A High Sensitivity PDCLC-based Electro-optic Modulator for TFT Array Inspector

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Abstract

We proposed a high sensitive electro-optic modulator based on a polymer-dispersed cholesteric liquid crystal (PDCLC) for the TFT array inspector. Since the PDCLC is operated in a reflective mode, the PDCLC-based inspection system is very simple since a dielectric mirror, which is generally used in a conventional TFT array inspector, is not required.

1. Introduction

Thin-film-transistor (TFT) liquid crystal displays (LCDs) have the advantages of picture quality such as contrast, response, and brightness. To reduce costs for the widespread use of TFT-LCDs, the yield and throughput of the fabrication process of TFT arrays must be improved. In order to increase yield and reduce costs, it is necessary to test TFT arrays and detect defects during the manufacturing process. A manufacturing the TFT-LCD with no pixel defects is one of the important issues in the TFT-LCD manufacturing industry. Therefore, the importance of the efficiency enhancement on LCD production process has been increasing and the ALDI (Automated LCD Defect Inspection) system is demanded for this efficiency enhancement. There are several established methods for various inspections [1-7]. In general, the inspector shows a common electrode configuration in a single substrate and the TFT array is acted as the other pixel electrode for inspection. Most of them are noncontact methods that use a two-dimensional electro-optic (EO) modulator and detect the surface potential of the TFT array induced by phase modulation [5, 6]. The positional resolution of the modulator is required to level of several tens of micrometers. However, the fringe electric field from the edges on the pixel electrode has influence on liquid crystal configurations even at the neighboring pixel regions. Thus, the EO variation penetrates into the neighboring pixels. The variation is increased with increasing the applied voltage and thus it gives rise to degrading the detection sensitivity of the inspector. With increasing resolution TFT-LCD, it is hard to detect a fine pitch pixel of TFT-LCDs by using the modulator based on polymer-dispersed liquid crystal (PDLC) [6].

In this research, we propose a novel high sensitive EO modulator based on the polymer-dispersed cholesteric liquid crystal (PDCLC) for TFT array inspector. The non-contact inspecting system for the novel light modulator based on PDLC is shown in Fig. 1. A conventional PDLC-based modulator has to require dielectric mirror. Conversely, the proposed modulator based on PDCLC is operated in the reflected mode. Therefore, the proposed modulator has the advantages of simple structure without the dielectric mirror instead of conventional modulators.

2. Experimental

The polyimide (PI) alignment layer (RN1199, Nissan Chemical industries Co.) for LC alignment was spin-coated on the indium-tin-oxide (ITO) substrate. The layer was soft- baked to evaporate solvent under 100 °C for 10 min and then was hard-baked under 220 °C for 1 hour 30 min. After rubbing the alignment layer, two rubbed substrates were assembled in anti-parallel direction. The mixtures for PDCLC device presented in this work are consisted of CLCs with chiral dopant (R-811, Merck Co.) mixed in the nematic LC MLC6608 (Merck Co.) and UV curable optical adhesive prepolymer NOA65 (Norland Products Inc.). The CLCs and prepolymer NOA65 are mixed in a ratio 50:50. The CLC 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 90 min which uses different UV intensities with 0.05 mW/cm^2, 8 mW/cm^2, 32 mW/cm^2. The samples were measured by a polarizing optical microscope (POM) equipped with a hot stage and computer program-assisted controller. The reflection spectra were measured using Ocean Optics spectrometer equipped with the spectroscopy operating software to calculate a variety of color-space values from the reflection spectra.

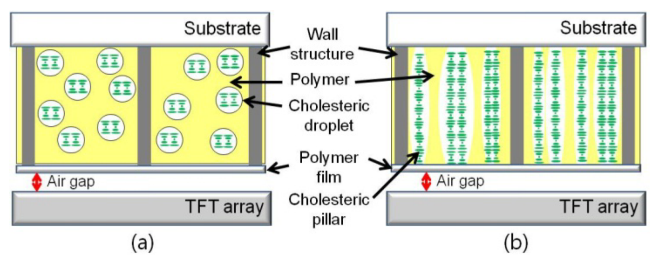

Figure 1. Schematic non-contact testing system for novel light modulator based on (a) cholesteric liquid crystal droplet and (b) pillar structure.

3. Results and Discussion

Figure 2 shows the microscopic textures and image profiling of a convention modulator based on PDLC and proposed modulator based on PDCLC which uses different UV intensities with 0.05, 8, and 32 mW/cm^2. The size of droplet on PDCLC according to UV intensity is about 7.34 μm (32 mW/cm^2), 14.4 μm (8 mW/cm^2), and 32.3 μm (0.05 mW/cm^2), respectively. As UV intensity decreases, the size of droplet on PDCLC is increased. Especially, the pillar structure on the PDCLC with the lowest UV intensity (0.05 mW/cm^2) is obtained as shown in Fig. 2(d). When the 50 V voltage on PDCLC based modulator is applied, it have changed to focal conic state from planar state, and then we can admit no pixel defect in TFT array substrate. The light variation induced by the fringe effect electric field of the edge on the ITO electrode is obtained by image processor as shown in Fig. 2. As shown in Fig. 2(a), the variation value of the modulator based on PDLC is about 20, and 33 μm at 20, and 50 V respectively. The variation is increased as increasing the size of droplets in the PDCLC.

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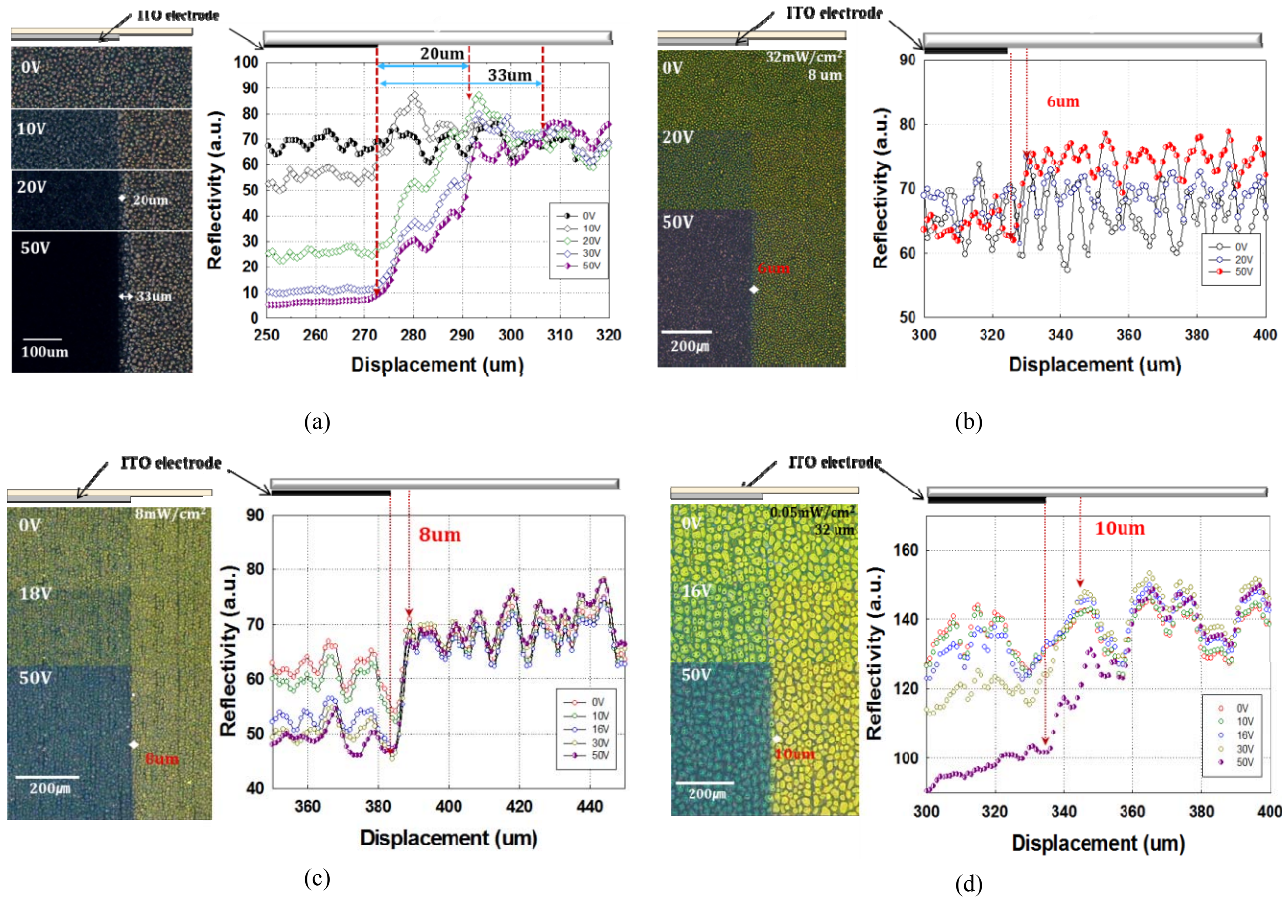

Figure 2. The microscopic textures and image profiling of (a) a convention modulator based on PDLC and proposed modulator based on PDCLC which uses different UV intensities with (b) 0.05 mW/cm^2, (c) 8 mW/cm^2, (d) 32 mW/cm^2.

Therefore, the variation of PDCLC based modulator is lower than that of PDLC based modulator.

Figure 3 shows the resultant reflectance spectra as a function of UV intensity. Generally, the helical pitches of the cholesteric liquid crystal induce the Bragg reflection, which central wavelength λ_0 is given by

$$\lambda_0 = nP_0, \qquad (1)$$

where P_0 is the pitch length of cholesteric liquid crystal and n is the average refractive index [8,9].

The central wavelength and the bandof all PDCLC cells was to be measured around 570 nm, as shown in Fig. 3. With increasing UV intensity, the reflected intensity and the droplet size of the PDCLC is decreased. With low UV intensity of 0.05 mW/cm^2, the maximum reflection and the pillar structure of the PDCLC were obtained; the reflectivity was 33.6 %, and the size of pillar structure was around 32.3 µm. On the other hands, with high UV intensity of 32 mW/cm^2, the minimum reflection and the droplet size of the PDCLC were obtained; reflectivity was 10.9 %, and the droplet size was around 7.34 µm. In this condition, it is considered that the reduction of the reflectivity by increase of the UV intensity is due to decrease the droplet size of the PDCLC cell. Finally, the reflected intensity and the droplet size of the PDCLC increases with decreasing the UV intensity for the UV irradiation. Therefore, the high reflectivity and the small variation of PDCLC modulator with low UV intensity (0.05 mW/cm^2) were obtained.

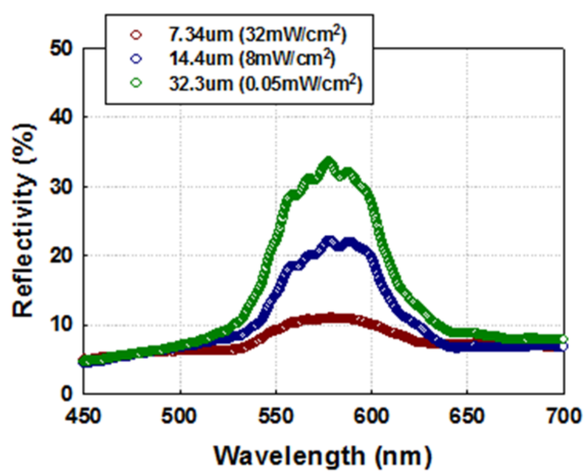

Figure 3. The reflected wavelength as a function of UV intensity.

4. Conclusion

In this work, we have demonstrated novel high sensitive electro-optic (EO) modulator based on polymer dispersed cholesteric liquid crystal (PDCLC) for TFT array testing applications. The droplet structure on PDCLC with low UV intensity was obtained. On the other hand, the pillar structure on PDLC with high UV intensity was obtained. Thus, the size of droplet is increased with the decrease in UV intensity; conversely, the variation is increased as increasing the size of droplet in the modulator. Also, the reflected intensity of the PDCLC increases with increasing the droplet size. This significant improvement can allow defect detection for TFT-LCDs with fine pitch pixels.

5. Acknowledgements

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