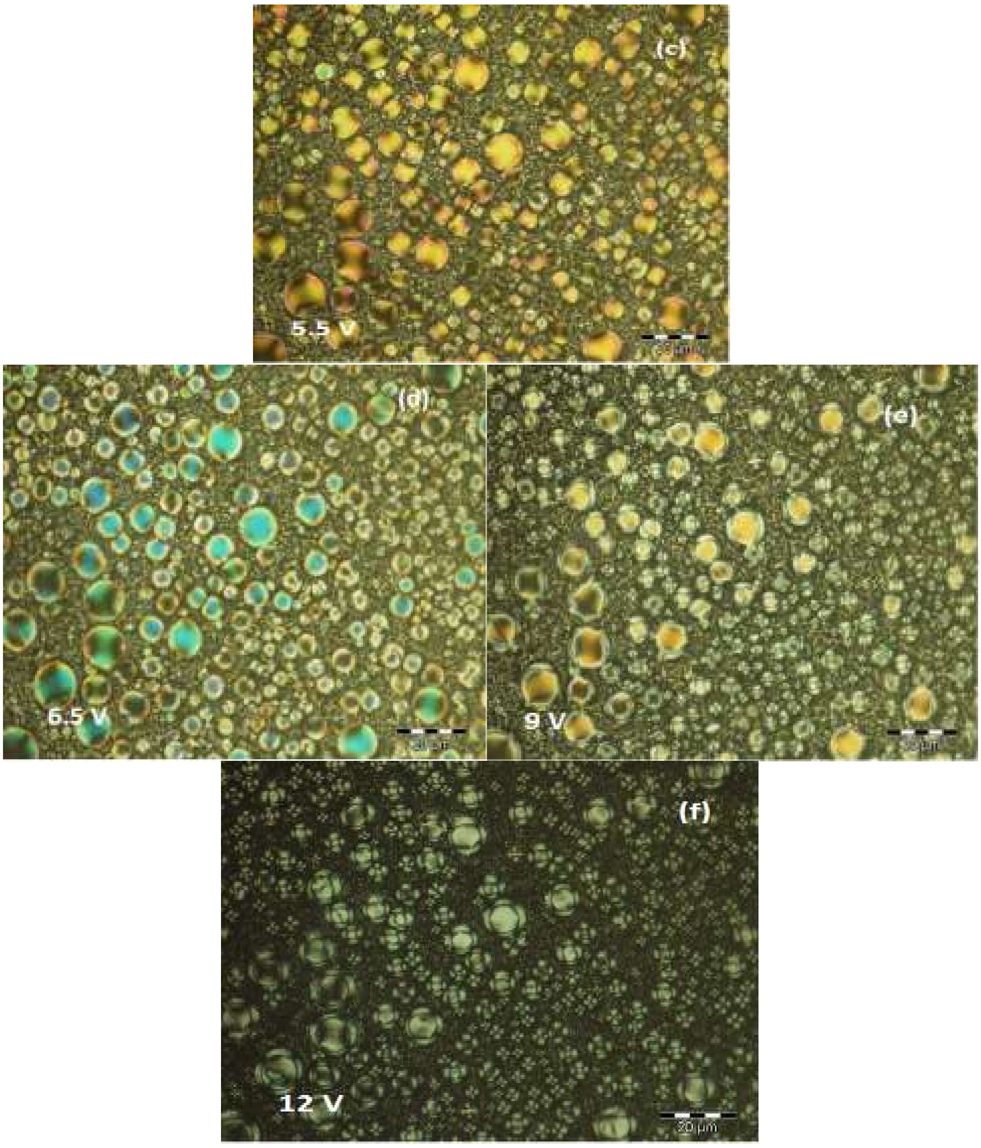


Figure (5) showing Morphology of nematic liquid crystal droplets dispersed in polymer matrix under crossed polarizers at 50 ^{0}C as a function of applied voltage (0, 4.5, 5.5,6.5,9 and 12)V at 100 Hz respectively.

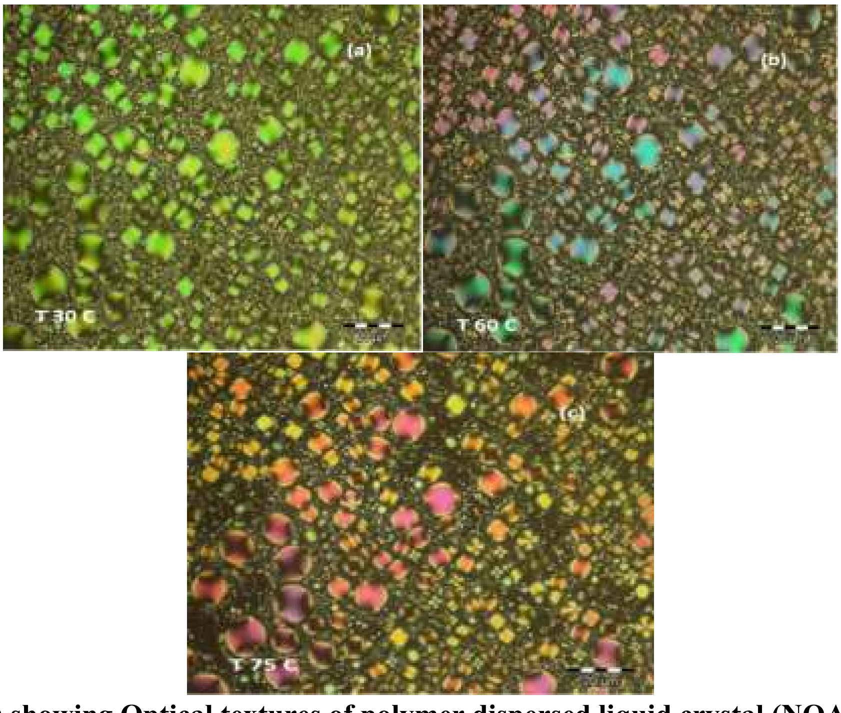
Figure (5) showing the morphology of nematic liquid crystal droplets which dispersed in polymer matrix and examined under polarize microscope, the temperature has been fixed at 50 ℃ while the voltage has been changed from 0 to 12V at 100 Hz At zero voltage (switch OFF). (Figure 5(a)), showing the liquid crystal droplets have a bipolar arrangement and their axes are randomly distributed in the matrix which is consist of polymer. At higher voltage, (Figure 5(f)) the liquid crystal molecules and their corresponding bipolar axes are oriented along the direction of applied electric field. However in the intermediate voltage range droplet size and shape does not change but it alignment increased with increasing the voltages. So the transparency depended on amount of applied voltage, director of the liquid crystal drop let and its configuration. As shown in the figure 5. This behavior matching with theory presented in the references. [18,19]

Effect of temperature on polymer dispersed liquid crystal

The nematic liquid crystal ZLI 3239 has been used in polymer dispersed liquid crystal film. The phase transition temperature has been determined from characteristic textures which observed under polarizing microscope when it cools down from isotropic phase to the crystalline phase. The heating rate in this measurement has been adjusted at 0.1. A mesophase (liquid crystal) namely the nematic have been found between the isotropic which above 90 ^{0}C and crystal phase which blow -30 ^{0}C. This result all most matching with theory presented in the references [19-21] in case of liquid crystal behavior with little bet change. The small changes in the result due to the surface interaction between liquid crystal drop let and polymer.

$$Crystal \quad \xrightarrow{< -30^oC} \quad Nematic \quad \xrightarrow{+95^oC} \quad Isotropic$$

Temperature dependent behavior of the polymer dispersed liquid crystal film was investigated with the help of optical microscopy. At room temperature, liquid crystal molecules have been aligned in different direction within the polymer matrix which led to the light scattering. Due to thermal process, orientation order of the liquid crystal molecules get distributed so we get different color corresponds to birefringence phenomena in liquid crystal molecules. Birefringence is also depended upon refractive index, which change with change in temperature. So we get different color in nematic liquid crystal droplets imbedded in polymer matrix in texture (as shown in figure 6). This result all most matching with theory presented in the references [22,23] in case of liquid crystal behavior with little bet change. The liquid crystal drop let color change from the core to the surface as showing in the figure 6. The small changes in the result due to the surface interaction between liquid crystal drop let and polymer.



Figure(6) showing Optical textures of polymer dispersed liquid crystal (NOA 71 + ZLI 3239) film with temperature variation at (a) 30 ^{0}C, (b) 60 ^{0}C and (c) 75 ^{0}C.

CONCLUSION

From the result above and the investigation of various factor like viscosity and refractive- index for both polymer and liquid crystal composites film which effects the electro-optic and morphology properties of the polymer dispersed liquid crystal composites films.

- Refractive index plays an important role for controlling droplet morphology of the system. During switching, in OFF state, refractive index of polymer and liquid crystal is mismatch initially, but with the application of electric field (higher then (10 V)). Refractive index gets match, which is again characterized by optical microscopy in switching response of polymer dispersed liquid crystal composites.
- The matching in the refractive index according to electrical effect (above 10 V) due to the alignment of liquid crystal molecular parallel to the light director which gives transmitted texture.
- Refractive index of polymer and liquid crystal is matching with each other at temperature above 75 ^{0}C due to phase transformation from isotropic crystalline to anisotropic morphs phase. This transformation increasing in the transparency of liquid crystal with in the polymer matrix. The refractive index is rather matching between the liquid crystal and the polymer matrix. This matching percentage increase with temperature.
- The liquid crystal drop let color change from the core to the surface, the small changes in the color due to the surface interaction between liquid crystal drop let and polymer.
- The controlling of refractive index according to electrical effect is faster than thermal effect.

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