# Novel RGB Polymer Dispersed Liquid Crystal Display using Color Pigments.

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## Abstract

*We have developed a RGB polymer dispersed liquid crystal film (RGB PDLC). To obtain the color display, color pigments are mixed in the prepolymer. We have presented an electro-optical performance of our cell and analyzed the electro optical properties for varying LC/ pre-polymer ratio and polymer type.*

## 1. Introduction

Study for using polymer dispersed liquid crystal (PDLC) for electrical information display has been on last decades. PDLC, a liquid crystal (LC) display mode, uses transmitted state and scattered state to display any information.

Cause PI and polarizer does not need to PDLC, PDLC mode gives more bright image than other LC mode's that and we can save the material cost and process. But, it has a demerit like this which it is difficult to get a dark state and color expression, their operation voltage is still high.

Some methods were proposed to solve those problems as dichroic dye doped PDLC, three color layer PDLC structures, and holographic PDLC (HPDLC) combined with color sequential method. Generally dye is very weak to UV, so it is not easy to get good result. And to operate the HPDLC, higher voltage is needed than that for operating normal PDLC.

PDLC manufacture methods are Polymerization-induced phase separation (PIPS), Thermally-induced phase separation (TIPS), Solvent-induced phase separation (SIPS), and so on. Among the methods, PIPS is universally used and we also use this method.

In this paper, we have focused on a new color expression method of PDLC without color filter by mixing a pigment with PDLC solution. It is the cause of using pigment that pigment is strong to UV light.

To achieve our object, we did various experiments as varying the material mixing ratio, changing the pre-polymer and pigment, and so on.

## 2. Experiment

Follow materials was used for our experiments. The material used is TL203 liquid crystal (Merck) and PN393 UV curable prepolymer. TL203 is a mixture for active matrix and has an extraordinary refractive index $n_e$ of 1.73, an ordinary refractive index $n_o$ of 1.529, $\Delta n$ of 0.201(at 589nm, 20℃) and a dielectric anisotropy $\Delta\varepsilon$ of 11.0. PN393 is a mixture of acrylate materials for use with Merck TL mixtures with a refractive index of 1.473.

Prepolymer mixture named PP series was specially developed for improving the RGB PDLC properties by DONGJN SEMICHEM Co., ltd.. PP series are a mixture of acrylate monomer, oligomer, cross-linker and photo-initiator, with different kinds of monomer and photo-initiator respectively. PDLC was prepared by using PIPS method. Its polymerization is caused by UV light.

**Figure 1. Microscope photograph of RGB PDLC mixed pigments. Red (left), Green (center), Blue (right)**

First, the liquid crystal, prepolymer and color pigment are mixed in the desired ratio by stirring at room temperature, and then coated on an ITO glass, covered with the other ITO glass. A target cell gap is 10 ㎛. The mixture is cured by exposure to main wavelength 365nm UV light with 72mW/cm$^2$ for 5 minutes at a room temperature. Figure 1 shows fabricated R, G, B PDLC each other.

## 3. Results

To fabricate novel RGB PDLC, we first made normal PDLC with TL203 LC mixture and PN393 UV-curable prepolymer. The normal PDLC with TL203 76~84 wt% was prepared with UV exposure condition of 72mW/cm$^2$ for 5 minutes. As a result, the normal PDLC made from 78wt% TL203 showed the good electro-optical properties. Its operation voltage and contrast ratio is 5.1V and 212:1.

A PDLC mixed 2wt% green color pigment (green PDLC) was made with the similar recipe. It shows very highly increased operation voltage as compared with the normal PDLC. Its operation voltage is 25.8V. Figure 2 shows a voltage-transmittance curve of normal PDLC and green PDLC and operation photograph of green PDLC is shown in Figure 3.

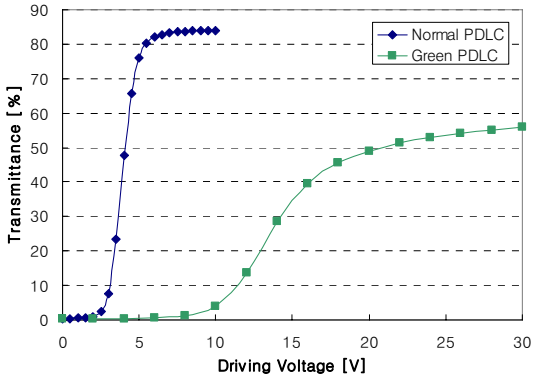


**Figure 2. V-T curve for normal PDLC and green PDLC.**

The electro-optical properties of green PDLC for various LC ratio and pigment ratio were evaluated. Figure 4 shows that the V90 increases slowly with the increase in LC ratio.

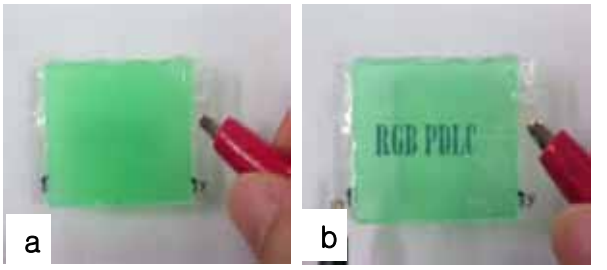


**Figure 3. Photograph of operating the Green Pigment-mixed PDLC. off-state(a) and on-state(b)**

The lowest V90 is at the condition of 80wt% LC and 2wt% pigment, but V90 is not enough to apply RGB PDLC to conventional TFT-LCD. The 2wt% and 4wt% pigment-mixed PDLC shows the same trend of electro-optical properties. And the 2wt% pigment-mixed PDLC have a lower V90 than 4wt%. But, it is insufficient for good color property. We need increasing the pigment mixing ratio to enhance the property.

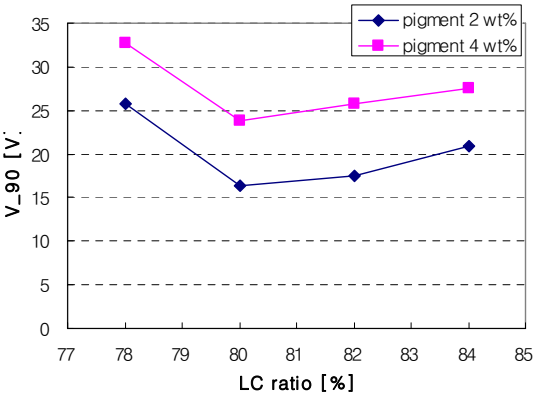


**Figure 4. Operation voltage (V90) variation during LC ratio and pigment ratio is changed.**

To form RGB PDLC, we also apply red and blue pigment to normal PDLC with same recipe of green PDLC. LC ratio given minimum V90 is slightly different with pigment type. An interesting point is that V90 is different as each color pigment. Blue PDLC shows the highest V90 and the red PDLC shows the lowest V90.

Generally, the operation voltage of PDLC film depends on the size and shape of the LC droplet, the dielectric constant, cell gap, and so on. But in practice, the surface properties of the PDLC polymer influences more importantly in determining the operation voltage.

The PDLC films contained R, G, B pigment have faster response time than that of normal PDLC. Response times of normal PDLC with 80wt% TL203 and 2wt% green PDLC with 80wt% TL203 are 49.6ms and 13.2ms, respectively.

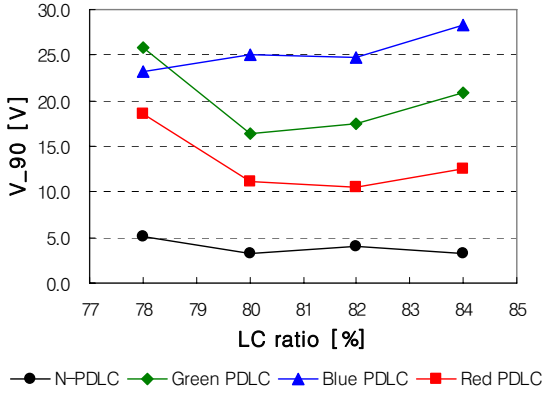


**Figure 5. Operation voltage variation when we change the LC ratio in normal, red, green, and blue PDLC**

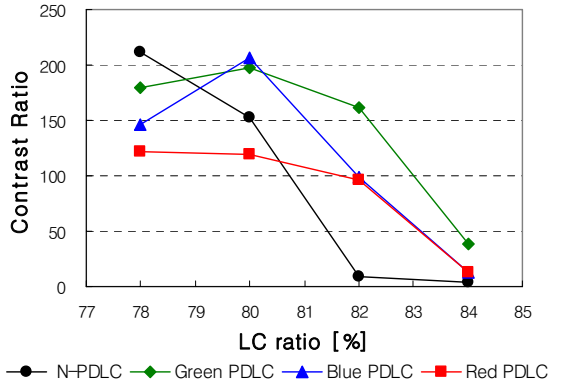


**Figure 6. Contrast ratio variation when we change the LC ratio in normal, red, green, and blue PDLC**

The contrast ratio of normal PDLC and RGB PDLC as varying LC ratio is showed in Figure 6. Normal PDLC represents highest contrast ratio at 78wt% LC. But RGB PDLC has a highest value at 80wt% LC. This contrast ratio is related to scattering ability for light source. At previous reported research data, the contrast ratio has something to do with LC droplet size. The contrast ratio in PDLC included small LC droplet is higher than one included big LC droplet. This results show that normal PDLC cells of 78wt% LC and RGB PDLC cells of 80% LC weight have higher contrast ratio than another cells because they have a small LC droplet size. At the point over 80wt% LC in RGB PDLC, contrast ratio is decreased smoothly or sharply as kind of cell. We expect that if LC wt% increases, LC droplet size increases.

**Figure 7. Demonstration photographs of pattern RGB PDLC cells switched ON (right) and OFF (left) for reflective type.**

To improve the RGB PDLC properties, we have tested various prepolymer which was supplied by DONGJIN SEMICHEM Co., ltd.. In this test, the changes of monomer's structure and ratio give only a little improvement or difference. Only the photo-initiator change gives an effect to improve the properties. It causes the fact that LC droplet size has

been increased with the change to photo-initiator given slower speed of polymerization.

Figure 7 shows the demonstration photographs of RGB PDLC with strip passive matrix pattern for reflective type. For making the active matrix RGB PDLC display based on TFT, we cannot apply the conventional TFT LCD process. An advanced technology as inkjet printing might be comfortable for that.

## 4. Conclusions

We have studied RGB PDLC mixed color pigments to get a colored PDLC. We have found the optimized mixing ratio and recipe to make a RGB PDLC.

In material test, monomer's structure and ratio of prepolymer is not effective to improve PDLC properties. The properties have been improved just when we change the photo-initiator, because the droplet size is affected by polymerization speed due to the change of photo-initiator.

Pigment ratio isn't still enough to get a good color quality. And it remains as a fact that the operation voltage increases when a PDLC contains a pigment. So it needs to develop the more appropriate pigments for RGB PDLC.

If a more improved technology like inkjet printing method is introduced, we can realize the active matrix RGB PDLC display based on TFT.

## 5. Acknowledgements

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