22.3: *Distinguished Student Paper:* Full-Color Transflective Ch-LCD with Image-Enhanced Reflector

Yi-Pai Huang,[1,2] Xin-Yu Zhu[1], Hong-Wen Ren[1], Qi Hong[1], Thomas Xinz-hang Wu[1], Shin-Tson Wu[1], She-Hong Lin[2], and Han-Ping David Shieh[2]

[1] School of Optics/CREOL, University of Central Florida, Orlando, Florida 32816

[2] Institute of Electro-Optical Engineering, National Chiao Tung University, Hsinchu, Taiwan, 30010, R.O.C

Abstract

A full color transflective liquid crystal display with low power consumption is demonstrated by using high Δn cholesteric liquid crystal (Ch-LC) as an LC layer and building an image-enhanced reflector (IER) on the top of the transmissive region. The high Δn Ch-LC can reflect wide band wavelength to display white image. With conventional color filter process, a full color image can be shown. Additionally, an IER on the top of the transmissive region provides the similar paths for both transmissive and reflective light. The two regions can always display same image color in any ambience, thus to greatly improve the image quality of the full color transflective cholesteric liquid crystal display.

1. Introduction

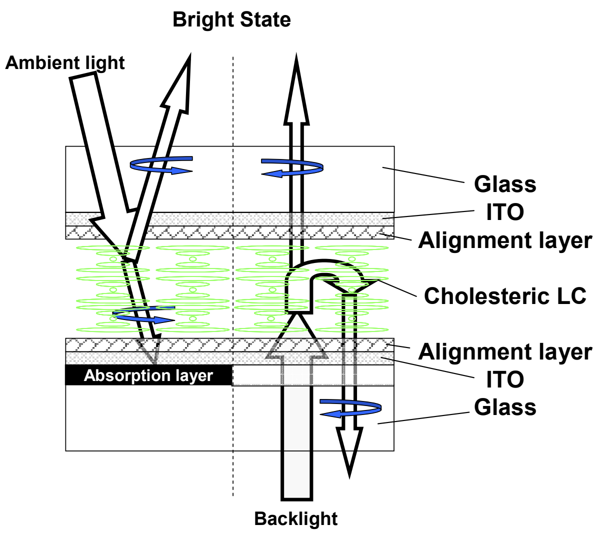
Reflective cholesteric liquid crystal display (Ch-LCD)[1] is a bistable device which consumes less power than the general reflective STN or TFT displays. Due to its bistability, the driving voltage is required when refreshing the screen. This power-saving feature is especially important for reading books or magazines. An ordinary people may take 2-3 minutes to finish reading a page. Thus, Ch-LCD is a strong contender for electronic newspaper or books.

The operation principle of reflective cholesteric display is shown in Fig. 1. The left part of Fig. 1(a) shows the bright state of a Ch-LCD. When an unpolarized light is incident into a right-hand cholesteric LC layer, the right-hand circularly polarized light within the bandwidth is reflected and the transmitted left-hand circularly polarized light is absorbed by the absorption layer. In an applied voltage state shown in the left part of Fig. 1(b), the cholesteric LC layer was driven into a focal conic state. Thus, the incident light passes through the LC layer and be absorbed by the absorption layer, resulted in a dark state.

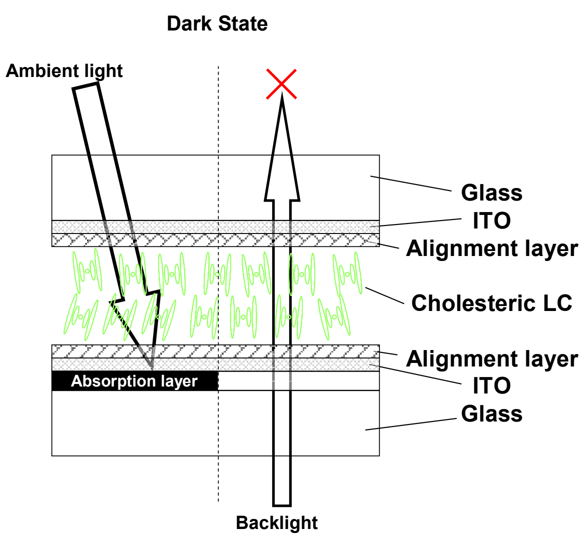
Several methods have been proposed to demonstrate a full color Ch-LCD, such as stacking cells of primary RGB colors[2], exposing different UV intensity to generate different pitch lengths[3], and doping different twist agents to create RGB color pixels[4]. However, these methods still have to improve display features and they are only as reflective displays. Therefore, ambient light is required to read the displayed information contents. In a dark ambient, these displays are not readable.

In the application of STN and TFT LCDs, transflective display enables a reflective display to be readable in dark ambience. In a transflective display, each pixel is divided into transmissive and reflective sub-pixels. However, cholesteric displays are not applicable for such transflective structure. As Fig. 1 shows, both reflective and transmissive sub-pixels display bright state, but lacks of dark state. In this paper, we demonstrate a transflective Ch-LCD that can be fabricated by conventional process and display full color image.

ISSN/0004-0966X/04/3502-0882-$1.00+.00 © 2004 SID



(a)



(b)

Fig. 1. Operation principle of reflective/transflective cholesteric display. (a) Homogeneous and (b) focal conic state.

2. Full color transflective cholesteric LCD

To achieve full color display, we select to use a broad band reflection cholesteric LCD for achieving black and white displays and implement RGB absorptive/transmissive color filters. The reflection bandwidth of a cholesteric LCD is proportional to the birefringence (Δn) and pitch length (P) as $\Delta\lambda = p\Delta n$. Therefore, high birefringence LC is used to widen the reflective band width. Our approach is to achieve a broad reflection band covering the entire visible spectrum, from 450 to 650nm. Under such a condition, a black and white cholesteric display can be realized. Since the reflected light is white, the conventional color filters can be patterned for obtaining full color displays.

In this novel full color transflective cholesteric LCD, each pixel is divided into reflective and transflective parts. In the transmissive part, an image-enhanced reflector (IER)[5] is in position to reflect the backlight into the reflection pixels. This IER design works equally well for both narrow and broad band cholesteric displays. Fig. 2 illustrates operating mechanisms of this transflective cholesteric display. In Fig. 2(a), an unpolarized ambient light is incident to the reflective pixels. Assumed the cholesteric layer is right-handed so that it reflects the right-hand (R) circularly polarized light and transmits the left-handed (L) part. The transmitted L light is absorbed by the absorption layer. As a result, a bright state is obtained. On the transmission channel from backlight, the R light is reflected back and L is transmitted to impinge onto the IER. Upon reflection, the L light becomes R and is reflected by the cholesteric LC layer to the viewer. Again, the bright state is achieved. The same bright state for both reflective and transmissive channels is critically important, as in a not-too-dark ambience, the backlight may need to turn on for enhancing the readability.

On the other hand, in an applied voltage state the cholesteric liquid crystal layer is reoriented to a focal conic state, as shown in Fig. 2(b). Unlike the cholesteric state, the focal conic state does not selectively reflect or transmit the input polarization. Both the incident ambient and backlight are transmitted by the LC layer and absorbed by the black paint. As a result, the black state appears.

The side view device embodiment of this novel structure is shown in Fig. 2. The IER's are implemented on the same substrate as the color filters, right above the transmissive sub-pixels to reflect the backlight into reflective region. The absorption layer can be a black paint, as used in CH-LCD's, absorbing the leaked light to provide a black state. Moreover, the fabrication for color filters and IER are compatible with conventional process.

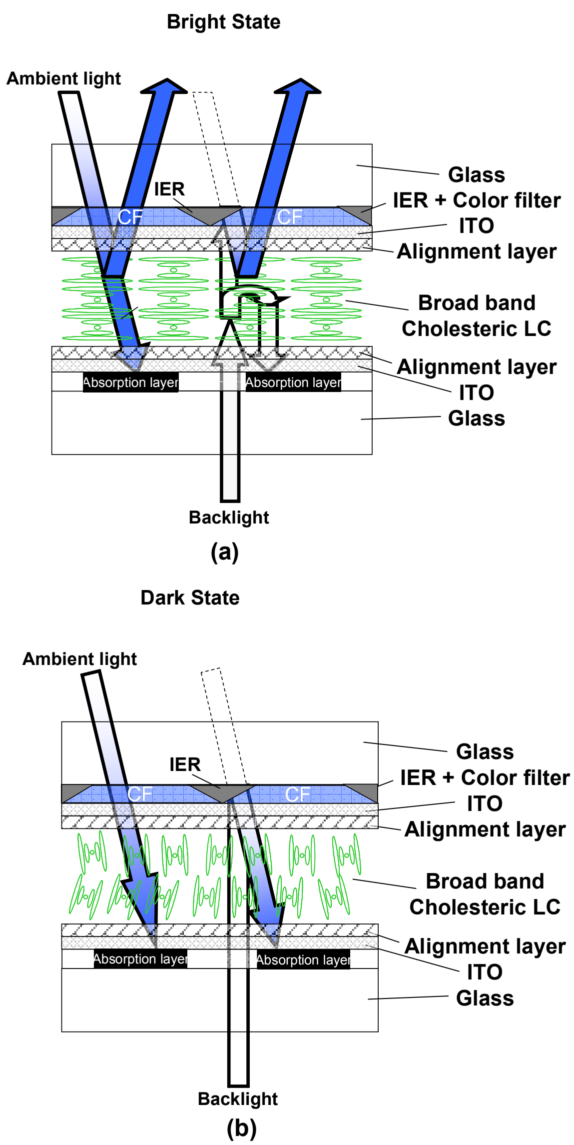


Fig. 2. Schematic plot of the proposed full color transflective cholesteric LCD with an IER and wide band reflective cholesteric liquid crystal. (a) Bright and (b) dark state.

3. Results

By using finite element method (FEM)[6], the relationship between birefringence and reflection bandwidth of a cholesteric display was simulated, as shown in Fig. 3. The incident light was unpolarized and LC layer was right-hand circular cholesteric. The □n values used for calculations are 0.2, 0.6 and 1.0, shown as green-dash, orange-plus and blue-solid lines, respectively. Obviously, when the birefringence is larger than 0.6, the reflection bandwidth covers almost the entire visible spectrum with 50% reflectivity that can display black and white image. By implicating RGB color filters on the display, a full color cholesteric LCD can be demonstrated.

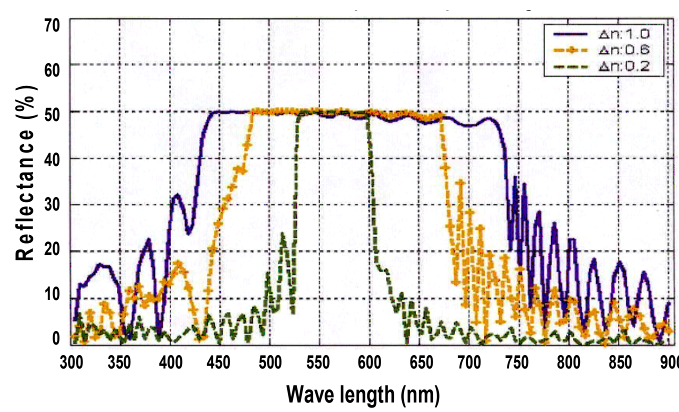
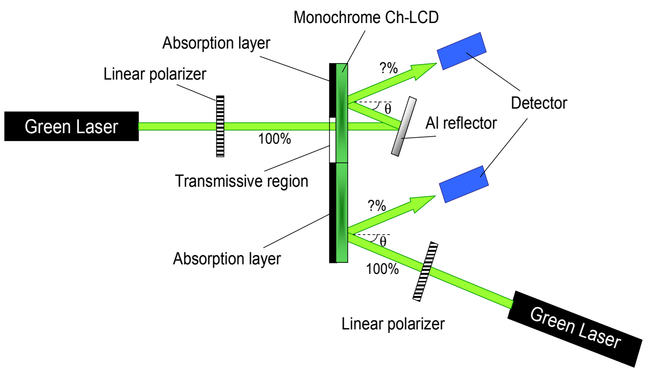
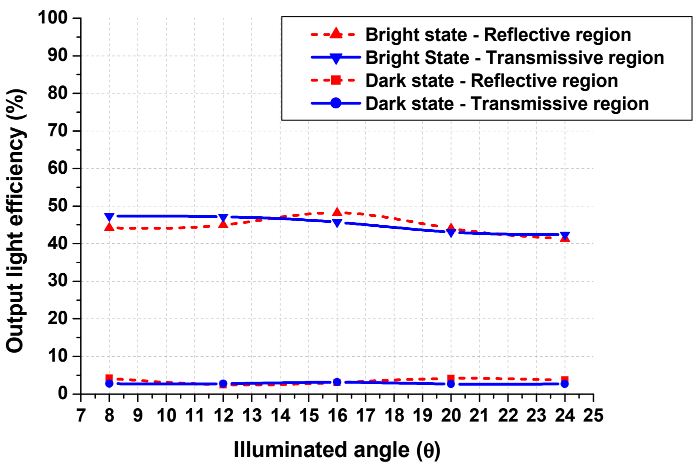


Fig. 3. Simulation results of the birefringence dependent reflection bandwidth of a Ch-LCD.

To examine the function of IER on Ch-LCD, two linear polarized He-Ne green lasers (λ=543nm) were used as backlight and ambient light, respectively, to illuminate on a monochrome Ch-LCD, whose reflective band width ranges from 530nm to 590nm, as shown in Fig. 4(a). An Aluminum reflector was set as an IER behind the Ch-LCD to reflect the transmit light to the Ch-LCD. The output light efficiency of transmissive and reflective portion with different illumination angle θ was measured by the detectors, and the results are shown in Fig. 4(b). From the results, the output light efficiency of bright and dark states of reflective and transmissive regions is similar. With different illuminated angles of green lasers, both regions have output light efficiency higher than 40% for bright state, and lower than 5% for dark state. The results demonstrate that by building IER above the transmissive portion of Ch-LCD really can yield a high quality image for both reflective and transmissive mode with same displayed colors.



(a)



(b)

Fig. 4. (a) The experimental setup and (b) the experimental results of demonstrating the IER function on Ch-LCD.

4. Conclusions

The proposed novel cholesteric LCD has low power consumption for its bistability; high brightness as the polarizers are not required. By using high birefringence LC material and conventional color filter process, the display can show full color images. The IER structure building above the transmissive region make the Ch-LCD displays same color images in reflective and transmissive modes and maintains good readability in any ambience. Furthermore, the fabrication processes of this full color transflective cholesteric display are compatible with conventional STN and TN LCDs. We are now fabricating this low power consumption transflective cholesteric LCD which can display high brightness full color image.

5. Acknowledgements

The project was partially supported by National Science Council, Taiwan, under contract No. 91-2215-E-009-016. We would like to express our appreciation to Dr. Wing Kit Choi of University of Central Florida, for valuable discussions and technical supports.

6. References

[1] D. K. Yang, L. C. Chien, and J. W. Doane, SID'92, p.759.

[2] K. ASAD. A, et al.: U.S. Patent 6,377,321 (2002).

[3] D. J. WILLIAM, et al.: U.S. Patent 6,061,107 (2000).

[4] Y. D. MA, et al.: U.S. Patent 5,949,513 (1999).

[5] Y. P. Huang, M. J. Su, H. P. D. Shieh and S. T. Wu, SID'03, p.86.

[6] Q. Hong, T. X. Wu, and S. T. Wu, Liquid crystal, Vol. 30, No. 3, P. 367.