P-198: Azimuthally Continuous Nematic Domain Mode Using Electrode Structure with Circular Slit

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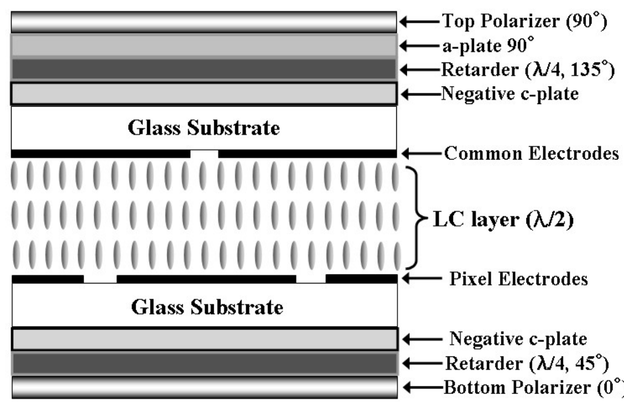
Abstract
We proposed azimuthally continuous nematic domain (ACD) mode characterized by a cone-like- field of patterned electrode with a circular slit. Such an electrode structure avoids the domain defect induced in a turn of chevron type electrode of patterned vertical aligned nematic (PVA) mode. Consequently, this ACD mode has wider viewing and higher transmittance with maintaining the merits of PVA mode. Therefore, we expect that this proposed mode will be applied to various liquid crystal displays.

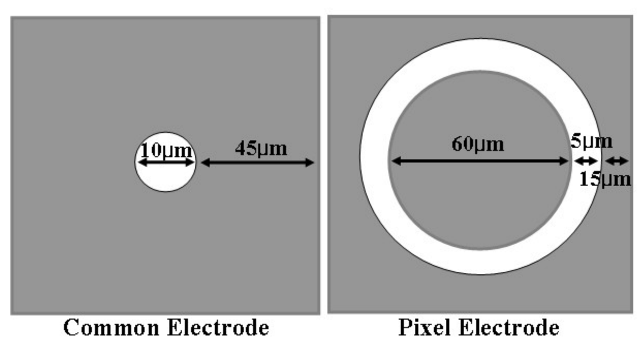
1. Introduction
The market for TFT-LCDs has increased rapidly, in their applications to mobile phones, LC monitors, televisions, etc. owing to their good display performance. However, TFT-LCDs have had the some subjects which should be overcome, to maintain the priority in display market. One of the biggest obstacles for TFT-liquid crystal display (LCD) as the most valuable device in the display market was its narrow and non-uniform viewing angle characteristics [1]. To solve the issues, several technologies have been proposed [2-5]. Among the several proposed LCD modes, vertical aligned (VA) nematic modes with multi-domain LC structure such as patterned VA (PVA) mode, advanced super view (ASV) mode, and multi-domain VA (MVA) mode have been attractive display due to its merits such as low driving voltage and high contrast ratio. PVA and MVA modes characterized by the chevron shape electrode to induce a multi-domain LC structure produce a practical wide viewing angle mode by adopting compensation films. But, the chevron structures in above two modes lead to singular points of LC's behavior at domain boundaries. Such singular points reduce the transmittance of these modes. ASV mode characterized by the continuous pinwheel alignment does not lead to such an optical defect due to azimuthally continuous LC domain. However, its transmittance is very low due to the LC domains aligned along to transmissive axis of polarizer. So, it should use a chiral compound which may be an impurity into the LC to make it possible to constructively utilize optical rotation rather than birefringence to alter the optical characteristics, enabling transmittance to be higher under field on state.

In this work, we propose an azimuthally continuous nematic domain (ACD) mode distinguished by a cone-like-field of patterned electrodes with a circular slit. The proposed mode can be simply constructed by designing the electrode structure through the cost-effective process. This shows optically higher transmittance than PVA or MVA modes by using two optical λ/4 films without any chiral dopant and excellent color characteristics due to azimuthally omnidirectional domains.

2. Cell structure and Operation Principle
Figure 1(a) shows a cross sectional structure of our proposed ACD mode. It is composed of two crossed polarizers, a a-plate, a λ/4 retardation film of which optical axis is 135° with respect to transmissive axis of a bottom polarizer, and a negative c-plate just



(a)



(b)

Figure 1. The schematic diagram of ACD mode: (a) is a cross sectional structure and (b) is the electrode configuration of the circular type

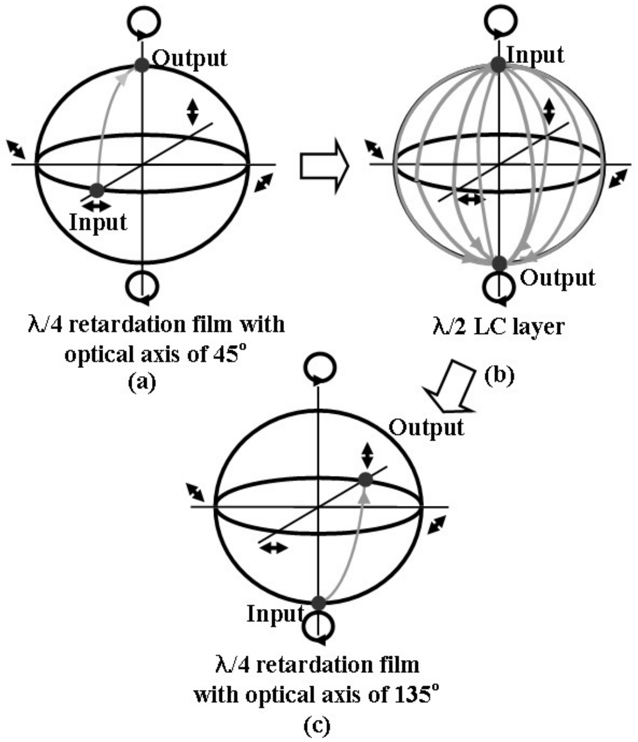


Figure 2. Poincare sphere representation of the optical principle of ACD mode: (a) The polarization path of light passing through the λ /4 retardation film with optical axis of 45°, (b) The polarization path of light passing through the λ /2 LC layer, (c) The polarization path of light passing through the λ /4 retardation film with optical axis of 135°

on the top substrate. And under the bottom substrate, a negative c-plate, a λ/4 retardation film with optical axis of 45°, and bottom polarizer are arranged in order. Since the VA mode was used basically, LC molecules were vertically algned initially and the maximum value of field-induced LC retardation should be λ/2. The electrode configurations of our LC mode are shown in Fig. 1(a). The transparent electrodes were made of indium-tin-oxide (ITO). The common electrode with the 10 μm slit of the circle type was patterned in 100 μm period. The pixel electrode on the bottom substrate was formed as the donut shape with slit of 5μm and patterned in 100 μm period.

Figure 2 illustrates the optical polarization states expressed in each light path of the proposed mode. In initial state with vertical aligned LCs, the linearly polarized light to 0° direction by bottom polarizer become the left-handed circular polarization state after passing through the λ/4 retardation film with optical axis of 45° as shown in Fig. 2(a). In next step passing through LC layer, the polarization of the light is not changed due to LC layer without optical phase retardation, so the light maintains the circular polarization state. In final step passing through the λ/4 retardation film with optical axis of 135°, the polarization state of the light returns to the original state, 0° polarization. Therefore, we can obtain the darkness at vertically aligned initial LC state. On the other hand, when the voltage was applied to electrode, the left-handed circular polarized light after passing through the λ/4 retardation film with optical axis of 45° become the right handed circular polarized state after passing through LC layer with optical phase ratardation of λ/2 as shown in Fig. 2(b). Finally, after passing through the λ/4 retardation film with optical axis of 135°, the light become the linear polarization state to 90° direction as shown in Fig. 2(c). So, we can get the maximum brightness under electric field that produces the effective retardation of λ/2 at LC layer. On basis of this optical principle, we obtain various optical states that can express gray levels as a preferred display.

3. Results and Discussion

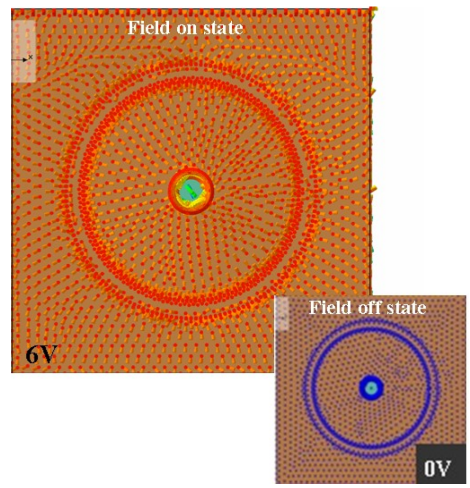


Figure 3. The calculated LC director profiles

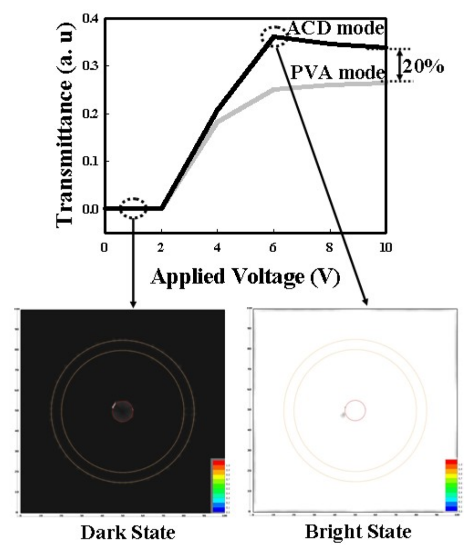


Figure 4. Simulated Electro-Optic characteristics of ACD mode

The simulated LC director profiles are shown in Fig. 3. In the field-off state (0V), LC molecules are aligned vertically. When the voltage applied to the proposed LC mode, LC molecules are rearranged along the field direction by the special electrode structure. The field induced between the common electrode with a slit of the circular shape and the pixel electrode with a slit of the donut shape aligns LC molecules to azimuthally all directions. So, ACD mode does not show any optical defects resulted from the domain boundary observed in PVA mode when applying voltages unlike PVA mode with the electrodes of the chevron shape. Figure 4 shows the simulated electro-optic characteristics of the proposed mode. The simulation was performed by Techwiz LCD (Sanayi System Co.) on the basis of the 2 X 2 extended Jones matrix method as a preferred optical calculation method [8]. Two polarizers are set to be crossed with each other and the cell gap is 3.5 μm. Because LC (MLC 6610, Merck) with the negative dielectric anisotropic ($\Delta\varepsilon$= -3.1 and Δn= +0.099) was used, the direction of the LC molecules under the presence of the applied voltage is perpendicular to electric field direction. We can know that the threshold voltage is about 2V and the driving voltage is below 6V. Moreover, we can confirm that the transmittance of proposed ACD mode is higher than it of the conventional PVA mode with electrode structure of the chevron shape. Figure 5 shows viewing angle characteristics of ACD mode in polar coordinate. We cannot almost see contrast ratio line of 10:1 within limitation of ±80° viewing angle. We also measured the shifts of chromaticity (Figure 6). Figure 6 shows the chromaticity coordinates of our ACD mode with viewing angle varied from 0° to 80°. As shown in Fig. 6, when our ACD mode was turned in the viewing angle range, chromaticity coordinates of white point changed within 0.004, 0.18 in x, y, respectively. In the result, ACD mode shows very excellent optical characteristics such as high transmittance, high contrast ratio, wide viewing angle, and low color shift (Figure 6).

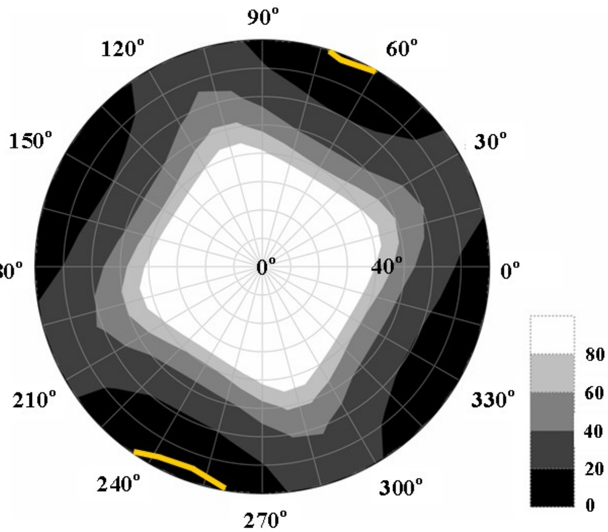


Figure 5. Viewing angle characteristics of our proposed ACD mode

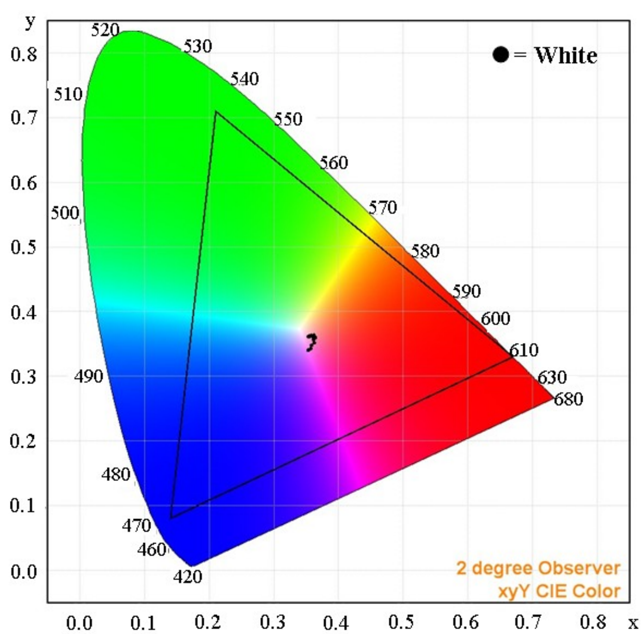


Figure 6. Gonimetric measurements of the chromaticity of our proposed ACD mode

4. Conclusion

We proposed azimuthally continous nematic domain (ACD) mode with a new electrode structure. In the field-on state, LC molecules of the proposed LC mode were rearranged by a cone field produced between the pixel electrode with a slit of a donut shape and the common electrode with a circular slit. This mode did not lose the merits of conventional PVA mode while it had wider viewing angle area and higher transmittance by decreasing the domain walls through using the new electrode structure with the slit of the circular shape.

5. Acknowledgements

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6. References

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