Single Mode Transflective Liquid Crystal Display based on Single Cell Gap without Sub-pixel Separation

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Abstract

In this paper, a new Twisted Nematic (TN) transflective liquid crystal display configuration with single cell gap for both transmissive and reflective mode and without sub-pixel separation is proposed. The Transmittance vs. Voltage Curve (TVC) and Reflectance vs. Voltage Curve (RVC) are matched.

1. Objective and Background

Transflective LCDs are generally preferred for mobile applications because the combination of backlighting and ambient light makes for excellent visibility in all lighting conditions. In conventional transflective LCDs, each pixel is separated into the transmissive and reflective sub-pixels. The transmissive sub-pixels transmit light from backlighting source and the reflective sub-pixels reflect light from ambient environment [1]. Double cell gap approach was used in the conventional transflective LCDs [2,3]. In such configuration, the cell gap of transmissive mode is twice of reflective mode, in order to maintain the same phase retardation for both reflective and transmissive mode. However, this approach makes the fabrication much more complicated.

Recent years, many single cell gap transflective designs have been proposed [4-9]. In our group, we proposed a single cell gap transflective LCD with Optically Compensated Bend (OCB) and Low Twist Nematic (MTN) Modes using photoalignment method [10]. In this paper, we further improve this design using a simple TN cell with the same cell gap for both transmissive and reflective mode. The parameters of the configuration in transmissive mode and reflective mode are the same, so there is no need for sub-pixel separation. The pixels are partially transmissive and partially reflective with the help of a semi-transparent mirror. Therefore, this configuration is much easier for fabrication. Also, the optical performance of our new design is better.

Figure 1 shows the schematic diagram of our new transflective LCD configuration with single cell gap. The angle indicates the anticlockwise value against the horizontal axis. Instead of dividing each pixel into separate transmissive part and reflective part, we use a semi-transparent mirror (so called transflector) attached on the bottom glass substrate to make the pixels partially transmissive and reflective. A quarter wave retardation film is attached on the top glass substrate and the bottom of the transflector. An additional half wave retardation film is attached on the two quarter wave films. Polarizers are placed on the top and bottom of the configuration with an anti-reflective layer attached on the top polarizer.

2. Methodology

We can see from the configuration, the transmissive mode requires additional bottom optical elements, making the polarization orientation of the light through transmissive mode be able to be adjusted by the bottom retardation films and bottom polarizer. So we choose to optimize the reflective mode first by adjusting the orientation of the top polarizer and top retardation films. After we obtain optimized result for the reflective mode, we fix the parameters of the top optical elements, thus the performance of the reflective mode is fixed. Then we focus on transmissive mode to optimize it by adjusting the orientation of the bottom polarizer and the bottom retardation films. By this means, we try to make the electro-optical performance of both two modes as close as possible, so TVC of transmissive mode and RVC of reflective mode can be matched.

During the simulation, we use the LC material of MLC-6096 from Merck. The cell gap for both transmissive mode and reflective mode is 2.5μm. The surface pretilt angle is 2 degree for both substrates. The light source used in simulation is D65 ranging from 380nm to 720nm.

3. Results and discussions

In our simulation, we use commercial available software-"MOUSE-LCD" for calculations [11]. The optimized parameters of our configuration are listed in Table 2. In simulation, we tried to make the TVC and RVC curves as close as possible. Figure 2 shows the normalized TVC and RVC curves. From figure 2, we can see that the TVC/RVC curves are very close, which means the same gray scale can be generated along the increasing of voltage.

Contrast ratio and viewing angle are important parameters for displays. Figure 3 shows the contrast ratio distribution of a) transmissive mode and b) reflective mode. The maximum contrast ratio for transmissive mode is 120 and for reflective mode it can reach 40. There is an improvement in the reflective mode comparing to our previous TN-OCB design which is 31.

Figure 4 shows the spectrum of a) transmissive mode and b) reflective mode. The transmittance and reflectance are both good for displays. The maximum reflectance can reach 63% of the polarized light.

Figure 5 shows the time dependencies of a) transmissive mode and b) reflective mode. The response time of transmissive mode and reflective mode are 7.2ms and 4.9ms respectively. This is a very good improvement comparing to our previous TN-OCB design which is 20ms and 8ms respectively. Such switching time is fast enough for different mobile and portable applications.

In experiment, we made 45° TN cells with LC mixture MLC-6096 from MERCK_and chiral dopant of S-811. The retardation films are from Nitto Denko with product code TR140 and TR280. In order to test both modes, the prototype was made reflective on the left with an aluminum reflector and transmissive on the right. Figure 6 a) shows the bright state with backlighting, and b) shows the dark state with 6V voltage. By changing the voltage from 0V to 6V, a bright state and a very dark state with high contrast can be observed. This normally bright design can reduce the complexity of the driving system [12].

4. Conclusion

In summary, a new transflective LCD with single cell gap based on 45°TN cell has been investigated. Without the requirement of sub-pixel separation, the conventional fabrication method can be used for this transflective display. Therefore the cost of manufacturing can be controlled relatively low. The TVC curve and the RVC curve are very close to each other, thus same gray scale can be generated along the increasing of voltage. The maximum contrast ratio of transmissive and reflective part can reach 120 and 40 respectively. The response time of transmissive part and reflective part are 7.2ms and 4.9ms respectively. Prototype was made base on our design. This normally bright design can reduce the complexity of the driving system. The optical performance of the configuration is good and the fabrication process is easy, as a result it is suitable for high quality transflective thin-film transistor (TFT) LCDs.

5. Acknowledgement

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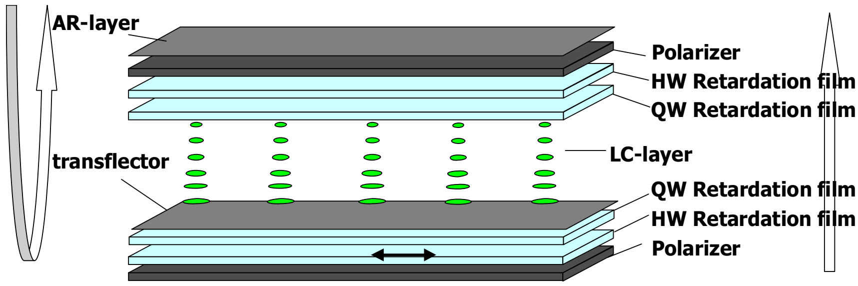
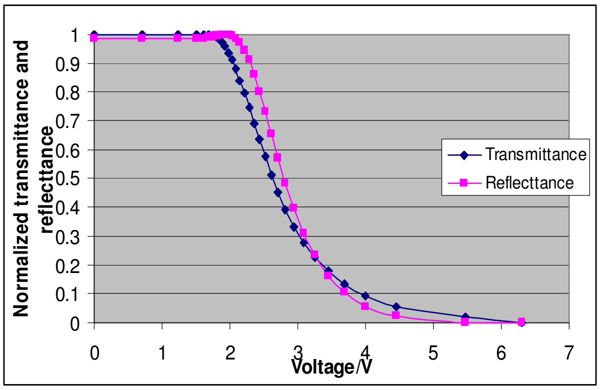
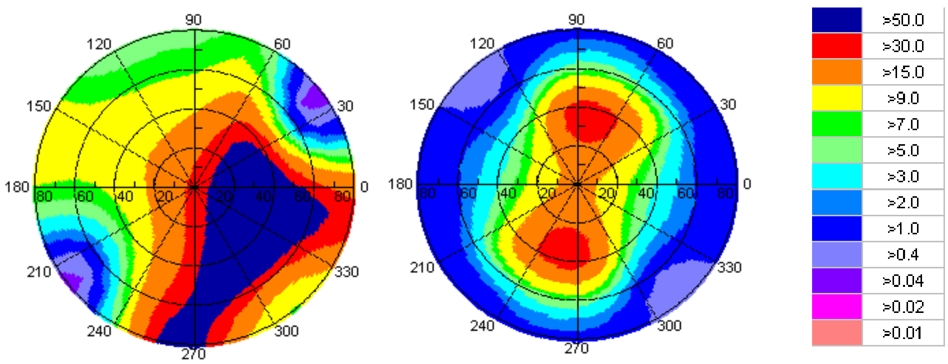


Fig. 1 Scheme of this transflective LCD



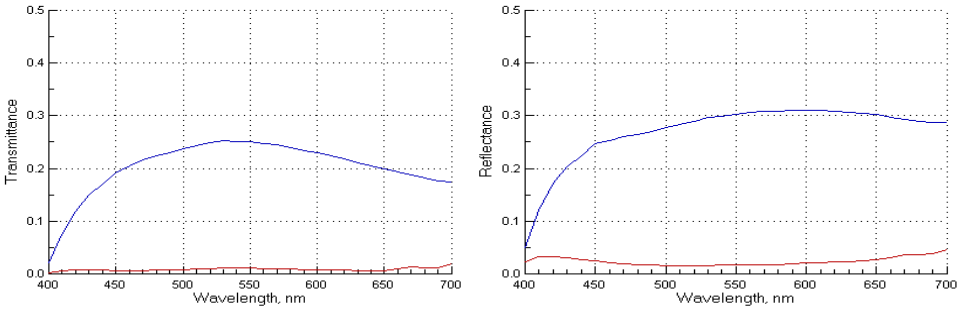
a) b)

Figure 2 normalized TVC and RVC curves of this transflective LCD



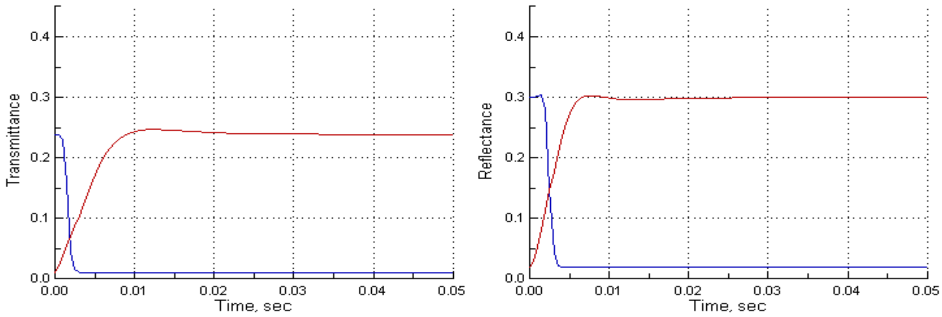
a) b)

Fig. 3 Simulated angular dependence of a) transmissive mode and b) reflective mode of this transflective LCD



a) b)

Fig. 4 Simulated transmittance of a) transmissive mode and reflectance of b) reflective mode



a) b)

Fig. 5 Simulated time dependence of a) transmissive and b) reflective mode of our transflective LCD

a) b)

Figure 6 experiment performance with backlighting of a) without voltage and b) with 6V voltage. The reflective part is on the left, the transmissive part is on the right.

Table 2 parameters of the transflective LCD configuration

parameters	Transmissive	Reflective
1st polarizer orientation	85°	850°
1st HW retardation film orientation	68°	68°
1st QW retardation film orientation	175°	175°
45°TN LC layer	0°	0°
TN LC layer thickness	2.5μm	2.5μm
2nd QW retardation film orientation	reflector	74°
2nd HW retardation film orientation		23°
2nd polarizer orientation		96°