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Brief Communication

Transflective Liquid Crystal Display with Single Cell Gap and Single Gamma Curve

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The vertical electric field-driven transflective nematic liquid crystal display with dual orientation has a problem that the voltage-dependent transmittance and reflectance curves do not match each other. Thus a dual driving circuit is required. This study shows that optimization of the surface pretilt angle in the transmittance solves this problem so that the transflective display with a single cell gap and single gamma curve for reflective and transmissive region is possible.
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KEYWORDS: transflective liquid crystal display, pretilt angle

Recently, various types of transflective liquid crystal displays (LCDs) have been developed. Among them, homogenous cells with a compensation film driven by vertical electric field (named ECB)[1–3] with dual color filter structures for a dual cell gap, have been commercialized. However, these devices are difficult to manufacture due to the varied cell gaps in the transmissive and reflective region. In addition, the voltage-dependent reflectance (R) and transmittance (T) curves do not match each other. Consequently, two driving circuits for the R and T region are required to realize a high image quality. To overcome the dual cell gap problem, a new cell structure was reported, in which the LC has a hybrid alignment in the R region and a homogenous alignment in the transmissive region.[4,5] However, there is still a significant difference in the electrooptic curves, between the reflective and transmissive region.

In the device, the threshold voltage (V_{10}), at which the maximum transmittance changes by 10%, is much lower in the reflective region than in the transmissive region. This is due to the fact that the LC is anchored vertically in the hybrid alignment. In order to solve this problem, a chiral dopant, with a ratio of cell gap to LC pitch of 0.25 was added. The results indicated a reduction in the difference of electrooptic characteristics.[6] In this paper, we suggest the cell conditions in which the voltage dependent-R and -T matches perfectly. These conditions are realized when the surface pretilt angle (Θ_P) of the transmissive region is altered, since the threshold voltage is lowered as the surface pretilt angle is lowered.

Figure 1 shows the cell structure of a single-gap transflective display previously proposed. In this case, the normally white cell is considered. In previous work, the Θ_P in the transmissive region was assumed to be 2° at both top and bottom substrates. Considering the manufacturing process for the alignment layer on the top substrate, the vertical alignment layer is coated first, and then, the Θ_P of the layer in the transmissive region is obtained by exposing the layer using UV[7,8] or ion beam[9] in the area. Therefore, the Θ_P of the top substrate in the transmissive region can be adjusted to achieve the proper voltage-dependent transmittance (V–T) curve.

To investigate the device's electrooptic characteristics, we performed a computer simulation using the commercially available software, "LCD Master" (Shintech, Japan). The motion of the LC director is calculated based on the Eriksen-Leslie theory,[10] and 2×2 Jones matrix is applied for the optical transmittance calculation. In this cell, an LC with a birefringence of 0.089, and a dielectric anisotropy of 7.4 were used. The cell gap (d) was 3.4 μm. The LC director was aligned to 75°, with respect to the absorption axis of the top polarizer.

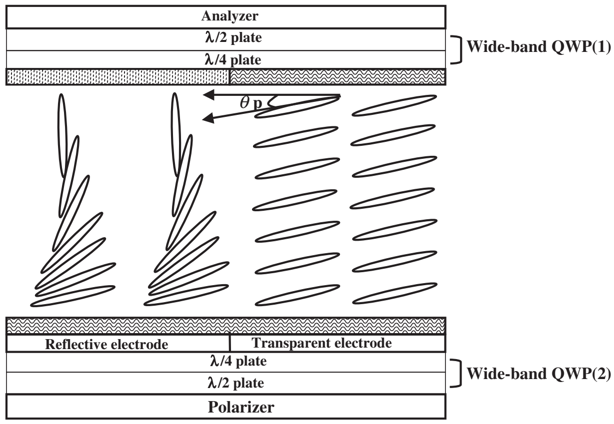

Fig. 1. The LC orientation in the single gap transflective LCD.

The voltage-dependent transmittance was calculated as a function of the Θ_P on the top substrate. Figure 2 shows how the V_{10} changes as the Θ_P changes from 2° to 38°. As clearly indicated, it decreases linearly with increasing Θ_P. This indicates that it is possible to shift the V–T curve to the left. Figure 3 shows voltage dependent reflectance and transmittance curves. When the Θ_P is 2° in the transmissive region, the difference in electrooptic curves, between transmissive and reflective regions, is large; however, as the Θ_P increases to 35°, it disappears. This informs that a single driving circuit can control the applied voltage in both the reflective and transmissive region.

Now the question arise how viewing angle characteristics are affected by this change. The transflective cell shows a white state before applying voltage. Therefore, a change of 2° to 35° in the transmissive region changes the isoluminance curve in the white state. When the Θ_P is 2°, the LC is almost perfectly homogenously aligned; that is, the retardation change is not as large, depending on viewing direction. This results in relatively good luminance uniformity. However, when the Θ_P is 35°, the symmetry of the LC alignment is broken such that the rate of change in luminance, as the viewing direction changes, is larger than

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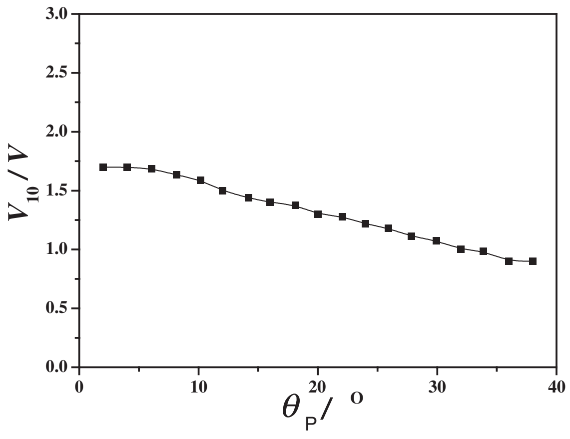

Fig. 2. Threshold voltage as a function of top surface tilt angle.

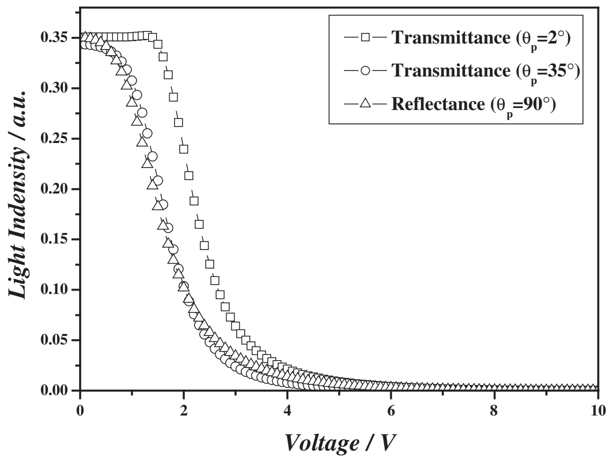

Fig. 3. Voltage-dependent reflectance and transmittance showing a shift of the *V–T* curve to the left with change of pretilt angle.

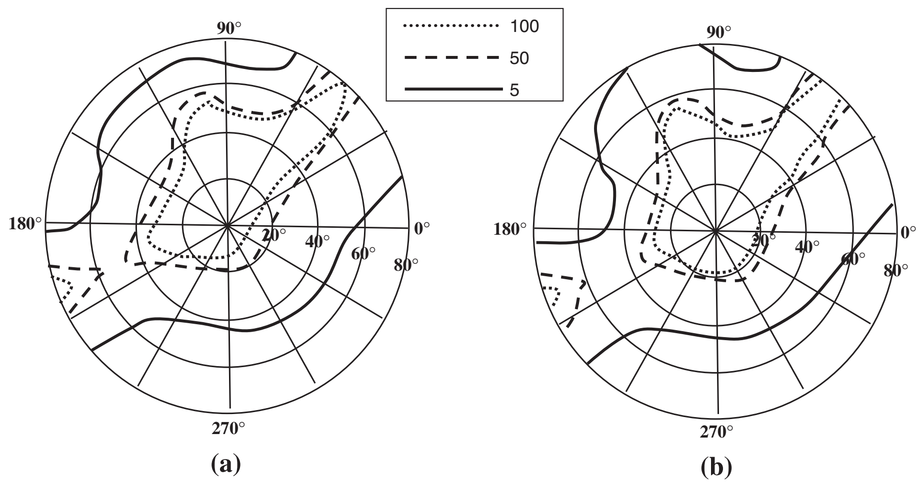

Fig. 4. Comparison of the iso-contrast curve between cells with (a) $\Theta_P = 2°$ and (b) $\Theta_P = 35°$.

that of the cell with $\Theta_P = 2°$, especially in horizontal direction due to retardation difference between left and right oblique viewing directions. However, the dark state of the cell with $\Theta_P = 35°$ shows slightly less light leakage than the cell with $\Theta_P = 2°$, since the cell with high tilt angle shows low residual retardation values than the cell with low one when the same voltage is applied. Consequently, the iso-contrast curve slightly changes as shown in Fig. 4, such that the region in which the contrast ratio (*CR*) is 5 is more asymmetrical in the cell with $\Theta_P = 35°$ compared to the cell with $\Theta_P = 2°$ but slightly wider in the cell with $\Theta_P = 35°$ than with $\Theta_P = 2°$ due to less light leakage.

To summarizing, we have suggested a transflective display associated the ECB mode, in which a single cell gap is realized with dual orientation and the electrooptic curves in the reflective and transmissive region are equal, which occurs when the surface tilt angle in the transmissive region is optimized.

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1) H.-I. Baek, Y.-B. Kim, K.-S. Ha, D.-G. Kim and S.-B. Kwon: Proc. 7th IDW, 2000, p. 41.
2) T. Uesaka, E. Yoda, T. Ogasawara and T. Toyooka: Proc. 9th IDW, 2002, p. 417.
3) K.-J. Kim, J. S. Lim, T. Y. Jung, C. Nam and B. C. Ahn: Proc. 9th IDW, 2002, p. 433.
4) T. B. Jung, Y. J. Lim and S. H. Lee: Proc. KJI, 2003, p. 15.
5) Y. J. Lim, J. H. Song, Y. B. Kim and S. H. Lee: Jpn. J. Appl. Phys. **43** (2004) L972.
6) C.-J. Yu, J. Y. Kim, D.-W. Kim and S.-D. Lee: Proc. Asia Display and IMID '04, 2004, p. 834.
7) M. Schadt, H. Seiberle, A. Schuster and S. M. Kelly: Jpn. J. Appl. Phys. **34** (1995) L764.
8) N. Kawatsuki, H. Takatsuka and T. Yamamoto: Jpn. J. Appl. Phys. **39** (2000) L230.
9) S. H. Lee, K. H. Park, J. S. Gwag, T. H. Yoon and J. C. Kim: Jpn. J. Appl. Phys. **42** (2003) 5127.
10) E. B. Priestley, P. J. Wojtowicz and P. Sheng: *Introduction to Liquid Crystals* (Plenum, New York, 1979).