

The Effect of UV Intensities and Curing Time on Polymer Dispersed Liquid Crystal (PDLC) Display: A Detailed Analysis Study

Farzana Ahmad,¹ Muhammad Jamil,^{2,3} Jin Woo Lee,¹ Seo Rok Kim,¹ and Young Jae Jeon^{1,*}

¹LCD Research Center, Department of Chemistry, Konkuk University, Seoul 05029, Korea

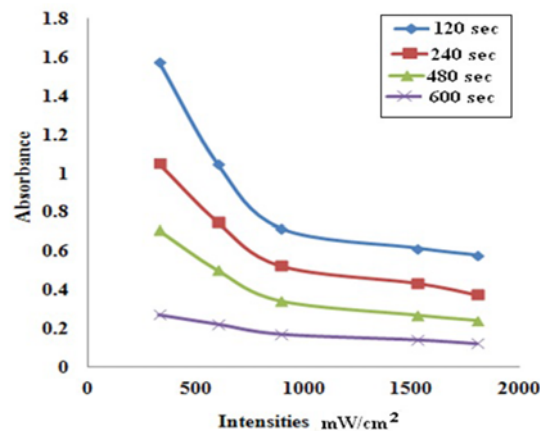
²Division of Global Business, University College, Konkuk University, Seoul 05029, Korea

³Department of Physics, Konkuk University, Seoul 05029, Korea

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In current study polymer dispersed liquid crystal (PDLC) films whose composition based on nematic liquid crystal (LC) E7 and pre-polymeric NOA65 were formed via the photo induced phase separation method, in a wide intensity range of the UV light ($I = 0.33$ – 1.8 mW/cm²) and curing duration ($t = 120$ – 600 sec). The PDLC characteristics were monitored by surface morphology, electro optical studies, as well as by phase separation process through measuring the FTIR absorption of the composite layers. Increase of curing light intensity accelerates the phase separation and drastically influences the final morphology of LC droplets inside PDLCs. Likewise by widening the curing duration the enhancement in phase separation was observed. Increase of light intensity from 0.89 mW/cm² and duration $t = 120$ – 240 sec resulted into transition from large LC domains of irregular shape (due to aggregation of droplets) to fine mono dispersed LC droplets. This morphology caused increase in optical scattering on zero voltage and high driving voltage. However unexpectedly, this response was not directly related with the curing conditions (intensity and time). These findings extend the potential applications of thiol-ene based PDLCs.

Keywords: polymer dispersed liquid crystal (PDLCs), phase separation, liquid crystal and polymer, liquid crystal (E7), pre-polymer (NOA65)



1. INTRODUCTION

Polymer Dispersed Liquid Crystals (known as PDLCs) devices are demonstrated as important new class of materials, which are employed for optical device applications in the last few decades. In their general form, PDLCs consist of micro sized birefringent liquid-crystalline droplets, which are randomly dispersed in optically transparent and uniform polymer matrix. PDLC films can be easily fabricated, typically by employing one of the few simple coating

techniques. Upon applying a small external electric field such films can be switched from a highly scattering state to a transmissive state.^[1-4] PDLC display technology included various advantageous features over other display technologies due to advanced electro optical properties, required no extra optical elements (i.e. polarizer in LCDs), no leakage of materials, simple fabrication, low-cost production.^[5-8]

From beginning, the major two classes of pre-polymeric compositions (Thiol-ene mixtures and acrylate compositions) are used for PDLC formation. The thiol-ene based mixtures undergo step growth and acrylate based system polymerize via chain growth radical polymerization.^[9,10] The thiol-ene based compositions are considered much better as compared

*Corresponding author: yjjeon@konkuk.ac.kr
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to acrylate based systems as provide better control of PDLC morphology (e.g., size and uniformity of LC drops), shorten the aging effects, show low toxicity, reduce non-uniform shrinkage and in holographic type PDLC they provide higher diffraction efficiency and switching contrast.^[11] Generally, thiol-ene based PDLC systems are made of commercial optical adhesive NOA65 from Norland Products and the cyano-n-phenyl LC mixtures, usually E7 from BDH/Merck. The refractive index of UV curable NOA65 (mixture of tri-functional thiol and a tetra-functional urethane allyl ether (the ene)^[12] are favorably very close^[13] to ordinary refractive index of LC E7. Following characteristic, lead to a fully transparent PDLC film on applying a small external electric field. Earlier studies on such PDLCs were focused on progress in electro optical performance by varying the curing conditions,^[14-17] adding the dye^[18] and a deep investigation in curing kinetics by FTIR spectroscopy.^[19-21]

We believe that essential gap for further improvement of NOA65-E7 composites still exists even without chemical modification of polymer mixture. This might be achieved by widening the curing intensity range and curing duration to find the optimum curing conditions. The present study considers physio-chemical investigations of following PDLC by considering the morphologies and electro optical properties of NOA65-E7 PDLCs, by selecting the widen area of curing intensities and curing time. Innovation of present work is selection of the much wider range of intensity and curing duration for control of morphologies, electro optical properties and phase separation of PDLCs. The chemical changes in PDLC have been investigated by using the FTIR analysis.

2. EXPERIMENTAL PROCEDURE

2.1 Materials and method

In the fabrication of polymer dispersed liquid crystals (PDLC) films nematic LC E7 (BDH/Merck) was used as the LC. It was a eutectic nematic mixture of cyanobiphenyl and contains a composition of 51% n-pentyl-cyanobiphenyl (5CB), 25% n-heptyl-cyanobiphenyl (7CB), 16% n-octyloxy-cyanobiphenyl (8OCB), and 8% n-pentyl-cyanoterphenyl (5CT). This mixture has nematic mesophase in the range -30 to 61 °C.^[19,20] The UV curable optical adhesive NOA65 (Norland Products) was used as a pre-polymer in this PDLC. It was reported to be a mixture of trimethylolpropane diallyl ether, trimethylolpropane tris thiol, isophorone diisocyanate ester and a benzophenone photoinitiator.^[22,12,19] Both, E7 and photopolymer NOA65 were used without further purification.

A PDLC blend was prepared by adding the NOA65 with ratio of 40 wt% and E7 as 60 wt%. This mixture was thoroughly mixed by spinning at room temperature condition for one day. Following this, the PDLC devices were fabricated inserting the PDLC blend inside two ITO glass by

capillary rise method. The gap between the PDLC device was controlled by the 20 μm spacer. Further, PDLC devices were fabricated by polymer induced phase separation (PIPS) method initiated by UV irradiation. The UV curing light intensity (I) of the 360 nm spectral range was changed from 0.3 mW/cm^2 to 1.8 mW/cm^2 at different levels. Similarly, the curing duration range was changed from 120 - 600 seconds.

2.2 Experimental measurements

The electro-optical experiments (transmittance and contrast ratios) were performed at room temperature by measuring the transmission of un-polarized HeNe laser light at wavelength range $\lambda = 400$ - 700 nm by Minolta UV-Vis spectrophotometer (model UV-3500d, Japan). The PDLC films were oriented normal to the laser beam. The distance between the sample cell and the detector was approximately 38 cm. The collection angle of the transmitted intensity was about 0° , so that principally forward scattering was detected. The transmission measurements were corrected using appropriate calibration standards. For measuring sample transmittance T vs. applied voltage curves, external electric field was applied across the PDLC sample. The transmittance against the applied voltage was measured by Minolta UV-Vis spectrophotometer as connected with the PC. The surface morphologies of the PDLC films were viewed by polarized optical microscope (Olympus Model BX-60) at $20\times$ magnification fitted with a digital camera connected to a computer.

Further, for FTIR investigations the spectrometer used in this study was the Nicolet, 6700 incorporating an MCT detector. A higher spectral resolution range at 0.935 s time resolution was used for kinetic studies. This time resolution was believed sufficiently small to capture the essence of the curing reaction while allowing satisfactorily high signal-to-noise ratio spectra. Five scans were recorded for each data point.

3. RESULTS AND DISCUSSION

3.1 Morphology

The microscopic structures of NOA65-E7 PDLC samples formed at different curing conditions $I = 0.33$ - 1.8 mW/cm^2 and $t = 240$ sec were shown in Fig. 1A to investigate the appropriate condition to get the good-quality PDLCs. The presented microscopic pictures were taken at about 30 min after finishing UV irradiation allowing efficient time to reach equilibration state to our samples. It was apparent from figures when $I > 0.6$ mW/cm^2 the samples contain big LC droplets (the average droplets' diameter d is 10 - 20 μm) with high polydispersity (various size structure). While previously by another group found smaller monodisperse droplets at curing conditions $I > 2$ mW/cm^2 , $t = 70$ sec.^[9] Previously, at such a small curing intensities (0.33 - 1.8 mW/cm^2) following

PDLC properties has not been explored. Our result is a good achievement from earlier studies to explore large difference in PDLC microstructures at such a small intensity. In turn, when intensity was $I = 0.89\text{--}1.8\text{ mW/cm}^2$ the smaller droplets $d = 5\text{--}10\text{ }\mu\text{m}$ were formed. As the intensity decreased below 0.5 mW/cm^2 at $t = 240\text{ sec}$; it resulted in formation of unstable or insufficiently stable samples in a form of liquid dispersions (LC drops dispersed in a liquid pre-polymeric composition with a high content of LC). It is possible that the degree of phase separation at $I > 0.6\text{ mW/cm}^2$ was quite slow than $I > 2\text{ mW/cm}^2$.^[9]

To clarify the dependence of samples morphology under UV irradiation intensities and the exposure time, the time was fixed at 600 sec and UV intensities were varied as $0.33\text{--}1.8\text{ mW/cm}^2$. The microscopic pictures of corresponding samples at $I = 0.33\text{--}1.8\text{ mW/cm}^2$, $t = 600\text{ sec}$ are shown in Fig. 1B. There was evident that longer exposure $t = 600\text{ sec}$ initiates formation of small LC droplets while the curing intensity was kept minimum $I = 0.33\text{--}0.89\text{ mW/cm}^2$. Even at further increase in intensity to $I = 1.8\text{ mW/cm}^2$ do not bring any visible difference in droplets size (Fig. 1B) due to formation of very small droplets size.

Shrinkage of PDLC structures at higher exposure intensity and time is easy to understand; as initially the formation of big LC droplets at lower exposure intensity/time were not stable and turned to smaller droplets as I and t is extended. General statement as the outcome of following findings can be; the formation of smaller LC droplets represented the stability of system at higher intensities, curing time.

Moreover, observed difference in structural evolution and resultant morphologies for low ($I < 0.6\text{ mW/cm}^2$) and high ($I > 2\text{ mW/cm}^2$) intensity of curing light might be explained by different LC- polymer phase separating mechanisms. Consider, at high UV intensities a gel point is rapidly reached for a polymer; so that LC and polymer separate mainly via the liquid-gel separation at which the rate of pre-polymer conversion is high.^[21]

Hence, this leads to formation of fine mono-dispersed droplets but of smaller size ($I = 0.89\text{--}1.8\text{ mW/cm}^2$, $t = 240\text{ sec}$). In contrast, at low intensity of curing light for shorter exposure the phase separation kinetics is slow for the system. This suggest that the system arrives at a gel point slowly and thus on the initial stage the phase separation occurs via the liquid-liquid de-mixing power ($I = 0.33\text{--}0.6\text{ mW/cm}^2$, $t = 240\text{ sec}$). At sufficiently low expositions (I) and time (240 sec), this slows separation dynamics results into formation of big spherical LC domains capable to fuse in a way and after the irradiation^[23] ($I = 0.33\text{--}0.6\text{ mW/cm}^2$, $t = 240\text{ sec}$) (Fig. 1A, B).

Our findings imply that, the morphology, the droplet size and the kinetics of NOA65-E7 are strongly dependent on the exposure intensities as well as the exposure duration. A small increase in intensity and curing duration may fasten

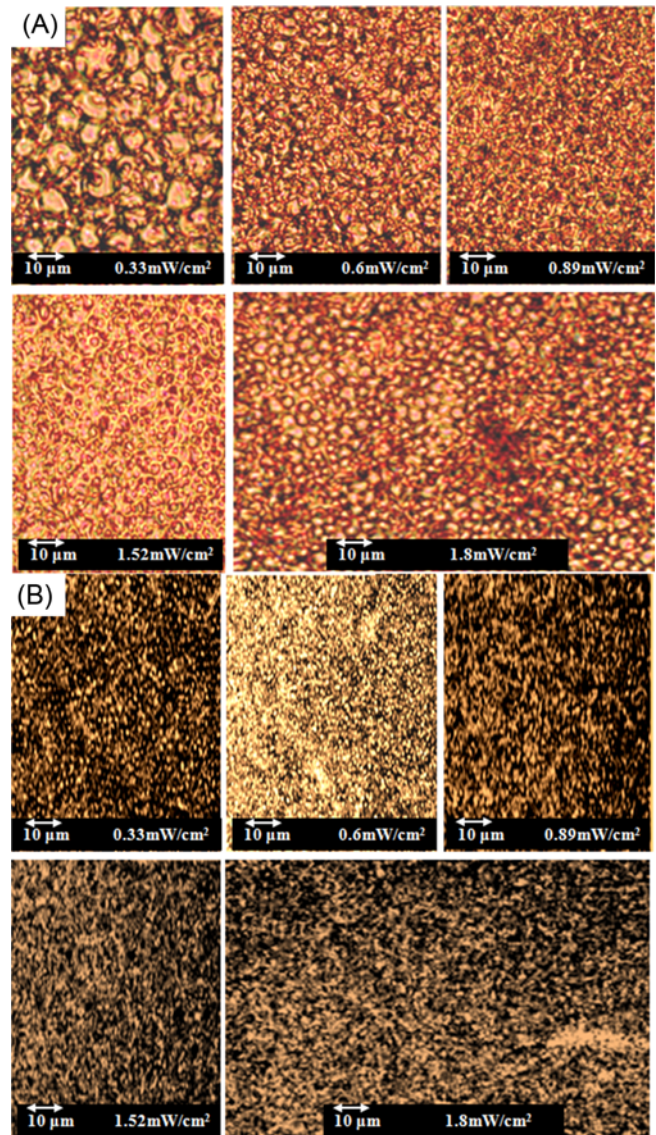


Fig. 1. Polarized Optical Microscope images of PDLCs, cured at (A) 240 sec and (B) 600 sec of curing at various UV intensities.

the polymerization rate that lead a big difference in droplet size. Similarly, by decreasing the exposure intensity and curing time may lead to bigger droplet size by slowing the phase separation process.

3.2 Electro optical properties

Figure 2(A), (B) and (C) illustrates typical transmittance with voltage (A, B) and contrast ratios (C) curves for the samples curing for various intensities at different exposure time. The fabricated NOA65-E7 PDLCs responded typically on applying the voltage; the transmittance amplified and subsequently reached to the maximum transmittance point once voltage reached to saturation (Fig. 2(A, B)).^[24]

Distinctive electro optical characteristics such as off

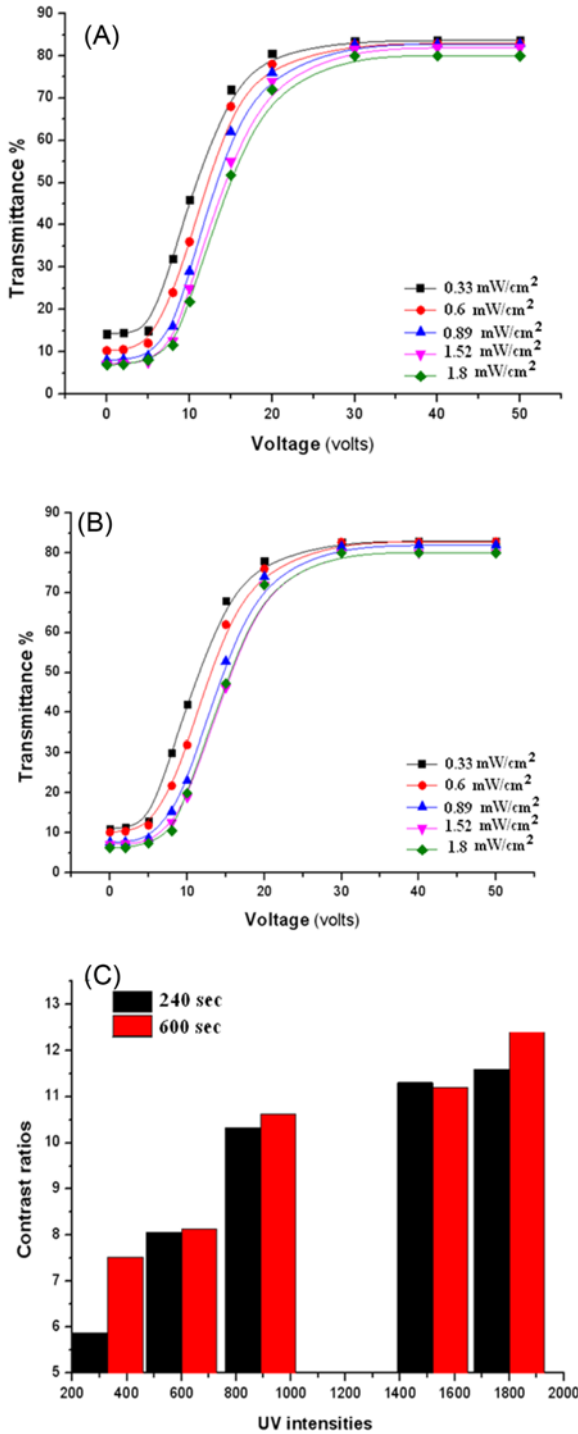


Fig. 2. Transmittance-Voltage curves at (A) 240 sec (B) 600 sec and (C) CR of NOVA65-E7 at various curing conditions.

transmittance (T_{off}), threshold voltage (V_{th}) are observed when the NOVA65-E7 cured at different conditions. Figure 2(A) illustrate the higher scattering at (T_{off}) for the samples cured at higher curing intensities ($I = 0.89-1.8 \text{ mW/cm}^2$) as compared to the PDLCs cured at the lower than this

intensities ($I = 0.6-0.33 \text{ mW/cm}^2$), while the curing duration was kept at level $t = 240 \text{ sec}$.

Similarly, the Fig. 2(B) demonstrated a higher scattering for higher curing intensities and comparatively less scattering for the samples cured at low intensities when curing time was kept as 600 sec. This behavior is typical reflection of decrease in droplet size. The higher curing intensities formed smaller droplets and this effect is intensifying when the curing time is extended.

Furthermore, the contrast ratios (CR) i.e. the ratio between the off transmittance with the on transmittance of the two PDLCs curing at different exposure time are plotted against the UV intensities (Fig. 2(C)). This revealed a general trend for CR, a rise in CR with the increase in UV intensities. However, the PDLC devices fabricated at 240 sec showed clearly less CR value as compared to curing at 600 sec. This electro optical properties as well as the transmittance are dependent on the droplet size. The smaller, homogeneous in size and nearly packed droplets well scattered the transmitted light. This behavior is similar to a larger variation in refractive indices of LC-polymer that enhanced the CR.

The electro optical properties the threshold voltage (V_{th}) for the NOVA65-E7 at two curing conditions ($I = 0.33-1.8 \text{ mW/cm}^2$ at 240 sec, $I = 0.33-1.8 \text{ mW/cm}^2$ at 600 sec) are calculated and plotted in Fig. 3. The V_{th} showed the applied voltage, at which the transmission approached 10% of the maximum. Literally, PDLC remain at off state once the applied voltage was lower than the threshold value; it implied that there was no induced arrangement in the LC droplets.^[25] Earlier, many studies have reported the dependence of V_{th} on many factors for example, the PDLC cell thickness, process of fabrication and LC types.^[25,26] According to theory^[18,26,27] [Eq. (1)], V_{th} depends on the reciprocal size of the LC droplets (R):

$$V_{th} \cong \frac{d}{R} \left[\frac{K(\omega^2 - 1)}{\omega_0 \Delta \epsilon} \right]^{1/2} \quad (1)$$

where d is the film thickness, K is the effective elastic constant, $\Delta \epsilon$ is the dielectric anisotropy of the LCs, ω is the aspect ratio of elongated droplet, and ϵ_0 is the vacuum dielectric constant. Figure 3 showed an increase in threshold voltage with the increase in curing intensities. Moreover, this showed a clear difference in threshold voltage while cured at different exposure time. The following figure showed higher V_{th} values for the PDLC as cured for longer exposure time. The reason behind this increase in threshold voltage with the increase in curing intensity and curing duration might be the increase in anchoring energies; due to decrease in droplet size as observed in Fig. 1. Hence, this is the reason for the decrease in off transmittance and V_{th} of NOVA65-E7 films with increase in curing intensities and time. The increase in off transmittance with the increase in curing duration and curing intensity is because of the increase in scattering of

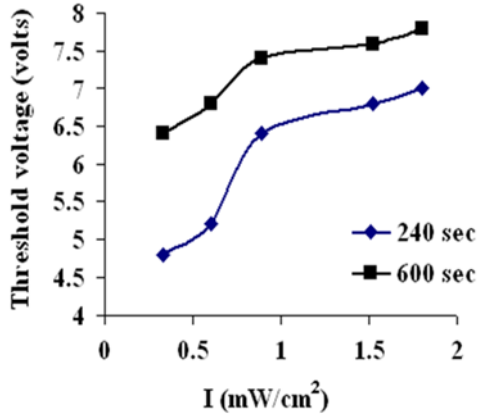


Fig. 3. Threshold voltage of NOVA65-E7 curing at various UV intensities while curing time was selected as 240 and 600 sec.

light and anchoring energy of the system that associated with small-sized domains and randomly dispersed LC directors. However, the Fig. 3 does not show a linear trend for the increase in V_{th} . It showed a sudden increase in V_{th} when $I < 1 \text{ mW/cm}^2$ for both curing times. Once the curing intensity is reached to higher limit $I = 1 \text{ mW/cm}^2$ it showed a leveled off situation in V_{th} . This behavior may attribute to the action of droplet anchoring energies as well as the droplet size and randomly dispersed LC directors. Initially, the system is unstable due to larger irregular shaped droplets size that tends to stable state the smaller size with increase in I / time. However, at smaller LC droplets the anchoring energies are at higher stable state due to the rearrangement of LC droplets in occupying the vacant space by the droplets.

3.3 FTIR analysis

The study of PDLC by the light scattering and by the morphology has some limitations as they do not disclose any chemical information and another set of experiment is necessary to determine the chemical state of film. Previously, FTIR spectroscopy has been successfully applied to study PDLC formation and found an comprehensive, absolute, and responsive method of examining chemical changes.^[18,19,22] Consider an initially clear homogeneous solution is turned to scattering state when cured and lead to phase separation at some point. The chemical composition of LC-pre-polymer from its isotropic homogeneous state on UV irradiation altered their phases (LC isotropic to nematic state & monomer to hard polymer matrix). This led to sudden increase in scattering; is due to the change in refractive index in PDLCs that termed as phase separation.^[18] Thus, if a homogeneous mixture (as is a precursor for PDLC preparation) is cured, leading to phase separation, optical effects leading to baseline changes would be expected as a sign of the onset of phase separation.^[21] However, IR spectroscopy is a chemically specific probe and allows for

detection of other (chemical and physical) processes at the same time.

Earlier the state of ordering in a liquid crystal is evident in its vibrational spectrum.^[28] Hence, here in particular the absorbance of the nitrile-stretching band from the liquid crystal (E7) considered here changes as the liquid crystal is brought into the nematic phase from an isotropic state. By monitoring these changes with time, it can be possible to detect the onset of nematic organization and possibly, the dynamics of organization leading to quantification of the fraction of total liquid crystal that is nematic (by Eq. (4)-(5)). For E7, only the liquid crystal in the nematic phase contributes to the performance of PDLC. It is then crucial to quantify the amount of liquid crystal in the nematic domains. The rest of the added liquid crystal is considered as wasted if dissolved in the matrix. On the basis of the absorbance of a liquid crystal specific band, that shows a change (in our case, the nitrile stretching band of E7), it is possible to quantify the fraction of liquid crystal that is evident itself in nematic domains. It is the objective of this work to demonstrate that the onset of phase separation and nematic ordering can be monitored along by using real-time FTIR spectroscopy along with morphologies and electro optical properties.

Expressions to Estimate Phase Composition

Let, A_I be the absorbance of the liquid-crystal-specific band in its isotropic state and ϕ be the fraction of liquid crystal (E7) in the initially homogeneous mixture with the matrix precursor (NOA65). Further, let ϕ be volume fraction of liquid crystal in initial homogeneous mixture with matrix precursor. For constant cell thickness, the absorbance of liquid crystal specific band can be simply found as:

$$A_{\text{CN,uncured}} = \Phi A_I \quad (2)$$

Here, $A_{\text{CN,uncured}}$ is the absorbance of nitrile band at uncured state. Further, If α is fraction of liquid crystal during phase separation, then total fraction of liquid crystal in droplets is $\alpha\phi$ and overall absorbance of liquid crystal specific band is given by:

$$A_{\text{CN,cured}} = A_N \alpha \Phi + A_I \Phi (1 - \alpha) \quad (3)$$

Here, the absorbance for cured nitrile band is $A_{\text{CN,cured}}$.

Further, by rearranging and the solving the Eqs. (1) and (2) for the $A_{\text{CN,cured}}$ it becomes:

$$A_{\text{CN,cured}} = \alpha \Phi \left(A_N + A_I + \frac{A_I}{\alpha} \right) \quad (4)$$

Whereas, by rearranging Eqs. (1) and (2) to eliminate ϕ gives α to evaluate the degree of phase separation as:

$$\alpha = \left(\frac{A_{\text{CN,uncured}} - A_{\text{CN,cured}}}{A_{\text{CN,uncured}}} \right) \left(\frac{A_I - A_N}{A_I} \right)^{-1} \quad (5)$$

Thus, the fraction of liquid crystal in nematic domains is simply the ratio of the fractional change in absorbance of a band on curing with the fractional change in absorbance due to the isotropic to nematic transition. The assumption of constant cell thickness is unnecessary, as it is the dependence on (ϕ). Preferential dissolution of components and the loss of specific interactions with the matrix that may affect absorbance are assumed small and are neglected.

Let, in Eq. (4) for a constant volume fraction (ϕ) of LCs the absorbance of nematic phase (A_N) and absorbance of isotropic phase (A_I) are considered as constant for the pure LC fractions at nematic and isotropic phases, thus absorbance of the cured cell $A_{CN,cured}$ can be related with degree of phase separation as expressed in Eq. (4). Accordingly, Eq. (4) can be stated as a change in absorbance of nitrile stretching band and give an indication about the direct change in degree of phase separation of the following mixture.

The E7 has nitrile ($C\equiv N$) functional group as having cyanobiphenyl. As demonstrated earlier the peak in FTIR for the nitrile $C\equiv N$ stretching band for E7 has been detected at 2226 cm^{-1} .^[19,29-33] Earlier in our work the degree of phase separation was measured as fraction of E7 liquid crystal molecules within each cured film by knowing the absorbance of nitrile band from FTIR.^[29,30] Accordingly, the absorbance of the nitrile ($C\equiv N$) stretching band of E7 liquid crystal was taken as the fraction of LC when brought into a nematic phase from an isotropic state. The absorbance of LC (E7) is recorded by casting the PDLC films on a NaCl tablet. The baseline for each sample was determined by taking the NaCl tablet spectra as the standard.

In the past, it has been investigated in detail that at onset of phase separation, the LC molecules trapped inside the monomer molecules and LC brought into a nematic phase from an isotropic state.^[19,31] Based on this concept it is likely to find the change in FTIR absorption intensity of nitrile band of LC functional group. During the phase separation, free monomer molecules become harder to make the polymer bed and no change is likely to observe in FTIR absorption of band for monomer.

The FTIR absorption for CN group was observed for PDLC, cured at various UV intensities and at different curing times (120, 240, 480 and 600 sec). In Fig. 4 and 5, the FTIR spectra of PDLCs cured at 240 and 600 sec has been plotted.

Figure 4, 5 both showed a decrease in CN absorbance with the increase in UV irradiation intensity. Initially for $t = 240$ sec of curing the FTIR maximum absorbance for nitrile stretching band at 0.33 mW/cm^2 was observed to be as 1.02. Further, at $I = 0.6\text{ mW/cm}^2$ the maximum absorbance value was decreased to 0.72 values. Further, at UV intensity 0.89 mW/cm^2 this value decreased to 0.51. Following the decreasing trend finally at $I = 1.8\text{ mW/cm}^2$ the maximum absorbance was observed as 0.36. Initially a drastic decrease

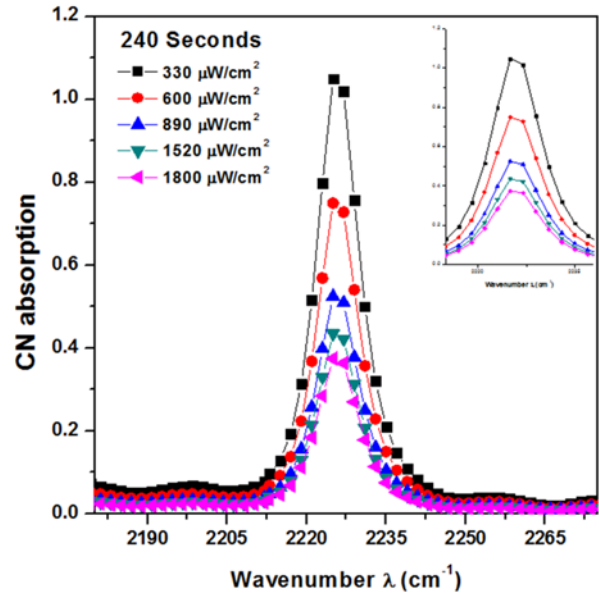


Fig. 4. The FTIR absorbance spectra of selected nitrile region of cured PDLC films at 240 sec while fabricated at various UV intensities.

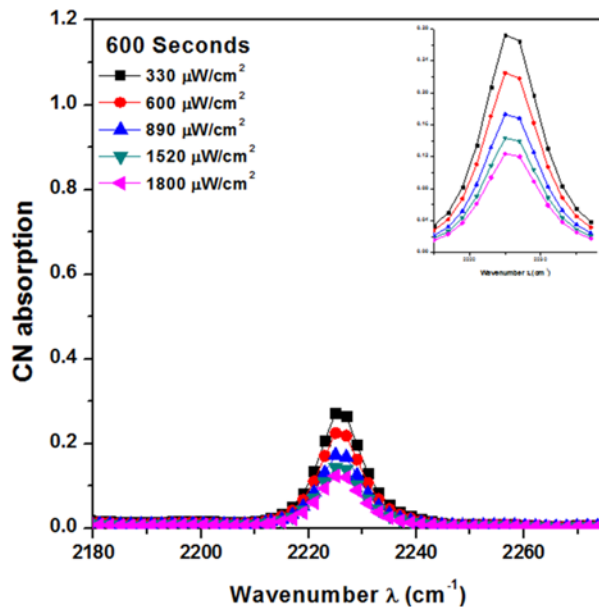


Fig. 5. The FTIR absorbance spectra of selected nitrile region of cured PDLC films at 600 sec while fabricated at various UV intensities.

in absorbance was found at low intensities ($I < 0.89\text{ mW/cm}^2$). Further, as the UV intensities increased the absorbance decreased steadily. This trend is almost similar to the threshold voltage effect.

A similar trend of decrease in absorbance with the increase in curing intensity was also observed for $t = 600$ sec of cured PDLC. Moreover, a large gap was observed in absorbance of two PDLCs, cured at 240 and 600 sec at 0.33 mW/cm^2 UV

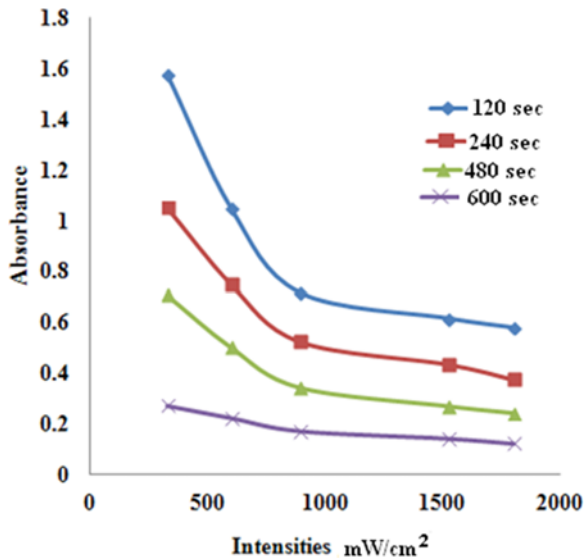


Fig. 6. The FTIR absorbance of PDLCs films cured at various time interval by selecting various UV intensities.

intensity. According to the Eq. (4) and (5), the decrease in absorbance of PDLCs was considered as the increase in the phase separation with the increase in the UV intensity and the curing time. In other words, more LCs turned to nematic phase as curing time is increased and thus absorbance of nitrile band for PDLC is decreased. This behavior reveals that degree of phase separation increased while increasing the curing intensities and time simultaneously.

Further this quantitative analysis were extended for four different intervals 120, 240, 480 and 600 sec of curing and plotted against the various curing intensities (Fig. 6). Figure 6 demonstrated the maximum absorbance for various time interval at $I = 0.33 \text{ mW/cm}^2$. However as the UV intensity increased the absorbance decreased abruptly. Even with the further increase in intensity, this trend was leveled off. Contrary to 600 sec of curing, the FTIR absorbance showed a small decrease in absorbance almost at all intensities. These results enlightened more precisely the effect of UV irradiation and curing time on the properties of PDLC devices. From such findings one can be concluded that the phase separation of PDLC films initially was found very much dependent when curing intensity was $I \leq 0.330$ to $I \leq 0.89 \mu\text{W/cm}^2$ and curing time $t \geq 480$ sec.

However, with the further increase in curing intensity and curing time it may deteriorate the PDLC performance by increasing the threshold voltage and decreasing the droplet size. From these findings, it can be said that with the further increase in curing I or t bring no obvious change in phase separation. The reason behind such behavior could be that maximum numbers of LC molecules have already attained the maximum room inside the droplets. The rest of the added liquid crystal was considered dissolved in the matrix and

hence, went-off wasted. Hence, these dissolved LC molecules in fact increased the threshold voltage and deteriorate the other electro optical properties.

4. CONCLUSIONS

In current study conducted for PDLCs, the effect of UV irradiation intensities and UV irradiation time have been investigated on considering the electro optical properties, the morphologies and the change in phase separation by observing the absorption of nitrile (CN) stretching band of E7. The UV intensities were selected starting from 0.33 mW/cm^2 with the gradual increase in intensity to maximum 1.8 mW/cm^2 at the various curing time ($t = 120\text{-}600$ sec). According to our findings, the morphologies and electro optical properties demonstrated the general trends i.e. decrease in droplet size with the increase in curing time/ curing intensities and a small decrease in OFF transmittance with the increase in UV intensities at the different intervals. In addition increase in threshold voltage was found; where a higher threshold voltage was recorded for the samples cured for $t = 600$ sec as compared to the sample cured for $t = 240$ sec. To enquire the quantitative analysis of PDLC devices, the FTIR technique has been successfully used by analyzing the change in the absorbance of CN stretching band for E7 LC molecules. It has been observed that the CN absorbance drastically decreased for the least curing UV intensity when the time interval for curing was increased from $t = 120$ sec to 480 sec. Thus, the phase separation process increased with the increase in curing time (t) and curing intensities (I) at some limit. It can be stated that initially the increases in curing intensity/time may swift the phase separation when I was taken as 0.33 to 0.89 mW/cm^2 and $t = 120\text{-}240$ sec. However further increase in (I) and (t) did not bring any obvious change in phase separation instead it brought increase in threshold voltage. We can conclude that such study could be very useful step for further understanding the characteristics of PDLC display to get the appropriate properties of such PDLCs by selecting the right compositions, curing intensities and curing duration for fabrications of such films.

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