Vertical Alignment Nematic Liquid Crystal Display with Patterned Electrode Using Positive Liquid Crystal Materials

Hun Ki Shin*, Tae-Hoon Yoon, and Jae Chang Kim

School of Electrical Engineering, Research Institute of Computer, Information

and Communication, Pusan National University, Busan 609-735, Korea

Phone: +82-51-510-1700, E-mail: metalslayer@pusan.ac.kr

Keywords: ***liquid crystal, normally black mode, vertical alignment, in-plane switching***

Abstract

We propose a vertical-alignment liquid crystal display with patterned electrodes using a positive dielectric anisotropic liquid crystal. In this structure, the threshold and on-state voltages are reduced compared with previous vertical-alignment configuration with positive liquid crystal.

1. Introduction

Nowadays liquid crystal displays (LCDs) are mainly used in various fields such as monitor, notebook, cellular phone, television, etc. In general, LCDs are divided into normally white (NW) and normally black (NB) modes by its initial state. NB modes have better performances than NW modes. The twist nematic (TN) mode, NW mode, is still dominant in LCDs due to its strong stability in structure and wide process margin. However, it has problems in viewing angle and response time. Therefore many different NB modes, such as in-plane switching (IPS) [1,2], fringe-field switching (FFS) [3,4] and vertical alignment (VA) [5], are suggested to improve image quality of displays. Among them, VA mode is widely employed because of its high contrast ratio and simple optical configuration. Negative dielectric anisotropy ($\Delta\varepsilon$) LC materials are often employed in VA mode, however they usually have a higher viscosity, smaller $\Delta\varepsilon$ value, and are more expensive than the positive $\Delta\varepsilon$ LCs. In this paper, we designed the NB mode using positive $\Delta\varepsilon$ LC materials. In our structure, rubbing process is not necessary, moreover an inherently two-domain structure results in a good viewing angle.

2. Device configuration

In the previous work [6], VA-IPS structure is rather difficult to lower threshold voltage (V_{th}) and on-state voltage (V_{on}) simultaneously. To overcome these drawbacks, we propose a new structure. The schematic diagram of our proposed configuration is shown in Fig. 1. It is composed of two linear cross polarizers and a vertically aligned LC. To compensate the dark state viewed at off-axis, a negative C plate [7] is placed on the top glass substrate. The LC mode used is a patterned VA mode using a positive LC material. The pixel electrode structure is an interdigital electrode which is deposited on the bottom and top substrates. The pixel electrode is made of indium-tin-oxide (ITO), which is patterned at 45° with respect to the input polarizer. In the off-state, the LC molecules are vertically aligned so that the polarization state of light does not change while propagating through the cell. Consequently, the light is blocked by the analyzer, bringing about good dark state. However, the light leakage occurs at off-normal directions. Figure 2 shows director profile and equivalent potential line at the voltage-on state. When the electrodes on the bottom substrate are grounded and a voltage is applied to the electrodes on the top substrate, this configuration generates the lateral fields to reorient the positive LC director. As a result, the LC directors tilt down to the left and right along the field direction, giving rise to transmission of the incident light.

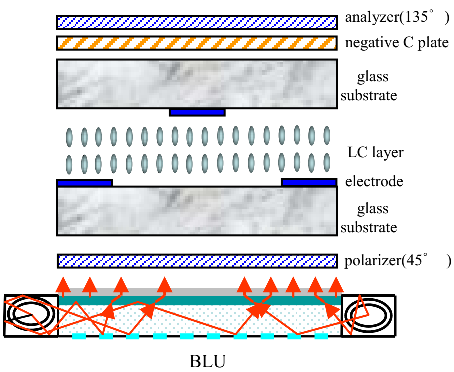

Fig. 1. Schematic diagram of proposed structure

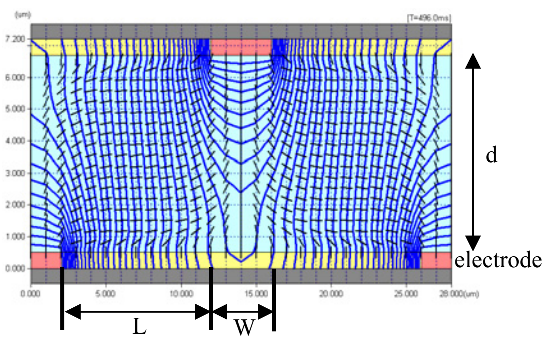

Fig. 2. Director profile and equivalent potential line at voltage-on state

3. Results and discussion

We investigated the effect of electrode width (W), electrode gap (L) and the LC cell gap (d) by using the *LCD MASTER* (Shintech) software. For the simulation, we used a LC characterized by K_{11} = 8.8pN, K_{33} = 14.6pN, $\varepsilon_{\parallel}$ = 14.5, $\varepsilon_{\perp}$= 4.5, γ = 0.102 Pa·s, n_o = 1.4824 and n_e = 1.5774 at λ = 589 nm. The LC directors in the cell are initially vertically aligned without rubbing. To examine the electro-optic (EO) characteristics by W and L, we first fix the cell gap d. d and W were fixed at 6 μm and 4 μm, respectively and the L was varied from 8 μmto 12 μm at 2 μm interval. The EO characteristics from calculation of proposed structure are shown in Fig. 3. The wavelength of light was fixed to 550 nm in calculation. The transmittance increases gradually as L increases from 8 μm to 12 μm, however threshold voltage V_{th} and on-state V_{on} voltage also increase. We chose W and L to be 4 μm and 10 μm, respectively. As shown in Fig. 4, V_{th} and V_{on} became lower in proportion to the increase of d, however transmittance deceases by increasing d. In our simulation, d = 5.5 μm, L = 4 μm and W = 10 μm were optimized parameters. To compare transmittance of VA-IPS cell with those of our proposed structure, we simulated two structures in the same conditions. As a result of calculation, transmittance of VA-IPS cell and those of our proposed structure were 20.3% and 21.8%, respectively. However, low transmittance is still problem because the directors do not tilt down in center of electrodes. Figure 5 shows a viewing angle of the proposed device with d = 5.5 μm, L = 4 μm and W = 10 μm. The horizontal and vertical viewings are nearly 180° and 180°, respectively. To compensate the off-axis contrast ratio, we attached an optical compensation film, negative C plate, of Δnd = 350nm to the upper plate of the cell. Because of 2-domain structure, viewing angle seems more symmetrical in the azimuthal directions than a single-domain VA cell.

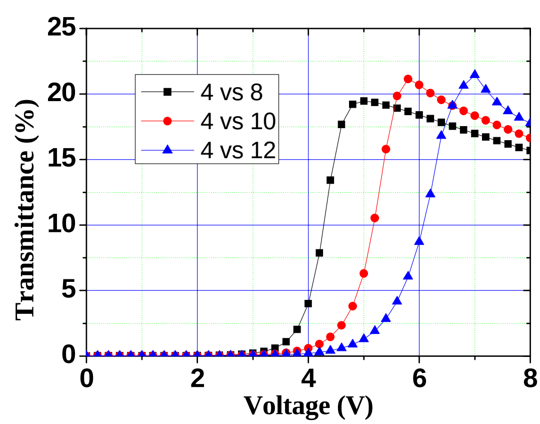

Fig. 3. Transmittances with the variation of the electrode width (W), and gap (L)

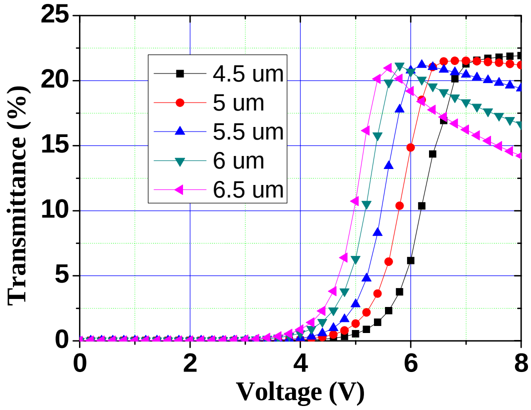

Fig. 4. Transmittances with the variation of cell-gap (d)

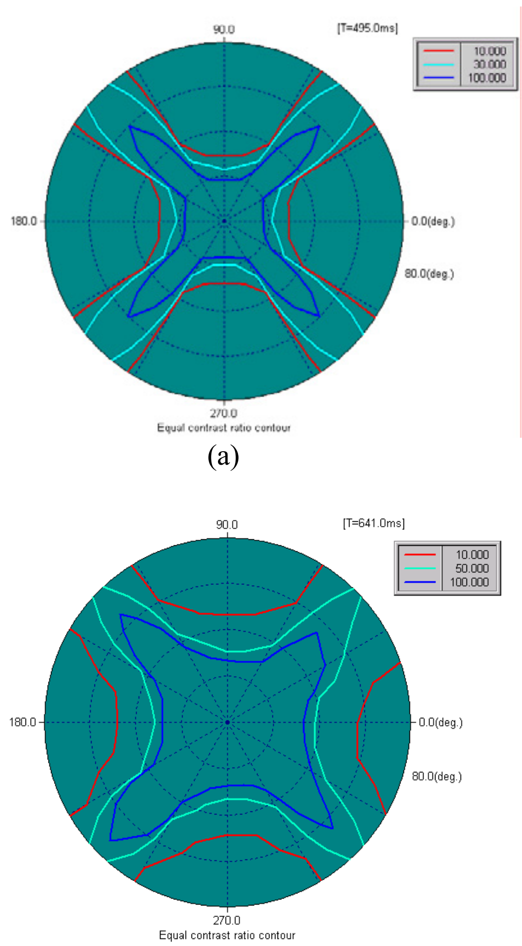

Fig. 5. Calculated iso-contrast ratio (a) without negative c film, and (b) with negative c film

4. Summary

We proposed a new structure which is initially vertical aligned with patterned electrodes using positive LC. By optimizing the parameters such as cell gap (d), electrode width (W) and gap (L), the threshold voltage (V_{th}) and on-state voltage (V_{on}), and light efficiency were enhanced. Due to 2-domain structure, viewing angle in the azimuthal directions is nearly symmetrical.

5. Acknolegement

This work was supported in part by the Second Phase BK21 Program of the Ministry of Education & Human Resources Development, Korea and by Samsung Electronics Co., Ltd.

6. References

1. M. Oh-e, M. Ohta, S. Aratani and K. Kondo, Proc. 15th Int. Display Research Conf., p577 (1995).
2. M. Oh-e and K. Kondo, Appl. Phys. Lett., Vol. 67, p3895 (1995).
3. S. H. Lee, S. L. Lee and H. Y. Kim, Appl. Phys. Lett. Vol. 73, p2881 (1998).
4. S. H. Lee, S. L. Lee and H. Y. Kim, Proc. 18th Int. Display Research Conf., p371 (1998).
5. A. Takeda, S. Kataoka, T. Sasaki, H. Chida, H. Tsuda, K. Ohmuro, Y. Koike, T. Sasabayashi and K. Okamoto, SID Dig., p1077 (1998)
6. S. H. Lee et al, Appl. Phys. Lett., Vol. 71, p2851 (1997).
7. S. T. Wu, J. Appl. Phys., Vol. 76, p5975 (1994).