P-143: Wide Viewing Liquid Crystal Display based on a Multi-Patterned Electrode

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Abstract

We proposed the wide-viewing-angle liquid crystal display (WVA-LCD) of the patterned vertical alignment (PVA) mode by adopting differential geometry of the electrode pattern. Due to the patterned electrode structure, we can obtain 8-domain LC alignment in a simple fabrication process while the conventional PVA mode has only 4-domain structure. This multi-patterned electrode technique enlarges the viewing angle of LCD about 12% compared to the conventional PVA mode.

1. Introduction

Currently, the liquid crystal display (LCD) is widely used in everyday life such as TVs, cellular phones, notebook computers, desktop monitors, and personal digital assistants (PDAs). For the high quality displays, realization of the wide viewing angle (WVA) is a critical requirement. Therefore, various techniques for achieving WVA has been developed and improved so far.

The multi-domain structure is the most viable and powerful solution to realize the WVA of LCD [1]. However, some approaches to achieve multi-domain LC structure (e.g. multi-rubbing, micro-structure etc.) were unattractive in the practical applications because the several bulky processing steps and the long line processing time were often required. Moreover, the stability and durability of the LC's anchoring in those methods were rather small and should be further examined. Therefore, many alternative technologies have been developed to achieve the WVA in LCDs such as IPS (in-plane switching) [2,3] and VA (vertically aligned) modes [4,5]. In particular, patterned vertical alignment (PVA) mode partly achieved WVA-LCD through use of the fringe field to obtain a multi-domain LC configuration. Moreover, for enhancing the WVA characteristics, super-PVA mode [6] which was composed with two TFT in a pixel to produce 8-domains or more and super-IPS mode [7] which included additional electrode were suggested. But they required the additional manufacturing process and the complex driving circuits.

In this work, we demonstrate multi-patterned vertical alignment (MPVA) for enhancing WVA properties very simpe fabrication process. The structure we developed uses multi-patterned electrode geometry for the wide viewing angle characteristics with respect to the conventional PVA mode. The patterned electrode structures had the different chevron angles and consequently we could obtain 8-domain LC alignment.

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2. Experimental

The schematic diagram of our proposed configuration is shown in Fig. 1. Vertically aligned LC layer was inserted between sandwiched glass substrates which has a patterned chevron type electrode. Two crossed polarizers (top and bottom) are placed as its optical easy axis lies at the angle of 0° (top), 90° (bottom), respectively. In our configuration, maximum field-induced LC retardation was designed as λ /2. When we increase an applied voltage, the light is passing through the sample due to the reorientation of LC alignment. Each pixel is divided into two regions where the pixel & the common electrodes are patterned with different chevron angles; half is patterned by 45° and the other half is patterned by 22.5°.

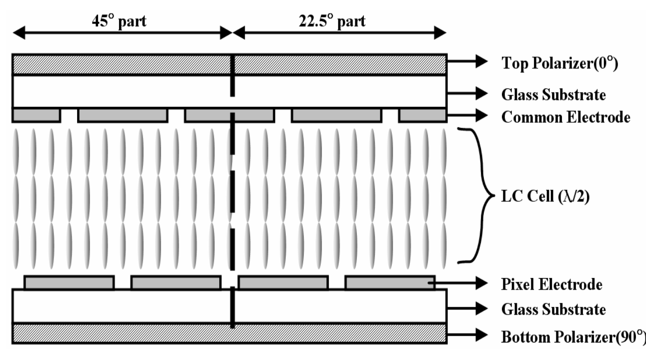

Figure 1. The schematic diagram of suggested MPVA structure.

Figure 2 represents the paths of polarization change of the 45° and 22.5° parts on the Poincare sphere. In the field-on state of the 45° part, the linearly polarized light maintains its polarization state with 90° rotation as the LC layer acts like a $\lambda/2$ wave plate rotated with 45°. So we can get the bright state because polarizers are perpendicular to each other, as shown in Fig. 1. For the field-on state of the 22.5 part, the linearly polarized input rotates 45° by passing through the LC layer as illustrated in the figure. Because of this reason, the bright state of the multi-electrode mode is lower luminance about 25% than the conventional PVA mode. This

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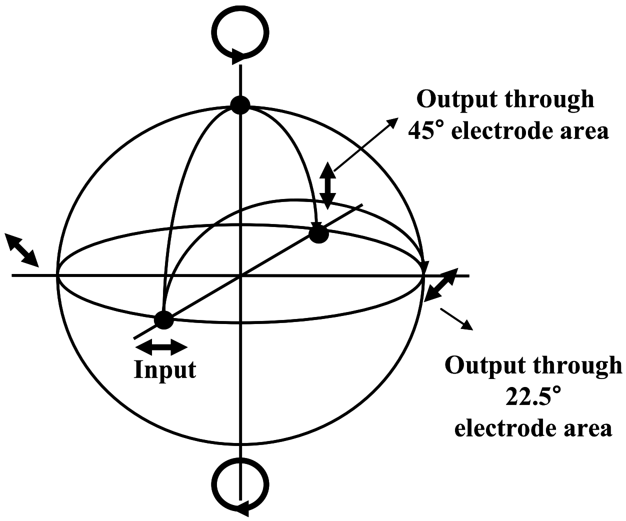


Figure 2. The Poincare sphere representations for the path of the polarized lights in the 45° and 22.5° parts.

reduction of luminance is unavoidable for widening of viewing angle with fixed intensity of input beam.

The multi-patterned LC cell was made using two glass substrates deposited with indium-tin-oxide. To apply fringe electric field, the patterned electrodes made angles of ±45° and ±22.5° with respect to the polarizer. The width of electrode and the distance between electrodes in the 45° part are 100μm and 20μm, respectively. Also, the width and the distance of the 22.5° part are 130μm and 20μm. In order to create a vertical alignment of LCs, we spin-coated commercial homeotropic aligning agent AL1H659 (JSR Co.) on upper and lower substrates and cured at 210°C for 1hour. The cell thickness was maintained by using glass spacers of 3.1μm thick. The nematic LC of MLC6610 (Merck) was injected into the cell by a capillary action at room temperature.

3. Results and Discussion

In order to confirm the viewing angle characteristics of device, we performed numerical calculation of conventional PVA structure and the proposed structure. A simulation was performed by commercial simulation program of TechWiz LCD (Sanayi system, Korea) and an optical calculation was based on the 2 X 2 extended Jones matrix methods [8]. For the simulation of the each mode, two polarizers were set to be perpendicular with each other and we chose device of PVA mode with the electrode width 30μm and the distance of the electrode 10μm. For the suggested structure, 45° part was the same structure at that in normal PVA mode and the electrode width and the distance were 40μm and 10um in 22.5° part, respectively. Also, the cell gap of the modes was 3.1μm. The used nematic LC has the material parameters as follows: the ordinary refractive index n_o = 1.5824, the extraordinary refractive index n_e = 1.4828, the dielectric anisotropy $\Delta\varepsilon = -3.1$, the elastic constants, $K_1 = 14.6 \times 10^{-12}$ N, $K_3 = 16.5 \times 10^{-12}$ N, and the rotational viscosity γ = 148 mPa·sec.

The simulated results of dark state at 0V were exactly same in the typical PVA mode and our structure because they have the same initial state. For evaluating the viewing angle characteristics, we

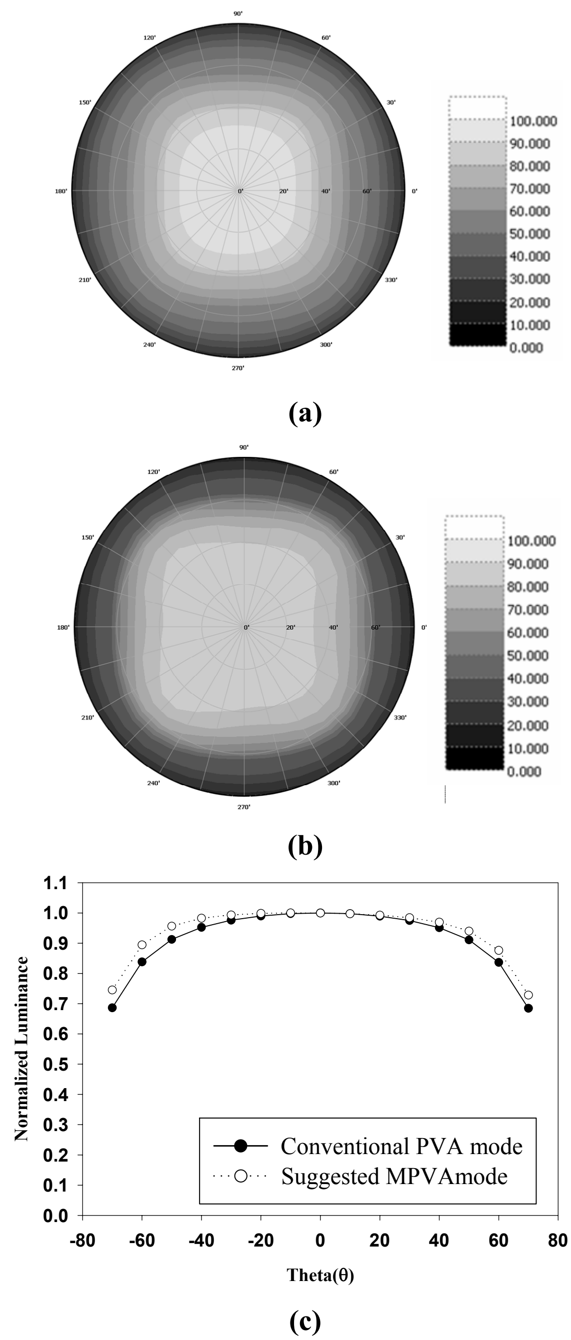


Figure 3. The simulated viewing characteristics of (a) typical PVA mode, suggested MPVA mode and (c) normalized luminance of φ=22.5°.

compared the bright state characteristics for viewing angle in each mode. The Fig. 3(a) and (b) show the calculated viewing angle characteristics in the typical PVA mode and the MPVA mode at 10V (field-on state), respectively. Even if the luminance of suggested MPVA is lower than that of the conventional PVA mode, the viewing angle characteristic is enhanced. To examine the essential characteristics of both parts, we compared the normalized luminance at each mode for azimuthal angle of 45° and

22.5° which are optical axes of multi-domains. For the 45° axis, the luminance between the conventional PVA mode and our MPVA mode are not different. However, the characteristics at the 22.5° axis have some differences, as shown in Fig. 3(c). The luminance differences between θ = 0° and 70° was 31% and 25% for the conventional PVA mode and our MPVA mode, respectively. Since the suggested mode has 8-optical axes by 8-domains from electrode structure, the luminance differences are decreased with respect to 4-domained conventional PVA mode. From calculated results, the multi- electrode mode enhanced the viewing angle properties about 6%.

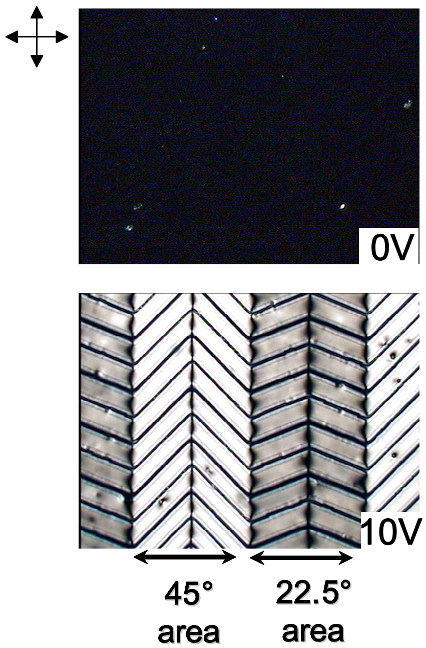


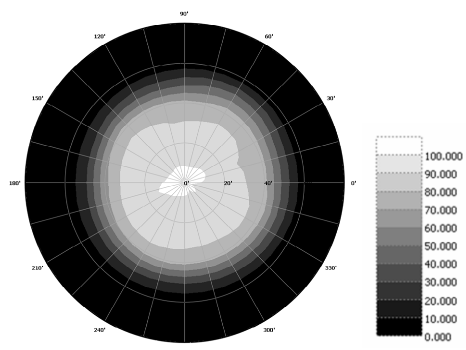
Figure 4. Polarizing microscopic images of MPVA mode at applied voltages of 0 and 10V.

To confirm the simulated results, we made a test sample. Figure 4 shows the microscopic textures of LC sample which have patterned multi-electrode with crossed polarizer (0°, 90°). The cell gap (*d*) was 3.1μm and the LC properties are identical with used one in simulation. The LCs was vertically aligned at the initial state (without voltage application). In the voltage-on states of 10V, the LC molecules were symmetrically reoriented along the fringe electric field. As shown in Fig. 2, the light intensity of the 22.5° area is smaller than it of the 45° area due to the retardation losses. We measured viewing angle characteristics of the typical PVA mode and our test sample, and the results are shown in Fig. 5. These viewing angle characteristics were measured by using DMS900 device (E-Tech Co.). As mentioned at previous part, we worked at the bright state (applied 10V) for the each mode because the initial state of each mode is the same. So, we compared the changes of normalized luminance for azimuthal angles φ of 22.5°. Figure 5(a) shows the luminance of bright state at 10V for the MPVA mode and Fig. 5(b) shows the variation of the normalized luminance at angle θ from 0° to 40°. In the viewing angle of the conventional PVA mode, the luminance was decreased to 42% at tilted angle from 0° to 40° and that in the suggested mode was changed 30%. The MPVA mode enhanced the viewing angle properties about 12%.

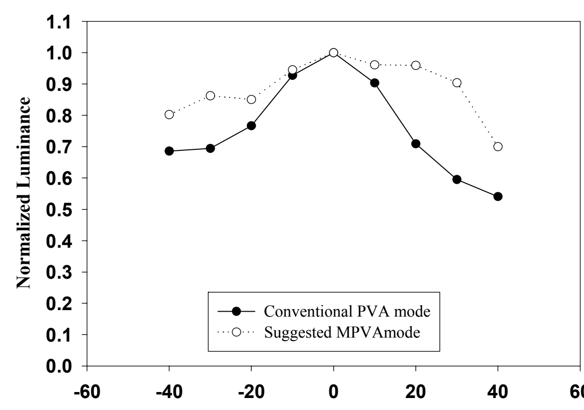
These characteristics have good agreement with simulation results and the enhanced viewing angle characteristics can make better performance LCDs for HDTV application.

4. Conclusion

We have fabricated an enhanced viewing angle LCD with the multi-patterned electrode in a patterned vertically aligned (MPVA) mode. The MPVA showed wider viewing characteristics due to the enhanced 8-domain LC structure than that of the conventional PVA mode. The viewing angle characteristic in our MPVA sample is enhanced by 12% with respect to the conventional PVA sample. Our proposed multi-patterning method is easily applicable for manufacturing process without cumbersome additional process.



(a)



(b)

Figure 5. The measured viewing characteristics of (a) suggested MPVA mode and (b) normalized luminance of φ=22.5°.

5. Acknowledgment

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6. References

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