Viewing Angle Controllable LCD by Thermal Modulation of Optical Layer

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Abstract

We suggest a viewing angle control mode of liquid crystal display (LCD) with additive thermal controllable optical layer [TCOL], which composed of homeotropically or homogenously well aligned LC layer and patterned heating lines on a substrate. In this system, LCD modes with wide viewing angle characteristics can be used as a main panel.

1. Introduction

Today as the increasing needs for mobile electronic devices such as personal mobile player (PMP), mobile navigator, and laptop computer, privacy protection has become a critical issue in display functions. Users who have mobile displays want to choose whether they share or protect the information on the display screen. So there've been some researches about viewing angle control methods in a way of privacy protection. For example, adopting additional LC layers or a dual backlight component or a hybrid switching mode has been proposed [1-7]. For conventional viewing angle control, however, they need well designed optical combination between liquid crystal layer and compensation layer to satisfy wide viewing angle (WVA) and narrow viewing angle (NVA) simultaneously. Furthermore additional cost problem is still remained.

In this paper, we suggest a new viewing angle control mode by additive thermal controllable optical layer [TCOL] with transparent ITO patterned electrical heating lines on a substrate. The proposed LCD has very simple optical structure and easy fabrication because an ITO patterned retardation film is only needed out of the main panel.

2. Principle

Figure 1 is the cell structure showing how to achieve WVA and NVA mode in the proposed LCD structure. The optical properties of the proposed LCD are determined by the only main panel with wide viewing angle when the TCOL is in the isotropic state by heating. Then the LCD shows a wide viewing angle. On the other hand when the TCOL is in the nematic state without heating, the optical properties of the LCD at off axis is restricted by TCOL. Therefore, we can obtain the NVA mode by controlling the retardation of TCOL at off axis.

The general optical transmittance in which uniaxial LC layer between crossed polarizers is given as

$$T = \frac{1}{2}\sin^2\left(\frac{\Gamma}{2}\right) \qquad \textbf{(1)}$$

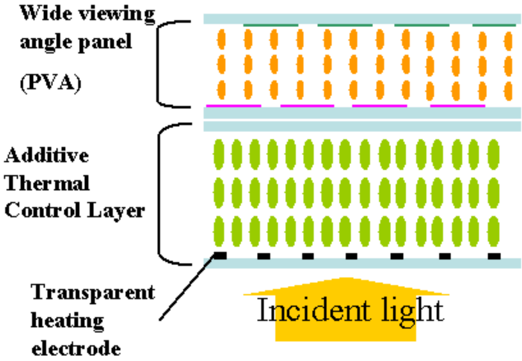
where the Γ is the phase retardation noted as

$$\Gamma = \frac{2\pi(n_e - n_o)d}{\lambda} \qquad \textbf{(2)}$$

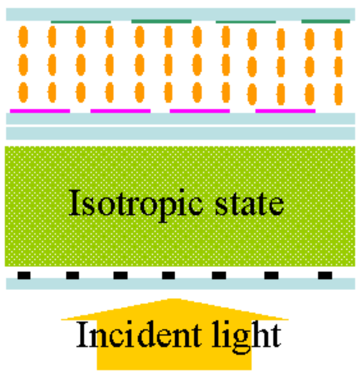
where n_e-n_o=Δn is the birefringence of LC, d is the thickness of cell, and λ is the wavelength of the incident light. The condition Γ=0 can be dark state because LC layer aligns vertically. But since the vertically aligned LC layer has optical anisotropy at oblique incidence, a leakage light may occur. So the vertical alignment mode requires compensation films. Here, the patterned vertical aligned nematic (PVA) mode used as main panel of the proposed LCD was compensated by a negative C-plate and a positive A-plate for wide viewing angle.

3. Experimental

For TCOL, We used LC which has relatively low nematic-isotropic transition temperature to reduce power consumption and to obtain fast transition time between WVA and NVA, by heating. As a good case, 4-n-pentyl-4'-cyanobiphenyl (5CB) liquid crystal, general product from Merck with transition temperature of about 34℃ was used in TCOL. In this case, the viewing angle control can be obtained by temperature control within 3℃.



(a)

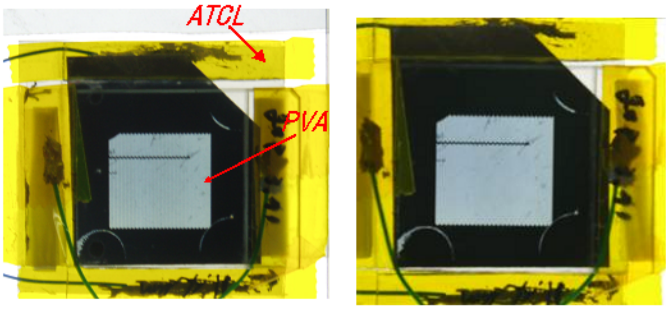


(b)

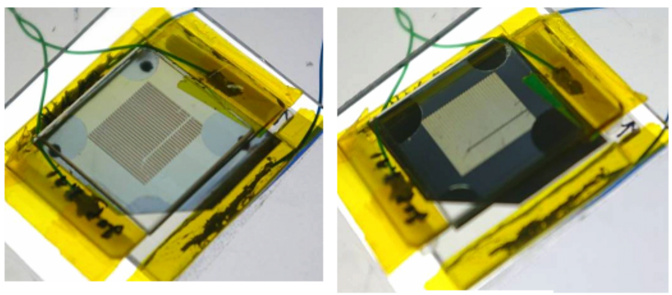
Fig. 1 Schematic diagram of viewing angle control LCD with TCOL: (a) is normal state (NVA) and (b) is isotropic state (WVA)

4. Results and discussion

We made PVA mode as a main panel and TCOL for controlling the retardation of transmitted light. The LC in PVA was negative LC, MLC-6610 (Merck) and its birefringence is Δn=0.0996. Cell gap was 3.71 um. The LC in TCOL we used is Δn=0.2120. The thickness of the TCOL was fixed to 11.4 um. Figure 2 shows the texture images of PVA cell coupled with TCOL. It shows that the viewing angle of PVA mode is determined by the birefringence of TCOL. The optical image at the front side is the almost same when TCOL is nematic and isotropic state as shown in Figs. 2 (a) and (b). However, the diagonal view shows obviously different images between nematic and isotropic states of TCOL as we can see Figs. 2(c) and 2(d). It is also possible to make continuous viewing angle that we expect, in the proposed LCD. In order to confirm this, we measured a viewing angle of a PVA-TCOL cell according to temperature. Figure 3 represent a viewing angle of each voltage steps.



(a) (b)

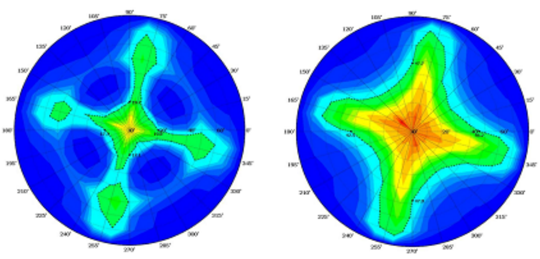


(c) (d)

Fig 2 Texture images of a PVA- TCOL cell; (a) front view when TCOL is nematic phase, (b) front view when TCOL is isotropic phase, (c) side view when TCOL is nematic phase, (d) side view when TCOL is isotropic phase.

The results show clearly the change of viewing angle with the change of TCOL. When TCOL is nematic state with large retardation without applied voltage (0 V), the PVA cell exhibits NVA as shown in Fig. 3(a). On the hand, When TCOL is isotropic state with no-retardation under applied voltage (2 V), the PVA cell shows WVA as shown in Fig. 3(b).

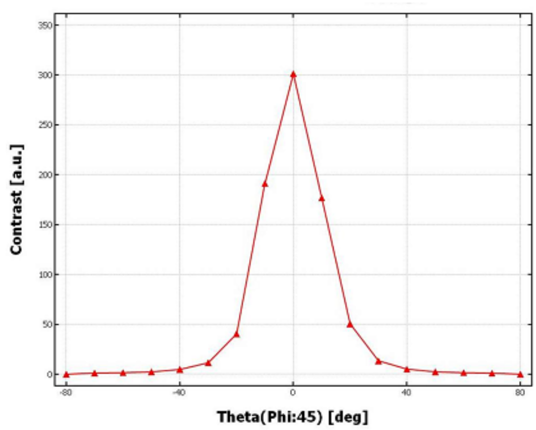
Fig 4 shows the contrast ratio in 45° azimuthally diagonal direction of the PVA cell when TCOL is isotropic and nematic states. According to each state of TCOL, the LC cell shows obviously distinguished contrast characteristics.



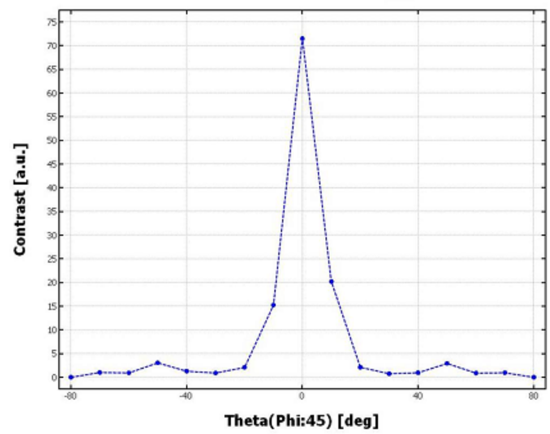
(a) **(b)**

Fig 3 Measurement of contrast results of a PVA-TCOL cell

The TCOL that uses the LC with a relatively low isotropic transition temperature, to induce lower voltage may be affected by the temperature of outside panel. It may make viewing angle control hard. Therefore, it can require a simple cooling system.



(a)



(b)

Fig. 4 Contrast of WVA an NVA along the 45° from measurement PVA- TCOL cell

5. Summary

We proposed a new viewing angle control structure by additive thermal controllable optical layer [TCOL] with transparent ITO patterned electrical heating lines on a substrate. The proposed LCD has very simple optical structure and easy fabrication. The experimental results show that it is possible to control a continuous viewing angle by modulating the retardation of TCOL in the proposed LCD.

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7. Reference

1. W.-J Shin and T.-Y Won, "Controllable Viewing Angle LCD Having a Single LC Layer" *IDMC, 540 (2007)*

2. K.-W. Chien, Y.-J. Hsu, and H.-M. Chen, "Dual Light Source for Backlight Systems for Smart Viewing-Adjustable LCDs ," *SID Int. Symp. Digest Tech. Papers 37, 1425 (2006).*
3. K. Takatoh, S. Kobayashi, S. Kimura, N. Okada, T. Kanetsuna, N. Hirama, S. Kurogi, S. Sekiguchi, and K. Uemura, "New Peeping Prevention Technology to Control Viewing Angle Properties of TFT-LCDs," *SID Int. Symp. Digest Tech. Papers 37, 1340 (2006)*
4. J.-I. Baek, Y.-H. Kwon, J.-C. Kim, and T.-H. Yoon, Appl. Phys. Lett. 90, 101104 (2006)
5. J. S. Gwag, Y. –J. Lee, M. –E. Kim, J. –H. Kim, J. –C. Kim, and T. –H. Yoon, Optic Express Vol. 16, No. 4, 2669 (2008)
6. J. Eun, Y. –J. Lim, M. –H. Chin, J. –H. Kim, S. –H. Lee, S. –H. Ji, G.. –D. Lee, K. –H. Park, H. –C. Choi, and B. –C. Ahn, Appl. Phys. Lett. 92, 261102 (2008)
7. C. –L. Kuo, T. Miyashita, M. Suzuki and T. Uchida, Appl. Phys. Lett. 68, 11 (1996)