Cell Gap Variation Tolerant Liquid Crystal Display

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Abstract

We report a cell gap variation tolerant liquid crystal display(LCD). Since the cell gap variation of the LCD results in the variation of brightness and contrast ratio, we should control carefully the process to get the uniform cell gap. For the projector application, this is more significant and the one reason of the low yield. We observed that the brightness variation of LCD is suppressed by insertion of dielectric layer between the pixel electrode and liquid crystal.

1.Introduction

A simple way to get large area display is to project the small display by projection lens. As the demand for large screen display increases, projection TV and projectors are getting widely used.

LCD projector is classified as reflection type and transmission type. The typical transmission and reflective microdisplays are the HTPS (high temperature poly silicon) LCD and the LCOS (liquid crystal on silicon), respectively.

The three panel projector [1] uses three micro-display panels. The white light split into each primary colors. After passing through each panel, they combined together and projected on a screen. Therefore, if the brightness of each color is not uniform the white uniformity at the screen becomes poor. Therefore, we should control cell gap uniformly to achieve good color uniformity.

In the case of reflective type such as LCOS, it is more significant since the optical path is twice of the cell gap [2,3].

Moreover, since the material of the bottom and top plate of the LCOS is different each other, the cell gap can be varied easily due to thermal coefficient difference of the plates [4].

To suppress the brightness change by cell gap variation, the way to make oblique pattern in pixel electrode was proposed [5]. However, to form the oblique pattern is difficult for the pixel pitch below 10 ㎛.

We proposed the compensation method to reduce the brightness change against the cell gap variation.

2. Model

We coated a dielectric layer on the electrode to reduce the brightness change by cell gap variation.

When the dielectric layer is coated on the electrode the schematic diagram is as shown in figure 1. We neglected the alignment layer since the thickness is much smaller compared to the dielectric layer.

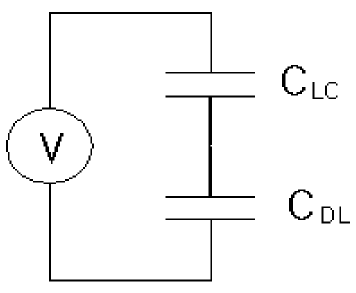


Figure 1. The schematic when the dielectric layer is inserted between electrode and liquid crystal.

C_{LC} is the capacitance of LC and C_{DL} is the capacitance of the dielectric layer.

Voltages applied to the liquid crystal were extracted by the following approximation,

$$(1 + \delta d/d)^{-1} \approx 1 - \delta d/d$$

where d is cell gap and δd is variation of the cell gap. The obtained voltage applied to the liquid crystal V'_{LC} is

$$V'_{LC} = V_{LC}\,(1 + \frac{C_{LC}}{C_{LC} + C_{DL}}\,\frac{\delta d}{d}),$$

where V_{LC} is the applied voltage to liquid crystal when cell gap is d. The above equation indicates that V'_{LC} increases as the cell gap increases. Since the refractive anisotropy increases as the cell gap increase, the increased voltage V'_{LC} compensates the increased refractive anisotropy. Therefore, the brightness change is suppressed by additional dielectric layer.

3. Simulation

Simulation was done for the cell gap of 2.5±0.5㎛, LC twisted angle of 90°, and pretilt angle of 5°. Table 1 shows the parameters of LC.

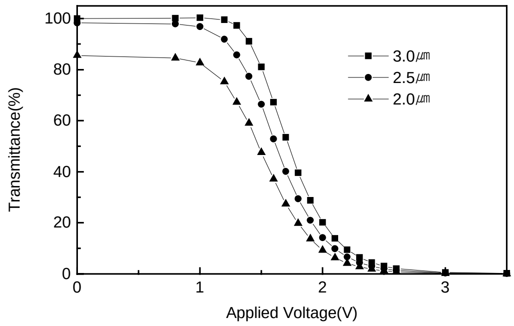
Table 1. The parameters of LC.

Items	Value
Elastic constant	K_{11} = 1.3pN, K_{11} = 6pN, K_{11} = 18pN
Dielectric constant	$e_{\perp}$ = 3.7, $e_{\parallel}$ = 13.7
Refractive index	n_o = 1.50, n_e =1.67 (550nm)

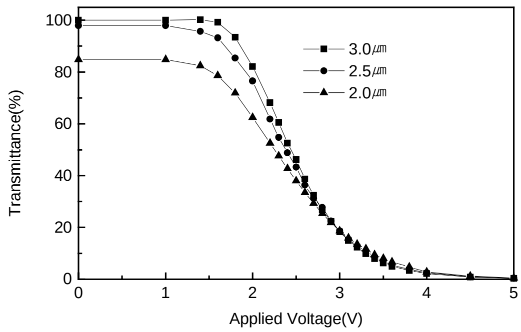
Figure 2 (a) and (b) show the simulation of transmittance curves for the cell gaps; 3.0, 2.5, and 2.0 ㎛. Figure 2 (a) is for the conventional LCD and (b) is for the proposed one.

The transmittance change was reduced in the case of figure (b) especially on the applied voltages over 2.5 V. At the simulation, the thickness of dielectric layer was 1.5 ㎛ and the dielectric constant was 4.0.

Figure 3 shows the simulation results of transmittance change from that of the 2.5 ㎛ cell gap for various gray levels. Figure 3 shows the simulated results for two cell gaps of 2.0 ㎛ and 3.0 ㎛. In the case of proposed one, the transmittance change is smaller than that of the conventional one.



(a)



(b)

Figure 2. Simulation results of the transmittance for the conventional LCD (a) and the proposed one(b).

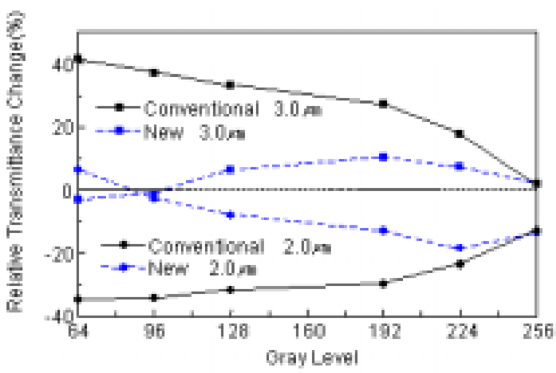


Figure 3. The transmittance changes for various gray levels. We simulated for the two cell gaps of 2.0 ㎛ and 3.0 ㎛.

4.Experiments and Results

We made a wedge cell with cell gap from 3.6 to 4.6 ㎛. ITO coated glass was used as a substrate. Before coating the alignment layer, the insulator was coated. The insulator was the Staroptiplana of Cheil Industries. The thickness of the insulator between the electrode and alignment layer was 1.5 ㎛. We used the Staralign-RB of Cheil Industries as a alignment layer. We used 90° TN mode. The dielectric anisotropy of the liquid crystal was 5.2 and refractive index anisotropy was 0.085 nm.

We measured transmittance of LC cell according

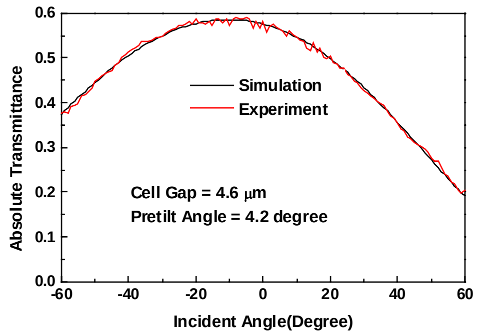


Figure 4. Measured transmittance curve and simulation result.

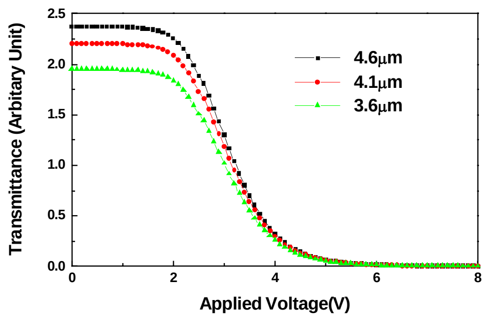


Figure 5. The transmittance curve without insulator layer.

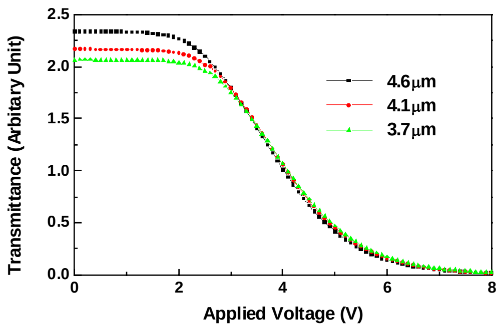


Figure 6. The transmittance curve with insulator layer.

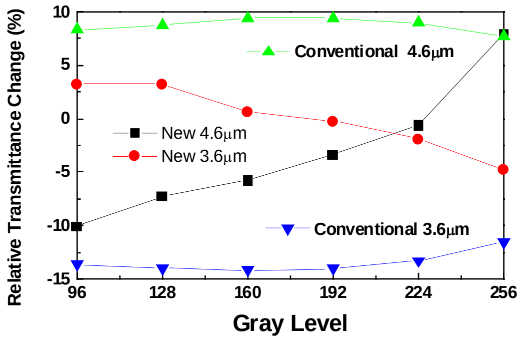


Figure 7. Relative transmittance change for both the conventional and the proposed one.

to the incident angle. The transmittance was with halogen lamp backlight. The measured cell gap was 4.6 ㎛ and pretilt angle 4.2°, which is shown in figure 4.

Figure 5 shows transmittance curve without insulator layer between electrode and alignment layer. Figure 6 shows transmittance curve with insulator. The transmittance was measured for the cell gaps of 4.6, 4.1, and 3.6 ㎛.

In the case of LCD with insulator, the transmittance curve shifted to the right compared to
the curve without insulator, this is due to the voltage drop by the insulator.

Figure 7 shows the relative transmittance change for both the conventional one and the proposed one which has thick 1.5 ㎛. insulator between electrode and alignment layer.

Figure 5, 6, and 7 shows that the transmittance dependence on the cell gap is smaller for the proposed one.

5.Summary

We proposed the new LCD cell which has insulator layer between electrode and alignment layer. The brightness change was reduced for the proposed LCD compared to the conventional one in the simulation and the experimental.

The cell gap tolerant LCD can increase the yield of products, such as HTPS and LCOS microdiaplay.

References

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