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Micro-sized Polymer-Dispersed Liquid Crystal Modulator for TFT array defect Inspections

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We proposed low driving voltage electro-optic (EO) modulator using the nano/micro-sized polymer-dispersed liquid crystal (PDCLC) for TFT array inspector. It was obtained high efficiency performance with detection sensitivity with low driving voltage at 20μm air gap.

1. Introduction

Recently, the requirements of the high-definition thin-film-transistor liquid crystal displays (TFT-LCDs) panel have driven forming fine-pitch and high-performance TFT array. Therefore, the sensitivity improvement of the TFT array testing system is strongly needed for detecting defects at fine-pitch TFT array. Generally, the conventional testing system for a non-contacting light modulator is based on the light scattering characteristics of nematic liquid crystal (NLC) droplets in polymer matrix film [4, 5]. The modulator based on an electro-optic material, a polymer- dispersed liquid crystal (PDLC), is a core part of the array testing system. In the presence of an applied field, the LC orients parallel to the field direction so that the light can propagate without scattering and then it is reflected from the dielectric mirror [4-6]. However, the modulator based on a PDLC usually requires a much higher operating voltage due to an air gap between the TFF arrays substrate and the PDLC film, which it is approximately 5-30 μm. Also, the positional resolution of the modulator is required to level of several tens of micrometers. With increasing resolution TFT-LCD, it is hard to detect a fine pitch pixel of TFT-LCDs by using the conventional electro-optic (EO) modulator based on conventional polymer-dispersed liquid crystal (PDLC) [5].

We report an investigation of a high sensitive EO modulator based on the Nano/ micro-sized PDLC for TFT array inspector. The proposed modulator has the advantages of high defect detection sensitivity and low driving voltage by using nano/micro-sized NLC droplets with low dielectric and high birefringence liquid crystals.

Figure 1 is a schematic diagram of EO Modulator for TFT array Inspector. In case of bad pixel, there is no charge. Therefore no capacitive coupling and the liquid crystals will remain in their random state. Contrastively, In case of good pixel, the stored charge from capacitive coupling will rotate the liquid crystal molecules so they can pass light.

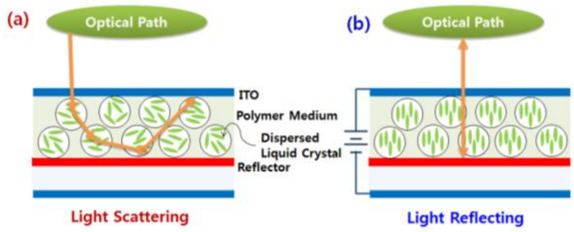

Figure 1. Schematic diagram of EO Modulator for TFT array Inspector; (a) Bad pixel, (b) Good pixel

2. Experiments

The mixtures for PDLC device presented in this work are consisted of the nematic Liquid Crystal (NLC) HTG118200-200 (HCCH Co.) and UV curable optical adhesive prepolymer NOA65 (Norland Products Inc.). The NLCs and prepolymer NOA65 are mixed in a ratio 60:40. The mixtures with the uniform cell gap of 15 μm were injected into the assembled cells with antiparallel rubbed homogeneous alignment layer by capillary action at a clearing temperature. And then, the UV light was exposed for 20min which uses different UV intensities with 0.2 μWcm^{-2}, 0.93 $mWcm^{-2}$, 23.4 $mWcm^{-2}$, and 180 $mWcm^{-2}$. The electro-optic (EO) switching behavior was observed using a polarizing optical microscope

(Nikon E600W POL) with a frame-grabbing system (Samsung SDC-450) and an arbitrary function generator (Stanford Research System DS345). The measurement was carried out at room temperature.

3. Results and Discussion

The nano/micro-sized PDLC system is controlled by the method of polymerization induced phase separation (PIPS) of a reactive monomer and liquid crystals mixture exposed with ultraviolet (UV) irradiation. The droplet size is decreased as increasing UV intensity as shown in Fig.2. The nano/micro-sized droplet was obtained by strong UV intensity (1000 W Hg lamp) as shown in Fig. 2(d) ;

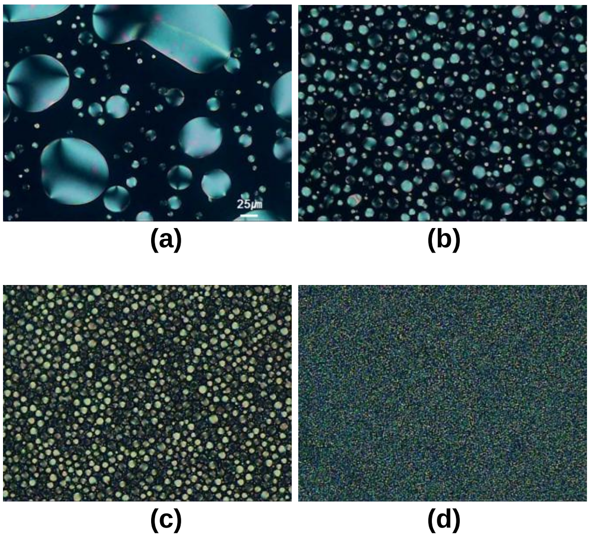

Figure 2. The microscopic images of PDLC droplets as a function of UV intensity;
(a) UV intensity (0.2µW cm^{-2}),(b) UV intensity (0.93 mW cm^{-2}),(c) UV intensity (23.4 mW cm^{-2}),(d) UV intensity (180 mW cm^{-2}),

Figure 3 shows transmittance-voltage (TV) curve according to UV intensity when there is no air gap. As shown in Fig. 3, the switching voltage of the PDLC film increased with increasing the UV intensity, conversely, the contrast ratio (CR) of the PDLC film is increased with increase in UV intensity. The switching voltage and contrast ratio depend on the size of droplet on the PDLC film. The decrease in drop size with a decreasing LC fraction leads to an increasing switching voltage. A switching voltage is given by [6,7]

$$V_{switch} \approx \frac{1}{C}\frac{d}{R}(L^2-1)\left(\frac{4\pi K}{\Delta\varepsilon}\right)^{1/2} \qquad (1)$$

where *R* is a drop radius, *d* the film thickness, and *L* the ratio of the largest to the smallest radii, assuming the drops to be ellipsoidal. *K* is the elastic constant, and $\Delta\varepsilon$ is the dielectric anisotropy of the liquid crystal. The prefactor C^{-1} means the effective electric field driven by dielectric or conductivity mismatch between the LC droplet and the surrounding matrix. Therefore, with decrease in the drop size of PDLC film, the switching voltage is increased. It is considered that the increase of switching voltage is due to the strong anchoring of the liquid crystal at the droplet surface [7]. However, the drop nano/micro-size of the PDLC film (Fig. 2d) leads to a decreasing the black level by increased scattering as shown in Fig. 3.

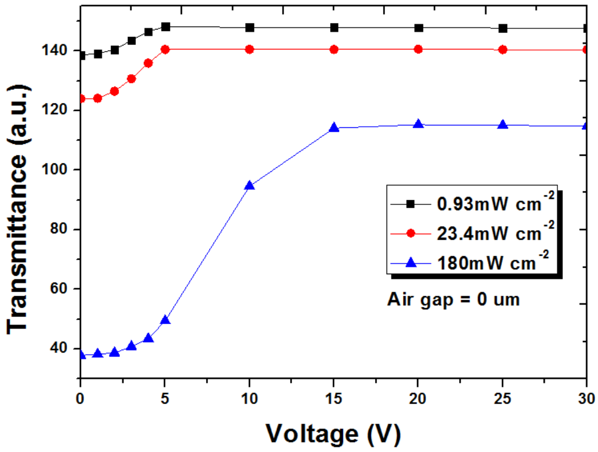

Figure 3. Transmittance-Voltage (TV) curve as a function of UV intensity such as 0.93 mW cm^{-2}, 23.4 mW cm^{-2}, and 180 mW cm^{-2}.

Figure 4 shows transmittance-voltage (TV) curve of the nano/micro-sized PDLC system with 20 µm air gap between the electrode substrate and the PDLC film. A low driving voltage and high detection sensitivity was obtained with the nano/micro-sized PDLC film as shown in Fig. 4. Here, the driving voltage was about 60 V. The detecting sensitivity of the inspector is directly proportional to the slope of the transmittance-voltage (T-V) curve [5]. The driving voltage and the maximum detecting sensitivity of the nano/ micro-sized PDLC cell was about 43V and 0.76(@60V), respectively. Therefore, we obtained high detecting sensitivity and low driving voltage in the nano/micro-sized PDLC system with 20 μm air gap between the electrode substrate and the PDLC film.

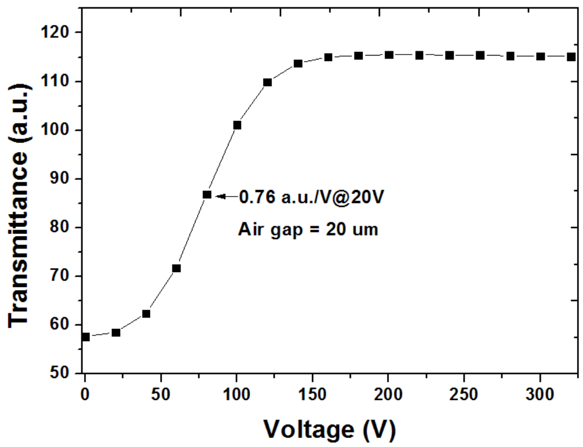

Figure 4. Transmittance-voltage (TV) curves of the EO modulator based on PDLC with a 20μm air gap.

4. Conclusion

We demonstrated the detecting sensitivity of the TFT array inspector based on the nano/micro-sized PDLC system using low dielectric and high birefringence liquid crystals through the PIPS method. The nano/micro-sized PDLC film leads to the low driving voltage and high detection sensitivity As a result; high detecting sensitivity enhances the manufacturing yield. With increasing the detecting sensitivity, the nano/micro-sized PDLC system is applicable to inspection of fine-pitch and high- performance TFT array. Furthermore, since low driving voltage at the large gap between modulator and TFT panel, the reliability and lifetime of TFT inspector would be enhanced.

5. Acknowledgements

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6. References

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