29.4: Dual-domain Transflective Liquid Crystal Display using TN and LTN Modes by Photoalignment Technology

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Abstract
In this paper, a new design of single cell gap transflective liquid crystal display (LCD) using twist nematic (TN) and low twist nematic (LTN) modes has been proposed, which has a simple configuration and only the bottom alignment layer need to be patterned by photoalignment technology to produce domains. This configuration shows high contrast, wide viewing angle, fast response and high transmittance / reflectance. The Transmittance versus Voltage Curve (TVC) and Reflectance versus Voltage Curves (RVC) are perfectly matched. Also the fabrication process is easy.

1. Background and Objectives
For their sufficient performance in both indoor and outdoor environment, Transflective Liquid Crystal Displays (LCDs) are commonly used in mobile and portable applications [1]. Normally, in conventional transflecitve designs, the pixels are separated into the transmissive and reflective sub-pixels, with the transmissive sub-pixels transmitting with backlight illumination and the reflective sub-pixels reflecting light from the environment under ambient illumination.

To solve the problem of the different retardation value between transmissive and reflective parts, double cell gap approach is applied in conventional transflective LCDs [2]. However, such double cell gap approach further increases the complexity in the fabrication process. In recent years, some new transflective configurations with single cell gap using two different modes have been proposed [3] – [5].

Our group had proposed the multimode configuration using low twist nematic (LTN) and electricity controlled birefringence (ECB) modes early this year [6]. In the configuration, LTN mode with 60 degree twist is applied to the reflective part while the ECB mode is applied to the transmissive part. The alignment domains in pixels are generated by photo-alignment technique [7]. Although the TN-ECB configuration obtains high transmittance and reflectance in the transflective characteristics, the contrast of both modes is not good, and the TVC and RVC curves are not very well matched. Also the fabrication is not easy because we have to generate domains on both of the alignment layers and have to align the two glasses very precisely to produce the required LC molecule orientation. In this paper, a novel multimode configuration using LTN mode with 36 degree twist and TN mode with 90 degree twist has been investigated, which shows much better performance and the advantage of easier fabrication.

Figure 1 shows the schematic diagram of the new transflective configuration with a single cell gap. Like conventional transflective LCDs, in our design, one pixel is divided into two parts. The LC molecules of the reflective part are twisted with 36 degree, while the LC molecules of the transmissive part are twisted with 90 degree. An ordinary polarizer coated with antireflection layer is used in the configuration to lower the surface reflection. Two λ/4 compensators are inserted in between the rear glass and rear polarizer, with a reflector in between them which defines the area of transmissive part and reflective part.

2. Methodology
In order to make the electro optical performance of transmissive and reflective part consistent, at the very beginning we should optimize the common parts of two modes, which are the front polarizer and the retardation value of the liquid crystal (LC), as well as the 1st compensator under the bottom glass.

According to the parameter space, 90˚ twist for the transmissive part was first determined and the twist angle for the reflective part is adjusted for matching proposes. The first λ/4 compensator is inserted to adjust the performance of the reflective part, and the second λ/4 compensator helps to adjust the performance of the transmissive part. As a result, a transflective display with matched TVC and RVC could be obtained.

In order to make the simulation more realistic, real dispersion is consider in different layers of the configuration. The LC material we chose is ZLI-4792 from E. Merck during the whole simulation.

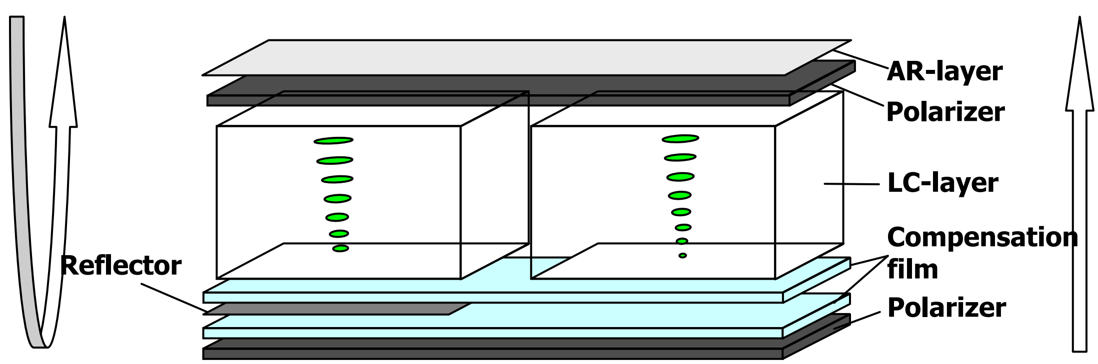

Fig. 1 Scheme of the transflective LCD; Left: reflective part; Right: transmissive part.

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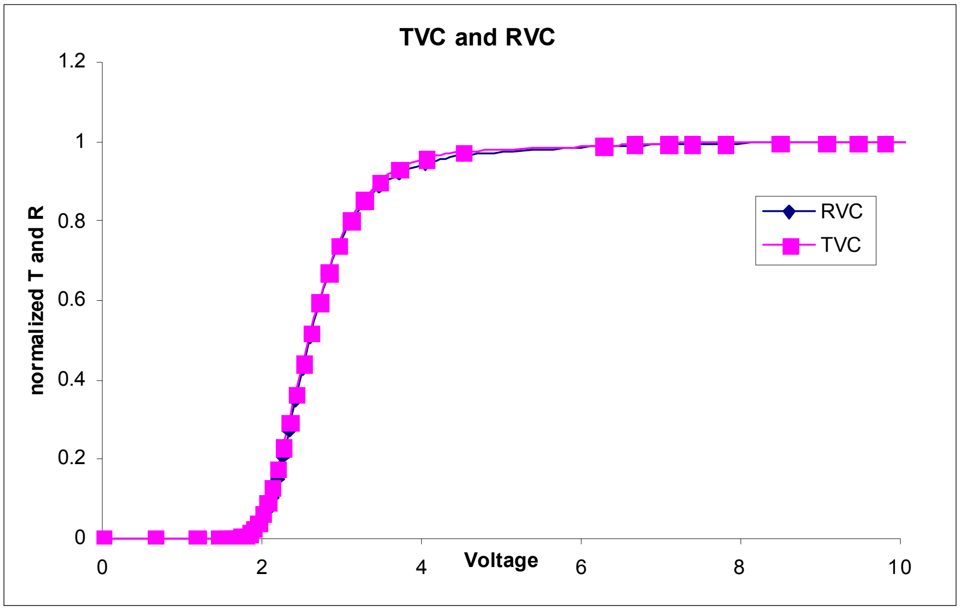


Fig. 2 Normalized voltage dependence of transmission and reflectance in simulation

Table 1. Optimized Parameters of the transflective LCD

Parameter	Transmissive	Reflective
Top polarizer Orientation (deg)	90	90
LC Twist angle (deg)	90	36
Cell gap (μm)	5	5
1st Compensator (140nm) Orientation (deg)	85	85
2nd Compensator (140nm) Orientation (deg)	87	-
Bottom polarizer Orientation (deg)	82	-

The ordinary refractive index and optical anisotropy for ZLI-4792 are no = 1.4939 and ne = 1.5987, no = 1.4774 and ne = 1.5734 and no = 1.4774 and ne = 1.5734 at the wavelengths of 436 nm, 546 nm and 633 nm respectively. The dielectric anisotropy and the elastic constants were $\Delta\varepsilon = 5.2$, K1 = 1.32 x 10-6, K2 = 6.5 x 10-7, and K3 = 1.38 x 10-6 dynes respectively. The cell gap for both transmissive and reflective part is 2.5μm. The surface pretilt angle is 2 degree for both transmissive and reflective part. The light source used in simulation is D65 ranging from 380nm to 720nm. Absorption and Dispersion of polarizer and compensation films are also considered in the simulation.

3. Results

A commercial available software "MOUSE-LCD" is used for calculating the optical characteristics [8]. In our configuration, the optimal values of the parameters for reflective LTN and transmissive TN are listed in Table 1. The angle indicates the anticlockwise value against the horizontal axis.

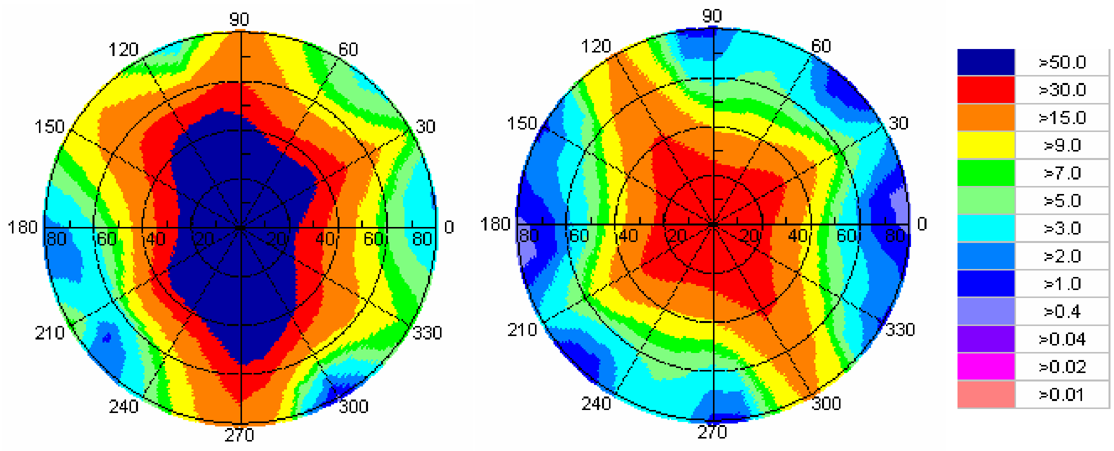
In order to obtain a transflective characteristic, the TVC and RVC should be as close as possible to each other. Figure 2 shows the normalized TVC and RVC curves. As we can see, they are perfectly matched, thus the same voltage can be used to generate the gray scale on both modes.

As the contrast ratio in our previous TN-ECB configuration is not very good, a great effort in the improvement was put. Figure 3 shows the contrast ratio distribution of both parts. The maximum contrast ratio of transmissive part and reflective part are 80 and 44 respectively. If consider reflections from every layer of the configuration, the maximum contrast of reflective part can still be 17.

Figure 4 shows the spectrum of a) transmissive and b) reflective part. The transmittance of the transmissive part is greater than 74% of the polarized light while the reflectance of the reflective part is greater than 58%.

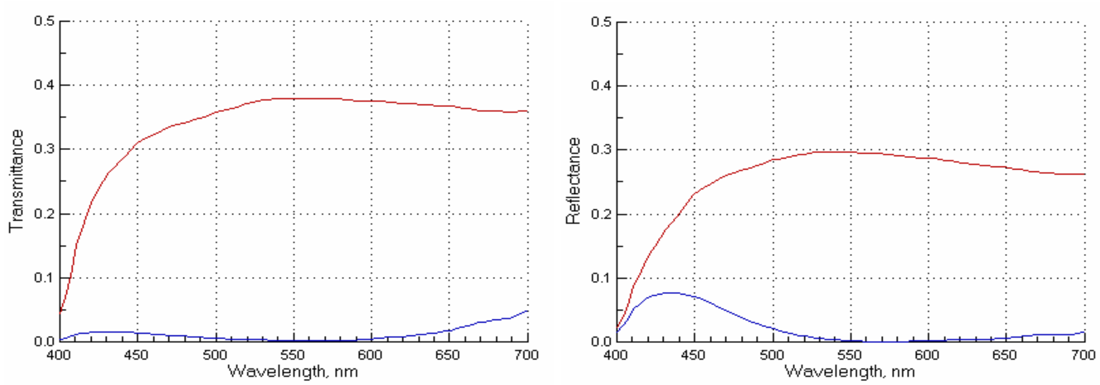
Figure 5 shows the time dependencies of a) transmissive TN and b) reflective LTN part. The response time of the transmissive part and the reflective part are 24.2ms and 22.4ms respectively. This response time can be reduced by changing the cell gap to 2.5μm and choosing liquid crystal with Δn of 0.2. All the other performance of the display will not be affected only with the response time reduced to 6.4ms and 5.8ms respectively.

Figure 6 shows the prototype of our new TN-LTN design. It was made by photoalignment technology with two step exposure to create the different domains of transmissive and reflective part on one of the alignment layer. The alignment layer on the other substrate can be treated using either photoalignment technology or rubbing method since the boundary conditions of both modes are exact same. As we can see, the dark state and bright state are good for both modes.



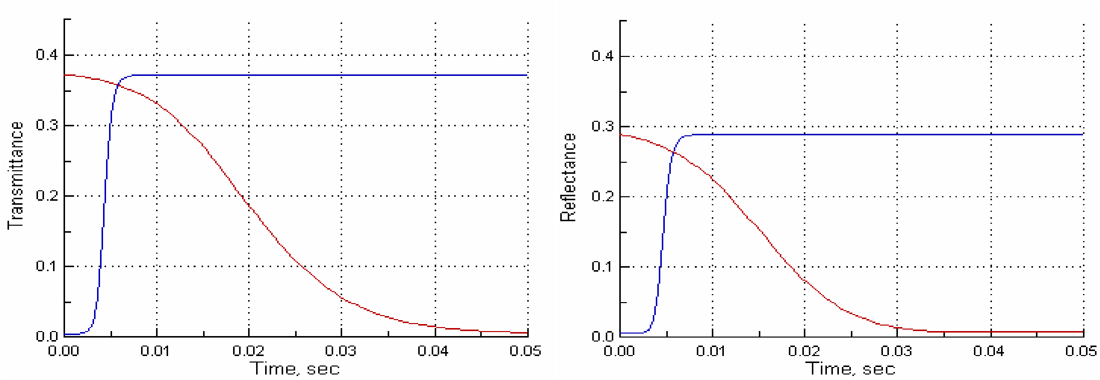
a) b)

Fig. 3 Simulated angular dependence for a) transmissive and b) reflective part of the transflective LCD



a) b)

Fig. 4 Simulated spectrum of a) transmissive and b) reflective part of the transflective LCD

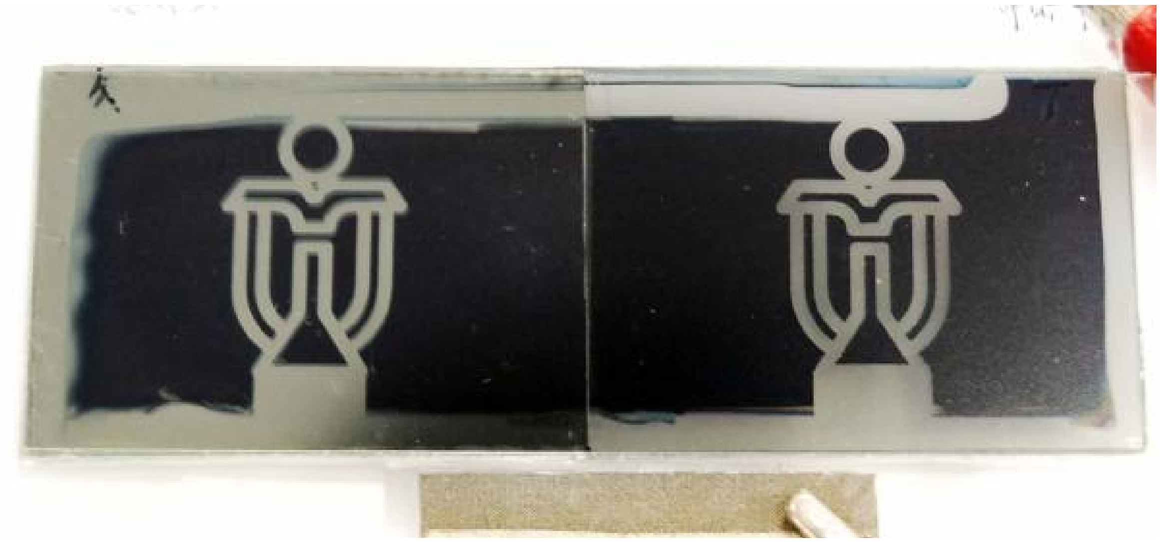


a) b)

Fig. 5 Simulated time dependence of a) transmissive and b) reflective part of the transflective LCD

4. Impact

In summary, a novel transflective LCD configuration with single cell gap using TN and LTN modes has been investigated. Photoalignment technology can be used to produce domains on one of the alignment layer. The TVC and RVC curves are perfectly matched. The contrast ratio of the transmissive part and reflective part can reach 80 and 44 respectively. The transmittance of the transmissive part is greater than 74% of the polarized light while the reflectance of the reflective part is greater than 58%. 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.



a) b)

Figure 6 photoaligned prototype of the design a) reflective part and b) transmissive part.

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