P-191: Reflective LCD Mode of Twisted Liquid Crystal Designed for Low Voltage Driving

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Abstract

We have investigated a reflective type of nematic liquid crystal display (LCD) using 180˚ twisted state configuration in the cell which comprises one polarizer and one optical retardation film. This reflective mode has lower driving voltage as well as sufficient gray. Consequently, proposed reflective LC mode could be suitable for low power consumption with excellent optical image by various gray levels..

1. Introduction

Nematic liquid crystal displays (LCDs) has widely studied due to the low power cost and high quality optical image. Reflective liquid crystal display (LCD) modes have attracted tremendous interest for many display applications which requires low power consumption and high brightness [1-5]. So, various reflective LCD modes have been proposed by many LCD engineers or optics scientists to produce them in LCD industry [6-11]. However, those modes may not achieve a considerable power save as expected, due to the high voltage applied to pixels to switch LCs, even though they don't use a backlight with high power consumption. Thus, reflective types of bistable nematic LCD without any power consumption in a freeze-frame of panel, saving dramatically power consumption have been exhibited as an epoch-making alternative [12]. Application for bistability with two stable states without the field can facilitate also multiplexing capability. However, they have a limitation at expressing various optical images and good color picture because it is very difficult to lead to perfectly various grey levels due to having only two stable states.

In this paper, we propose a reflective type of nematic LCD using the 180˚ twisted state configuration in the π cell which comprises one polarizer and one optical retardation film. This reflective mode has lower driving voltage as well as sufficient gray. We optimized the LC cell parameters by numerical calculation and evaluated the resultant electro-optics (EO) characteristics of the fabricated LC cell. The LC cell structure is shown in Fig. 1.

We use the 180˚ twisted state and the low pre-tilted bend state in π cell. Since the free energy difference between two states is small, it is possible to be operated by low driving voltage. The normal π cell is actually stable in the splay state at the low pre-tilted angle. Thus, the π cell has to be converted to bend state first by applying a critical conversion voltage, then a minimum bias voltage which is needed to maintain the LCD in low pretilted bend state becomes a driving voltage in our reflective mode. When field is off, LCs becomes 180˚ twisted state. The π cell without the chiral dopant has a short twist duration time [12], in this study, we add the small chiral component which has a function of increasing the twist continuation time [13].

2. Experiments

In our process, samples of π cell were assembled with two Indium Tin Oxide (ITO) glass which were sputtered on glass plate. As LC alignment layers, the homogeneous LC alignment, AL3046 (pre-tilt angle ≈ 3°) and JALS-1371 (pre-tilt angle ≈ 7°) supplied from JSR was spin-coated on the ITO glass using the spin coater. LC materials used in our experiment were MLC-3449-000, MLC-6233-000 and MJ00993 supplied from Merck. Each birefringence and dielectric constant are Δn=0.1287 ($\Delta\epsilon$ =16.8), 0.0901 ($\Delta\epsilon$ =4.3)and 0.151 ($\Delta\epsilon$ =11.1), respectively. The d/p ratio was controlled as 0.2 by adding the chiral dopant S-811 from Merk to LC.

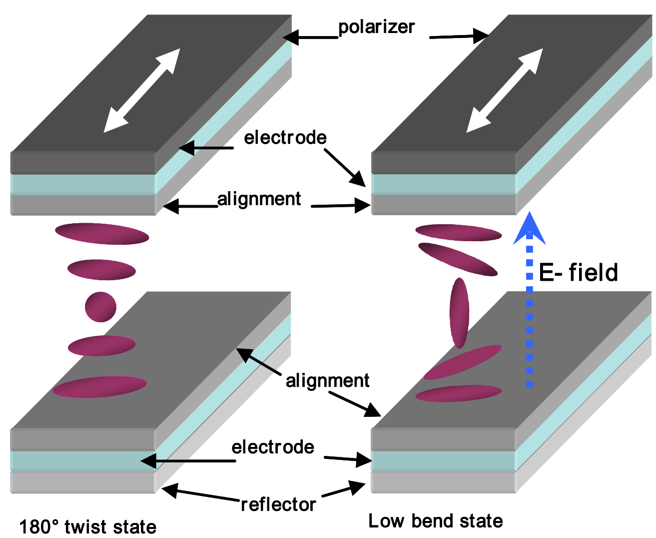

Figure 1. Schematic diagram for reflective LCD mode

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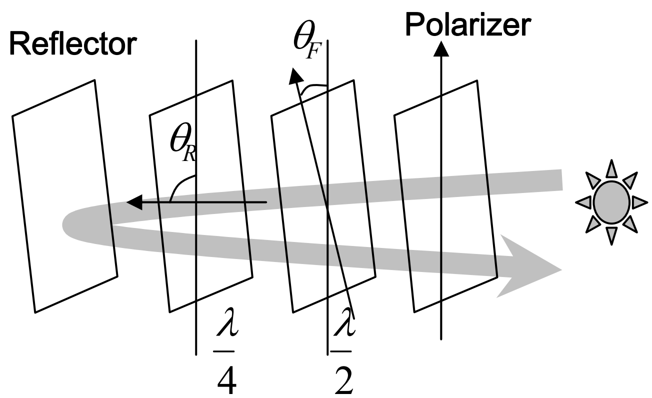

Figure 2. Optical configuration of reflective LCD mode

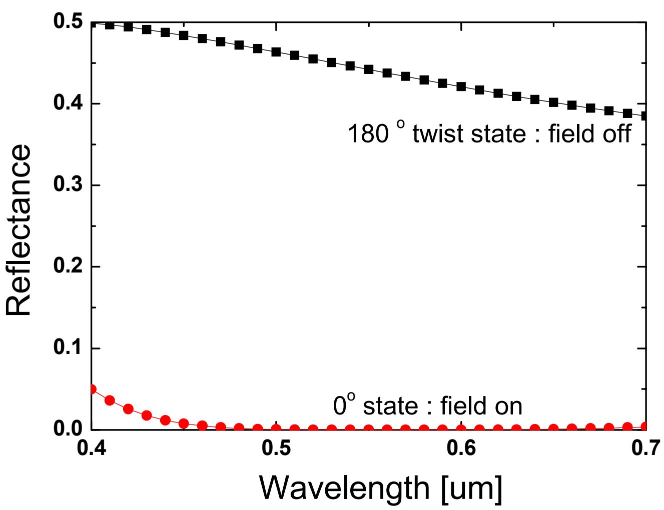

Figure 3. Simulated dispersion characteristics of reflective cell

To inspect the dependency of cell gap, pretilt angle, and chirality of LC relating to lower driving voltage at this reflective mode, we fabricate a set of LC cells with three pretilt angles, three cell gaps, and three d/p.

Figure 2 shows optical configuration of our LC cell. In this experimental setup for measuring the reflectance, the θ_R, which is the angle between the rubbing direction and the optic axis of polarizer and θ_F, which is the angle between the optic axis of film and polarizer are determined by wide band optical condition. Then, θ_F and θ_R are 15° and 75°, respectively. In the result, the proposed LCD structure is composed of one polarizer, one λ/2 film rotated by 15° with respect to the optic axis of polarizer, and each parallel aligned LC on two substrates with polyimide layer rubbed by 75° with respect to the axis of polarizer. As a simple expression about such optical principle, we describe dark and bright states of this reflective type mode through the polarization of light at each layer. When electric field is not applied to the electrodes, the light with linear polarization of 0° direction by the polarizer becomes linear polarized light rotated by 30° after passing through λ /2 retardation film layer with the optic axis of 15°. After passing twice 180° twisted LC layer by the reflector, it becomes nearly 30°- linearly polarized light again via elliptical polarization. Finally, λ /2 retardation film layer undo it as the 0°-linearly polarized light. Then, therefore, we can obtain a good bright state. When a vertical electric field is applied to the LC cell, LC layer becomes non-twisted state having comparatively high tilt angle. In this case, the light with linear polarization of 0° direction by the polarizer becomes linear polarized light rotated by 30° after passing through λ /2 retardation film layer having the optic axis of 15°. After passing twice the LC layer of λ /4 retardation with the optic axis of 75° by the reflector, it becomes 120°-linearly polarized light. Finally, the λ /2 retardation film layer is rotated by 30° and then, the light becomes 90°-linearly polarized light. Consequently, we can get a good dark state Figure 3 shows spectrum characteristics simulated at above optical configuration. It exhibits good dispersion properties in an entire visible range at dark and bright states as expected.

3. Results

In order to reduce driving voltage at this reflective type LC cell, we examine several parameters relating to driving voltage of this mode. First we consider cell gap dependency, which is one of the most crucial parameters at electro-optic characteristics of LC cells. Figure 4 shows the measured electro-optic characteristics, namely, the reflectance defined as a function of voltage, when the cell gaps of LC cells are 3.4㎛, 2.5㎛ and 2.0㎛, respectively. In this case, LCs of which electrical anisotropy, Δε is almost same were used. In result, the driving voltage at which the retardation of LC cell becomes λ /4 to achieve a dark state was 1.7 V in cell gap of 2.5 ㎛, while it was 2.1 V in cell gap of 3.4 ㎛ and 1.6 V in cell gap of 2.0㎛. As we expected, this result shows a cell gap dependency which indicates that the driving voltage decreases at lower cell gap influenced by stronger electric field. So we know

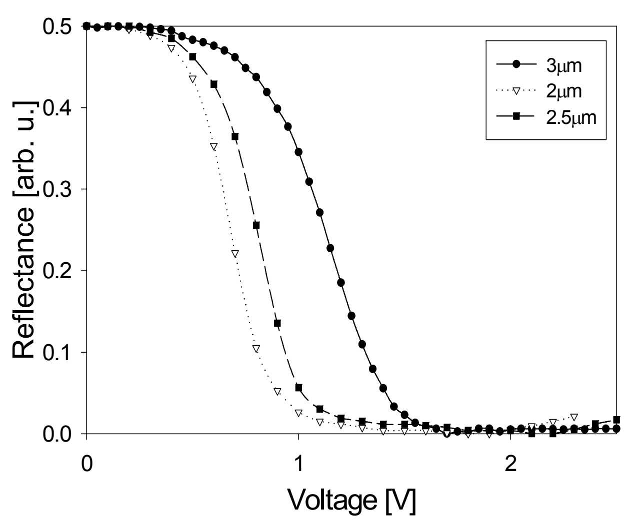

Figure 4. Measured EO characteristics of our π cell. Each curve denotes the experimental data of the reflectance depending on the cell gap, respectively.

that lower LC driving can be achieved by appropriate combination of cell gap and LC.

As another LC cell parameter for decreasing the driving voltage, we consider the pretilt angle of LC, which is also one of the most important factors at electro-optic characteristics of LC cells. In this case, cell gap and electric anisotropy are fixed with 2㎛ and 11.1. Figure 5 shows EO characteristics with pretilt angles of LC which were controlled by each alignment layers. Saturation voltages of each pretilt angle have 1.5V at the pretilt of 20°, 1.65V at the pretilt of 7° and 1.8V at the pretilt of 3°, respectively. Here, the pretilt of 20° was produced by a mixture of a proper homogeneous LC alignment component and another proper homeotropic LC alignment component. To lead to uniform pretilt angle at whole cell area, the mixture was mingled evenly by magnetic bar acted on iron plate producing magnetic field at room temperature for one day. The determination of the pretilt angle was obtained from the general crystal rotation method and the transmittance fitting corresponding to each rotation angle. As we expected, this result indicates an LC pretilt angle dependency which shows that the driving voltage decreases at higher LC pretilt angle more easily acted by electric field. So we know also that lower LC driving can be achieved by appropriate combination of pretilt angle and LC component.

As an additional LC cell parameter for decreasing the driving voltage, we consider the chiral twist power of LC, which is also one of the most important factors at electro-optic characteristics of LC cells. In this case, LC pretilt angle and LC cell gap was fixed with 7° and 2.8㎛. We measured each reflectance of the cells which were classified by the different d/p (0.25, 0.15 and no chiral dopant). Figure 6 shows the result of the experimental data of the reflectance. The EO characteristics of LC cells with d/p ratios of 0.15 and 0.25 are very similar to each other as getting the driving voltage of 2.5 V. On the other hand, the LC cell with no-chiral dopant shows the lower driving voltage, 1.75 V. As we expected, this result indicates an LC chiral twist power dependency which shows that the driving voltage decreases at lower chiral dopant moving to vertical direction easily by electric field. So we know also that lower LC driving can be achieved by appropriate combination of a chiral dopant and LC component.

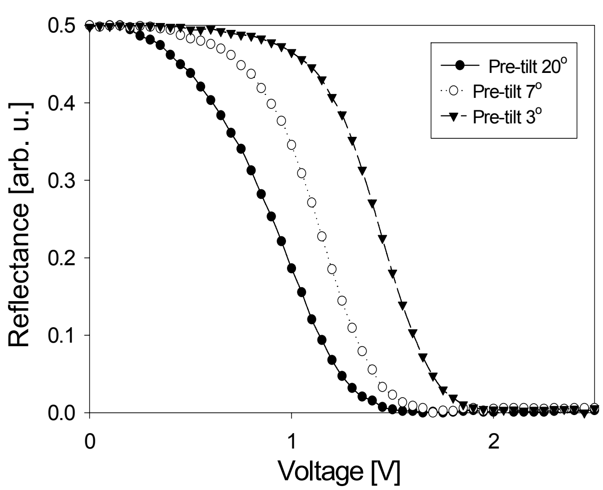

Figure 5. Measured EO characteristics of the π cell. Each curve denotes the experimental data of the reflectance depending on pretilt, respectively.

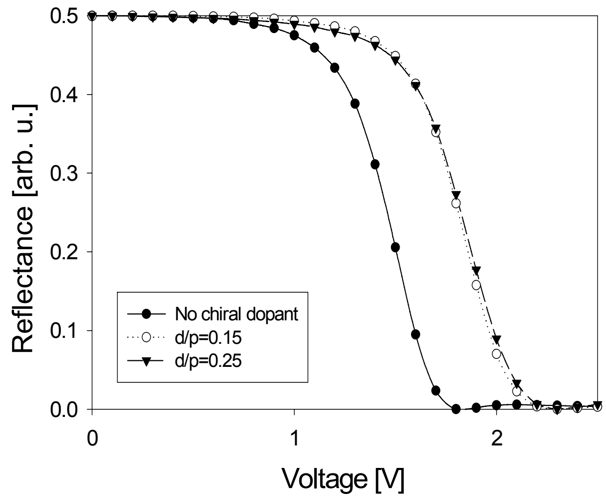

Figure 6. Measured EO characteristics of reflective cell. Each curve denotes the experimental data of the reflectance depending on the chiral dopant, respectively.

4. Conclusion

We proposed a reflective type of nematic LCD using 180° twisted state configuration in π cell. This reflective mode has lower driving voltage as well as various gray levels. Therefore, the proposed reflective LC mode is suitable for low power consumption with excellent optical image in various gray. In our limited experiment, we could obtain lower driving voltage under lower cell gap, higher pretilt angle, and smaller chiral dopant. We believe that lower voltage driving can be achieved by optimizing cell parameters of this reflective mode.

5. Acknowledgement

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6. References

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