P-187: Photoaligned Transflective Liquid Crystal Display using Low Twist Nematic and Electricity Controlled Birefringence Modes

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Abstract

In this paper, transflective liquid crystal display (LCD) with two different modes low twist nematic (MTN) and electricity controlled birefringence (ECB) has been proposed. The structure contains only a single cell gap in transmissive and reflective part, therefore the fabrication process is easy and only one more step UV exposure is needed during photoalignment process to produce domains. This configuration has a good contrast, viewing angle, response time and transmittance / reflectance. As a result it is suitable for high quality transflective thin-film transistor (TFT) LCDs..

1. Introduction

Transflective Liquid Crystal Displays (LCDs) combine the characteristics of transmissive LCDs and reflective LCDs. Normally, the pixels of the traditional transflective LCDs are separated into the transmissive and reflective sub-pixels. The transmissive sub-pixels in a transflective display are transmitting with backlight illumination and the reflective sub-pixels are reflecting light from the environment under ambient illumination. Transflective LCDs are commonly used in mobile and portable applications since they got sufficient performance in both indoor and outdoor environment [1].

Double cell gap approach is applied in conventional transflective LCDs in order to solve the problem of the different retardation value between transmissive and reflective part [2]. However, such double cell gap approach will further increase the complexity in the fabrication process. Therefore in recent years, newly designed transflective LCDs with single cell gap using two different modes had been proposed [3] – [5].

Our group had invented the multimode configuration using optically compensated bend (OCB) and low twist nematic (MTN) modes last year [6]. In the configuration, OCB mode is applied to the reflective part while the MTN is applied to the transmissive part. The alignment domains in pixels were realized by photo-alignment technique [7]. Nevertheless, the OCB mode requires high power consumption for the splay to bend transition voltage. Although the OCB-TN configuration obtain high transmittance and reflectance in the transflective characteristics, the transmittance versus voltage curve (TVC) and reflectance versus voltage curve (RVC) could not be perfectly matched. The viewing angle is also insufficient due to the limited of retardation value chosen in OCB part. As a result, optimization is necessary to improve the optical performance. In this paper, a newly designed multimode configuration using MTN and electricity controlled birefringence (ECB) had been investigated.

Figure 1 shows the schematic diagram of our new transflective LC cell configuration with a single cell gap. In this two modes configuration transflective LCD, one pixel is divided into two parts. The first part is the reflective part, in which the LC molecules are twisted with 45 degree determined by the boundary condition. A low concentration chiral dopant is added to LC material for assisting twist deformation. The other part is the transmissive part, in which the LC molecules are homogenous and parallel to the substrates. An ordinary polarizer coated with antireflection layer is used for in the configuration to lower the surface intensity. One compensation film is added in between the rear glass and rear polarizer, which affect only for transmissive part since the light in reflective part is blocked by the reflector.

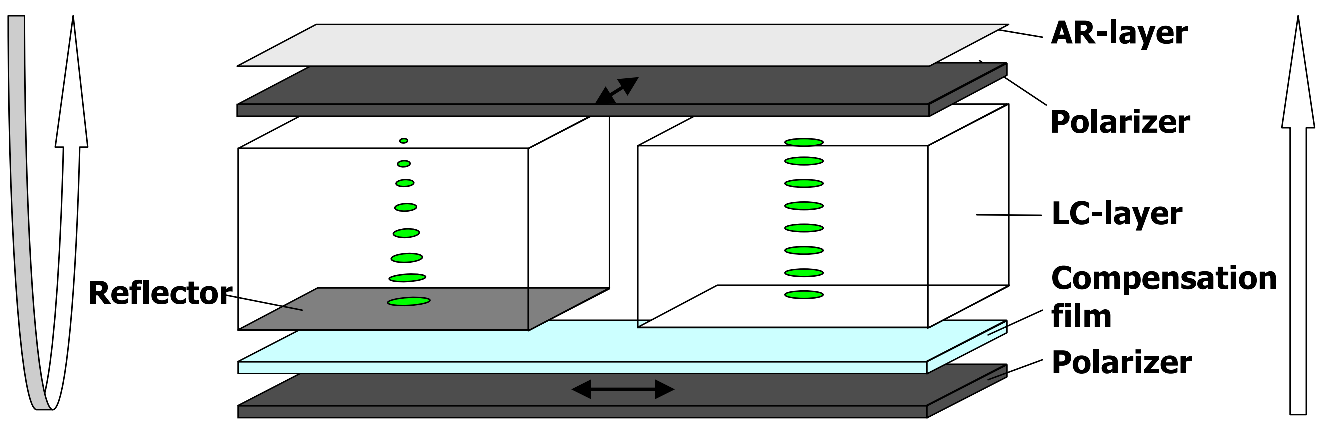

Fig. 1 Scheme of the transflective LCD; Left: reflective part; Right: transmissive part.

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2. Modeling

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. That is the front polarizer and the retardation value of the liquid crystal (LC).

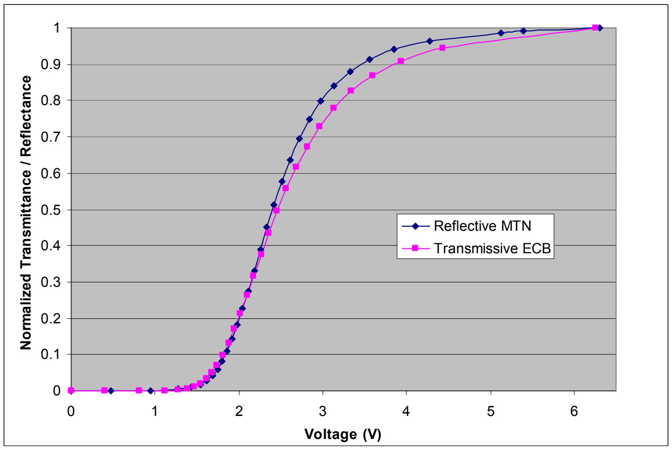

Fig. 2 Normalized voltage dependence of transmission and reflectance for MTN mode and ECB mode

As the polarizing orientation of the transmissive part could be changed by the compensation film, the reflective part is first optimized. Once we obtained a good result, we tried it in the transmissive mode to see if the result is also good enough. By orienting the bottom polarizer and the compensation film, electro optical characteristics of the transmissive part can be as close as the reflective 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. The ordinary refractive index and optical anisotropy for ZLI-4792 are $n_o = 1.4939$ and $n_e = 1.5987$, $n_o = 1.4774$ and $n_e = 1.5734$ and $n_o = 1.4774$ and $n_e = 1.5734$ at the wavelengths of 436 nm, 546 nm and 633 nm respectively. The dielectric anisotropy and the elastic constants were $\Delta\varepsilon = 5.2$, $K1 = 1.32 \times 10^{-6}$, $K2 = 6.5 \times 10^{-7}$, and $K3 = 1.38 \times 10^{-6}$ dynes respectively. The chiral dopant of S-811 is used to produce a d/p ratio equals to 0.05, where d denotes the cell gap of the LC cell and p denotes the neutral pitch. The cell gap for both transmissive and reflective part is 2.8μm. 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.

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 TN and transmissive ECB 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. Figure 2 shows the normalized TVC and RVC curve. From the curve, the different between the TVC and RVC along the x-axis is not greater than 5%.

Table 1 Optimized Parameters of the transflective LCD

Parameter	Transmissive	Reflective
Top polarizer Orientation (deg)	0	0
LC cell Orientation (deg)	45	74.5
Twist angle (deg)	0	60
Cell gap (μm)	2.8	2.8
Compensator Orientation (deg)	-90	-
Compensator retardation (nm)	140	-
Bottom polarizer Orientation (deg)	-5.5	-

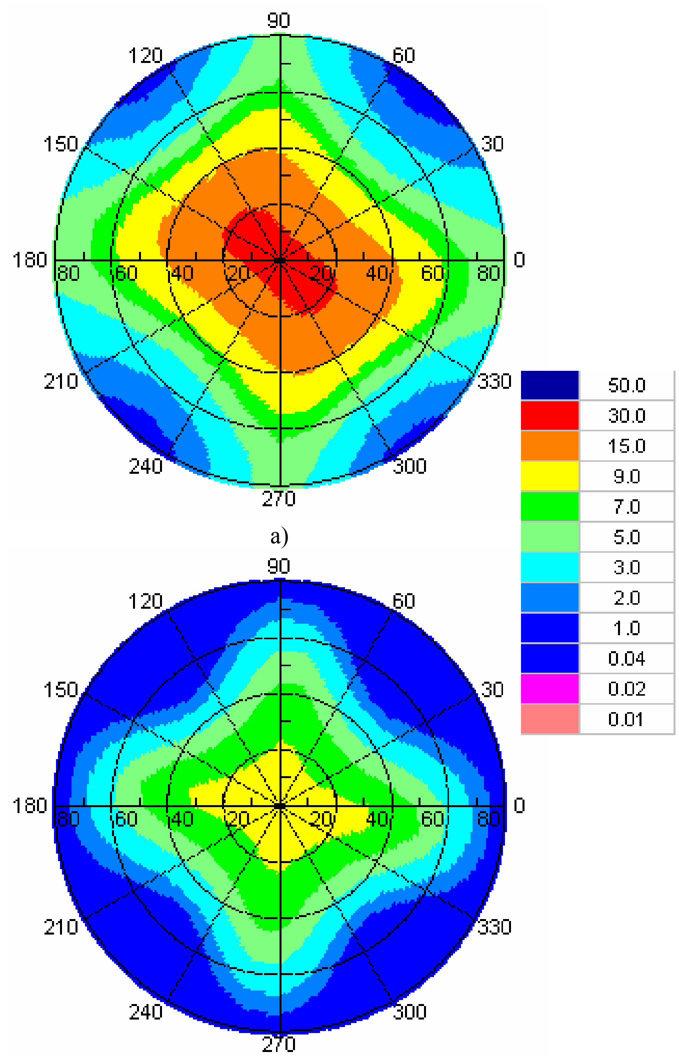

Fig. 3 Simulated angular dependence for a) transmissive and b) reflective part of our transflective LCD

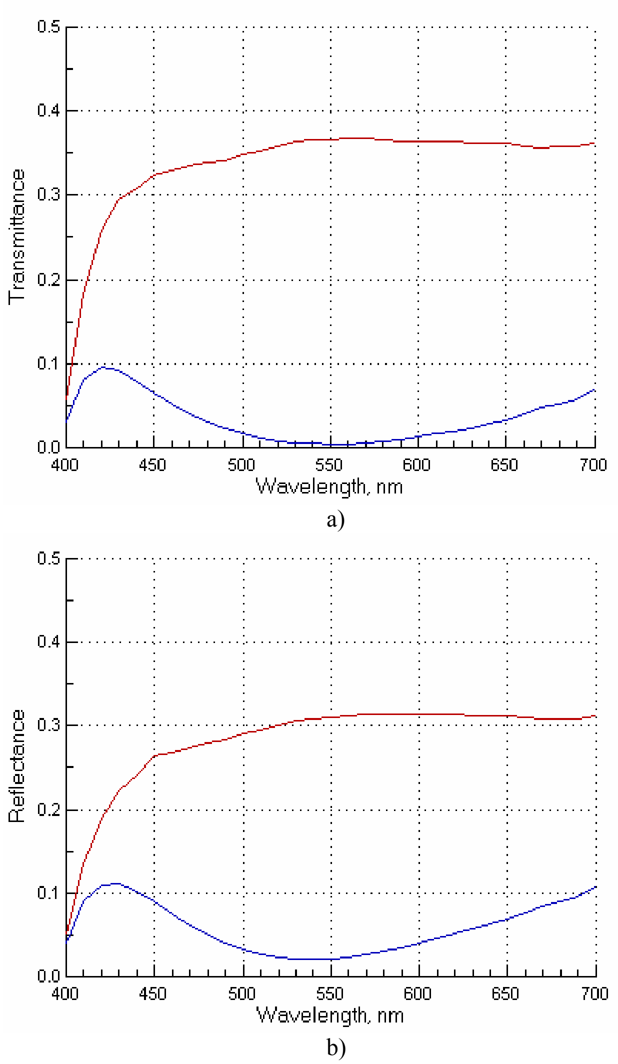

Fig. 4 Simulated spectrum of a) transmissive and b) reflective part of our transflective LCD

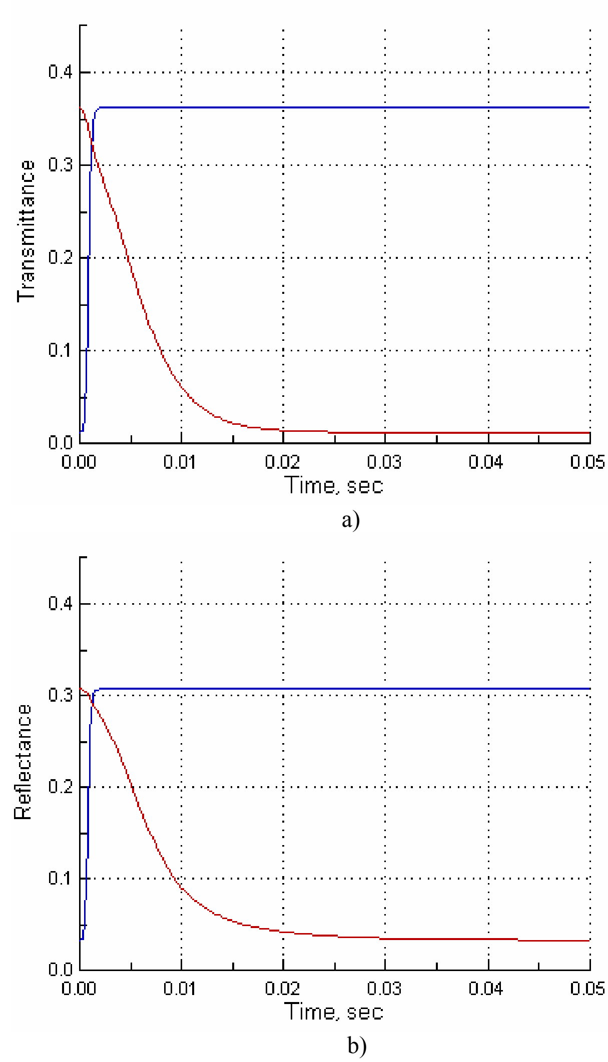

Fig. 5 Simulated time dependence of a) transmissive and b) reflective part of our transflective LCD

Contrast ratio and viewing angle are also very important for a good display. As the viewing angle in our previous OCB-TN configuration is not so well, a great effort in the improvement was put. Figure 3 shows the contrast ratio distribution of a) transmissive ECB part and b) reflective MTN part. The maximum contrast ratio of transmissive part and reflective part are 40 and 10 respectively.

Figure 4 shows the spectrum of a) transmissive ECB and b) reflective MTN part. The transmittance of the transmissive part is greater than 70% of the polarized light while the reflectance of the reflective part is greater than 60%.

Figure 5 shows the time dependencies of a) transmissive ECB and b) reflective MTN part. The response time of transmissive part and reflective part are 10.5ms and 12.1ms respectively. Such switching time is fast enough for different mobile and portable applications.

4. Conclusion

In summary, a new transflective LCD with single cell gap consisting MTN and ECB has been investigated. Single cell gap approach is applied to the configuration and only one more step of UV exposure is need during photoalignment process to produce domains. The different between TVC and RVC curve along the x-axis is not greater than 5%. The transmittance of the transmissive part is greater than 70% of the polarized light while the reflectance of the reflective part is greater than 60%. The response time of transmissive part and reflective part are 10.5ms and 12.1ms respectively. 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.

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