Twisted Nematic LC Modulator for TFT Array Inspection

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Abstract

A twisted nematic type liquid crystal electro-optic modulator (TN-LC modulator) was developed. The modulator used single polarizer and the reflection on-off ratio was maximized by optimization of twist angle and retardation of liquid crystal cell. The TN-LC modulator shows better sensitivity and response time than conventional liquid crystal modulator.

1. Introduction

A LC (liquid crystal) modulator measures the pixel voltage for TFT (thin film transistor) array test. The pixel voltage can be measured by applying voltages between a panel and the LC modulator. Guided light to the modulator is reflected and the reflection ratio is settled by the pixel voltage.

By the TFT array test, faulty panels are selected before going to following liquid crystal process [1, 2, 3]. Forward admittance sensing, charge sensing, electro-optic modulator and e-beam are the ways to detect the defects on TFT array.

Currently LC modulator is widely used for the detection of the defect on TFT array. The pixel voltage modulation of the pixel electrode is converted to the light modulation by the LC modulator. Conventional LC modulator is using polymer dispersed liquid crystal (PDLC) [4]. PDLC can modulate light transmittance by electrically controllable light scattering; therefore, it doesn't need rubbing and polarizer.

Typical LC mode which is widely used for the TFT LCD is TN (twisted Nematic). We developed TN LC modulator instead of PDLC. Since the PDLC is light scattering mode, the PDLC modulator shows less sensitivity than the TN LC modulator.

The TN LC modulator shows high sensitivity compared to the PDLC modulator because TN LC is not light scattering mode but light retardation mode. With proposed LC modulator, reflection spectrum and response characteristics are studied and compared with conventional one.

2. Experimental

We used a glass block and a thin glass to make LC modulator. Conventional TN LC process was applied, that is, alignment layer coating, rubbing, assembly, LC filing and end seal were applied in order.

Figure 1 (a) shows the schematic structure of the conventional PDLC modulator. PDLC is coated on ITO coated glass block and mirror layer is located on bottom of the PDLC. Incident light is reflected from mirror pellicle and light is modulated by the pixel voltage which controls the light scattering of the PDLC.

Figure 1 (b) is the schematic structure of the TN LC modulator. TN LC is filled between the ITO coated glass block and the thin glass. Mirror layer is formed on bottom surface of thin glass and polarizer is attached on the top surface of the glass block.

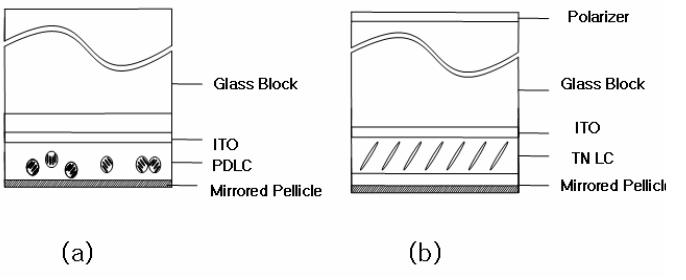

Fig.1. The cross sectional structure of PDLC modulator (a) and TN modulator (b).

Incident light is polarized and retarded by TN LC depending on the near by pixel voltage.

3. Results and Discussion

Figure 1 (a) is the cross sectional structure of the conventional PDLC modulator, the TN modulator is shown in figure 1 (b). LC modulator is sensing the applied electric field to the LC layer by the measurement of reflected light intensity.

Requirement of the reflective LCD is 180 degree polarization transformation which is adjusted by twist angle and $d\delta n$. Table 1 shows the requirements for each twist angle [5].

TABLE 1. Requirement of LC cell.

Twist Angle(degree)	120	150	180
$d\delta n$ (μ m)	0.75	0.72	0.69

Figure 2 shows the simulated reflectance curves for various twist angles. The air gap between the modulator and pixel electrode was 20 μ m. Twist angle dependence of reflectance is small compared with that of transmittance of transmissive type.

Figure 3 shows the on/off reflectance spectrum of the 120 degree TN modulator. Reflectance is a function of incident wavelength. Around 660 nm wavelengths, we can get maximum on-off reflectance ratio.

Figure 4 shows the electro-optic characteristics of the TN and PDLC modulator. The slope of electro-optic curve of the TN modulator is over 5 times higher than PDLC modulator.

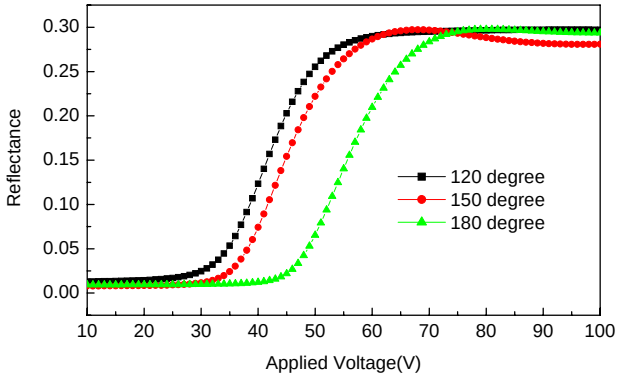

Fig. 2. Reflectance curves according to the LC twist angle.

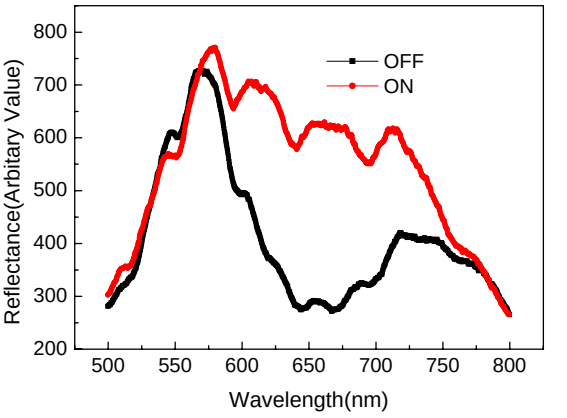

Fig. 3. The measured on/off reflectance curve of the TN modulator.

Shaper electro-optic curve gives the better sensitivity of LC modulator which is used for sensing the pixel voltages.

Figure 4 shows the response characteristics of TN and PDLC modulators. The TN modulator shows shorter response time which is an advantage for the TFT array test.

Shorter response time and sharper electro-optic characteristics are good characteristics for TFT array test which measures the pixel and line voltage change by sensing of reflected light modulation.

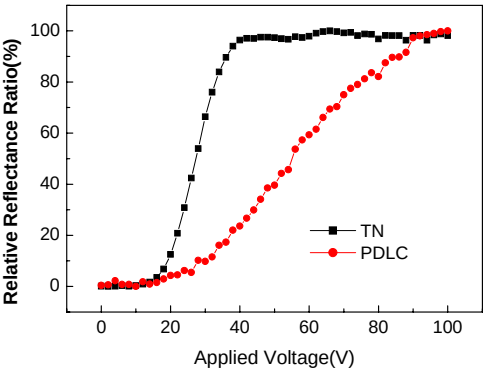

Fig. 4. The electro-optic characteristics of TN modulator and PDLC modulator.

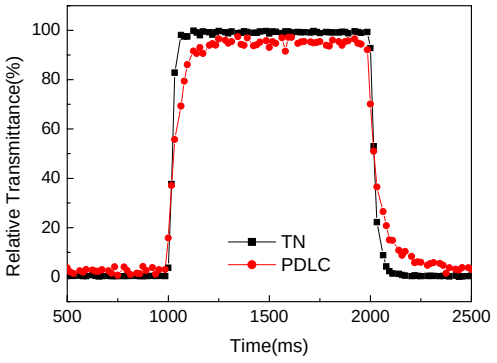

Fig. 4. The response characteristics of TN and PDLC modulators.

We used a thin glass for the bottom side. The thin glass improves the reliability and life time of the LC modulator.

4. Summary

The developed novel TN LC modulator shows the higher slope of electro-optic curve and shorter response time than the conventional LC modulator. The high slope of electro-optic curve and short response time are advantages for non contact defect detection of TFT array because it gives high sensitivity.

We improved not only the sensitivity by improved LC mode, but also the reliability and life time due to thin glass for bottom side of LC modulator.

5. References

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