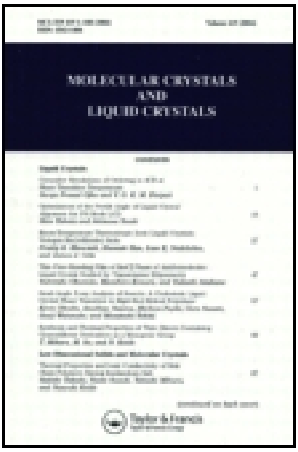

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Improvement of Outdoor Readability Using Novel Switchable Transmissive and Reflective Twisted Nematic LCD

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For the first time, we have fabricated a novel Switchable Transmissive and Reflective (STR) LCD based on dual gap TN (Twisted-Nematic) mode using a general a-Si TFT process. This new technology creates ultra low power LCD using reflective mode. This new device has no power consumption of backlight in ordinary room light environment. Moreover our new LCD offers superior outdoor visibility and enhanced portability to user. We will show vision as a future LCD mode for portable electronic devices.

Keywords Switchable Transmissive and Reflective LCD; low power; outdoor readability

Introduction

Nowadays, outdoor displays such as PD (Public Display) and EPD (E-Paper Display) are getting attention in emerging market. Transflective LCD plays an important role in mobile display devices for its strength in both indoor and outdoor visibility. Previous studies about transflective LCD [1, 2] are mainly discussed on ECB (Electrode Controlled Birefringence) mode with dual cell gap structure [3–5] or TN (Twisted Nematic) mode with compensation film [6]. Unfortunately, electro-optical properties of transflective LCD with ECB or TN mode are reduced in transmissive mode.

Recently, demands for new display having equivalent electro-optical properties compared to ordinary transmissive LCD are getting higher. Here we suggest novel structure for Switchable Transmissive and Reflective LCD showing high performance in both reflective and transmissive modes.

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Simulation Result

In common, Jones matrix is used for analysis on transmittance and reflectance of TN mode [7]. The normalized transmittance of TN mode can be described as follow:

$$T = \cos^2 X + \left(\frac{\Gamma}{2X}\cos 2\beta\right)^2 \sin^2 X$$

[8] Here, β is the angle between transmissive axis of polarizer and the front LC director. To find the maximum transmittance of normal transmissive 90° TN mode, Gooch-Terry condition is used [9].

$$\frac{d\Delta n}{\lambda} = \sqrt{m^2 - 1/4}$$

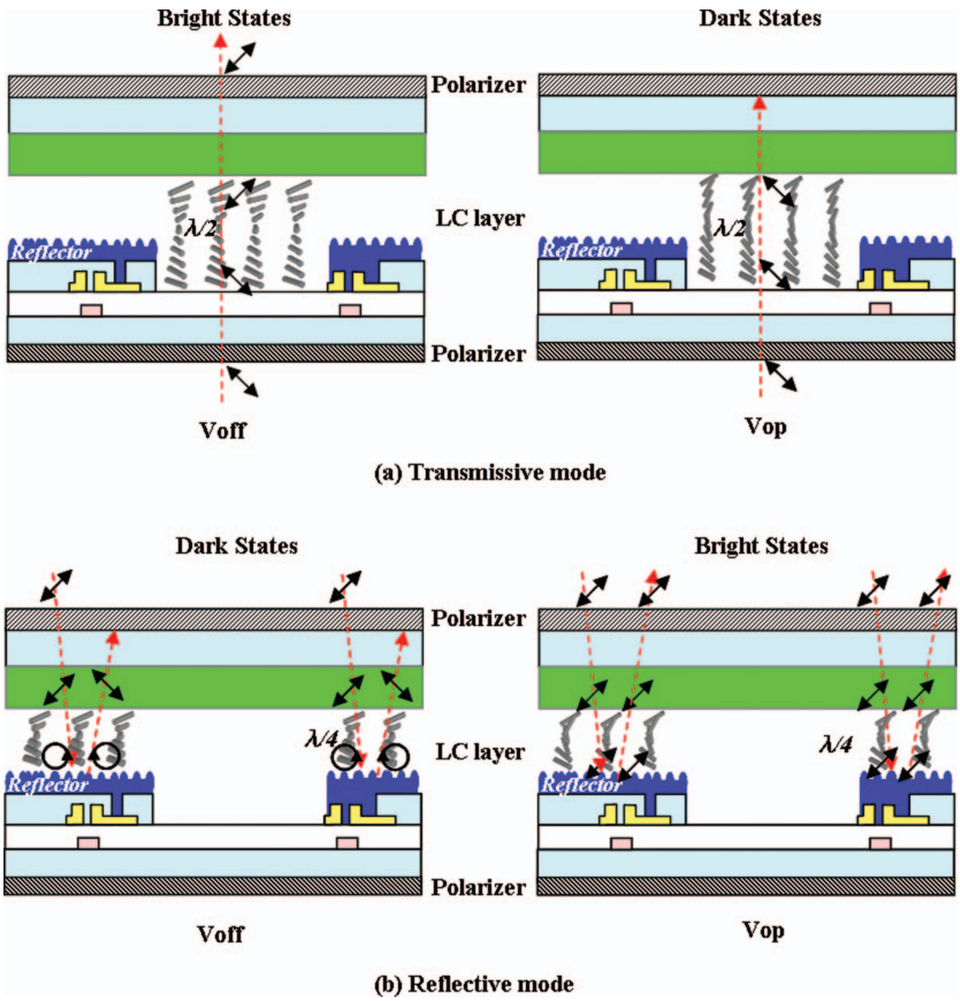

Figure 1. Cell configuration of Switchable (a) Transmissive mode and (b) Reflective mode.

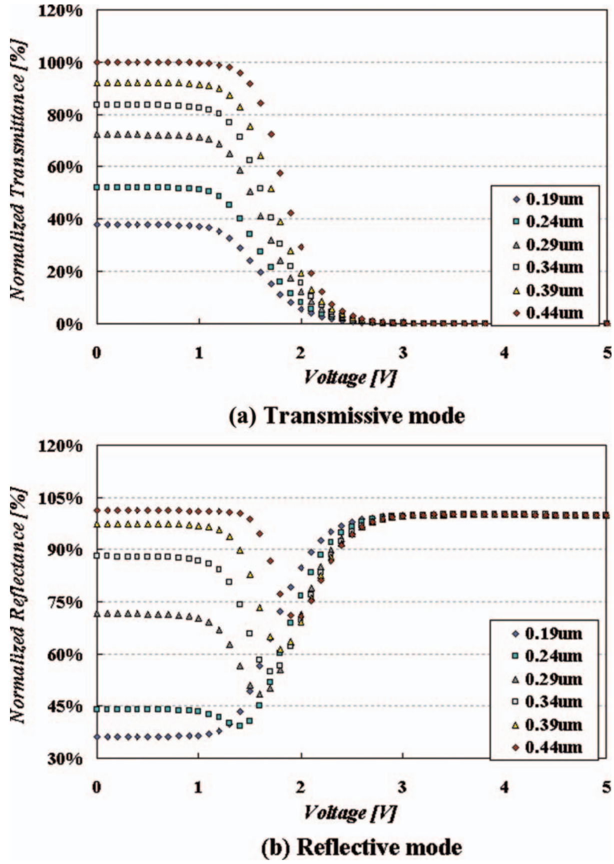

Figure 2. Voltage dependent (a) Transmittance and (b) Reflectance Curve as various retardation values.

From the equation, first minimum value of transmittance is obtained when $d\Delta n = \sqrt{3}/2$. We optimized retardation value of transmissive area applying Gooch-Terry conditions.

We designed a dual gap switchable display using normally white TN mode. For we set the retardation values of transmissive and reflective area as λ/2 and λ/4, our new approach has no reduction in transmissive characteristics compared to normal transmissive mode LCD. Figure 1 shows a cell structure of our new dual gap switchable display and stack structure. Dual gap is obtained by setting distance from top electrode to reflective area and transmissive area. In the device, the common electrode exists on the top substrate and pixel electrodes exist opposite substrate. Two polarizers are crossed to each other and an optical axis of the LC coincides with one of the polarizer axis. In order to estimate the characteristics of Switchable LCD, we have calculated transmittance and reflectance using Techwiz 1D simulator (Sanai Techwiz 1D simulator, Korea). The physical properties of Liquid Crystal is dn = 0.1023 (ne = 1.592, no = 1.485), de = 10.7 (e-par. = 14.5, e-per. = 3.8), K11 = 7.3, K22 = 12.1,K33 = 25.6. Simulation result in Fig. 2 shows that it can be operated in normally black mode only in case of λ/4 retardation. In other cases, it is impossible to set the gray level for its black excitation along the increase of retardation value. From the result, reflectance curve is inversion of transmittance curve, so it needs

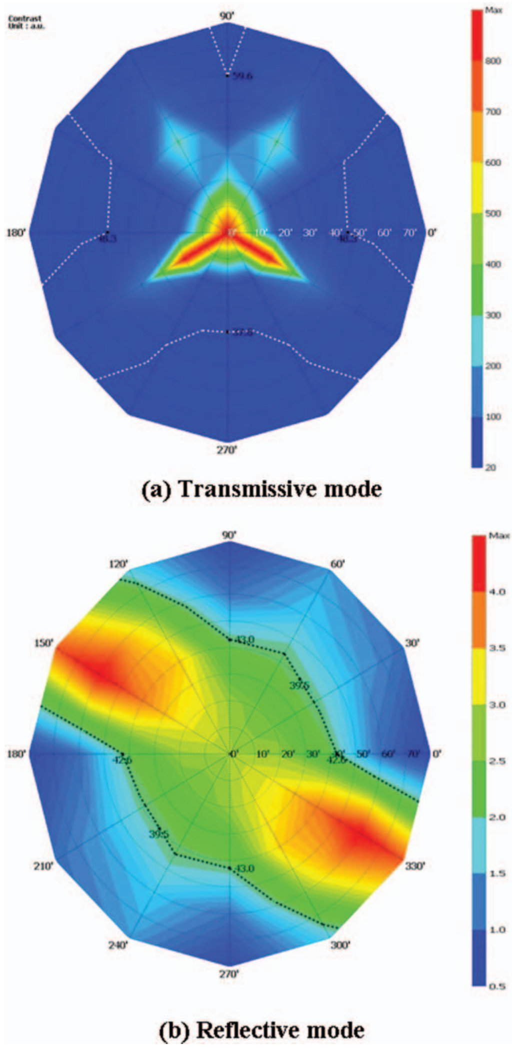

Figure 3. Isocontrast for (a) transmissive and (b) reflective area.

signal data inversion to operate reflective mode. Based on the simulation result, we set the optimized dΔn as a 0.19 um for reflective mode and 0.40um for transmissive mode.

Figure 3 shows is contrast contour of transmissive and reflective area in the range of incident light from 380 to 780 nm. Simulation result indicates that the region where contrast ratio is greater than 5:1 exists at a polar angle greater than 45° in all direction. That is similar to viewing angle characteristics of ordinary transmissive TN LCD.

Result

Considering simulation results, we have fabricated WSVGA (1024 × 600) 10.1 inch dual gap TN mode panel. To obtain high reflectance, dot pixel was designed that the proportion of transmissive area to reflective area is three to seven. Also, the retardation of transmissive area was designed as λ/2 and that of reflective area was designed as λ/4.

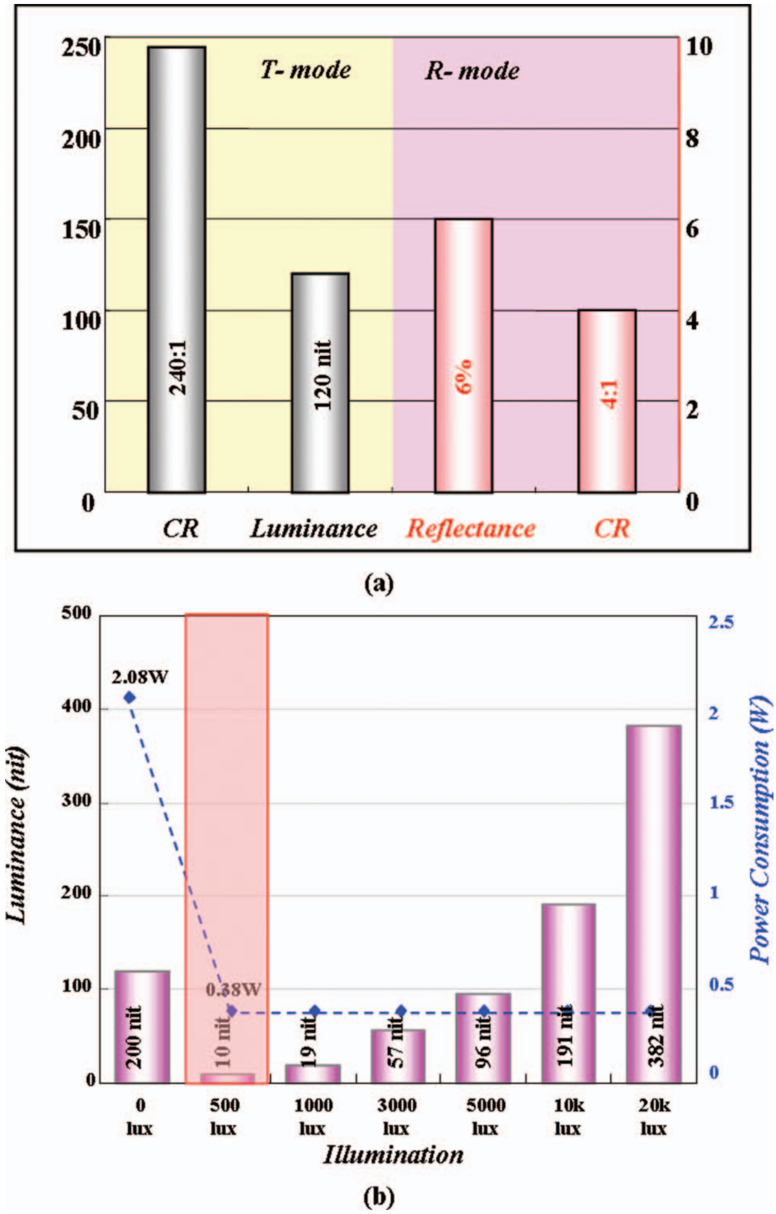

Figure 4. Fabricated LCD module characteristics: (a) Electro-Optical properties (b) Power Consumption and Luminance according to Illuminations.

Measured data of electro-optical properties and power consumption is shown in Fig. 4. Total power consumption in reflective mode is under 20% of normal transmissive mode with backlight.

Finally, Fig. 5 shows pictures of transmissive mode and reflective mode under 500 lux circumstance. We achieved good characteristics in both transmissive mode and reflectance mode.

(a) Transmissive mode **(b) Reflective mode**

Figure 5. Real Image of Switchable Transmissive and Reflective LCD at (a) transmissive mode and (b) reflective mode.

Conclusions

In this work, we have developed Switchable Transmissive and Reflective (STR) LCD based on dual gap TN mode. Our device is differentiated from previous studies of transflective LCD for its high electro-optical properties in transmissive mode. This new Switchable Transmissive and Reflective LCD can be easily fabricated in normal a-Si TFT process. Also, STR LCD has lower manufacturing cost than ECB or VA mode transflective LCD by using normal polarizer without retardation film. Moreover, total power consumption is much lower than ordinary transmissive LCD for the existence of reflective mode. In result, this new approach can be adopted in new applications with environment-independent visibility.

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