A Single Low Twisted Nematic Mode for a Transflective LCD with a Self-Integrated Retardation Layer

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Abstract

We have developed a transflective liquid crystal display (LCD) with a single cell gap and a low twisted nematic (LTN) mode in combination with a self-integrated retardation layer. The retardation layer was made of UV curable liquid crystalline material in one step of photo masking process and has both the homeotropic and the planar parts. The proposed transflective configuration has advantages in a simple fabrication process, and the possibility for a single driving scheme due to the similarity between the transmittance and the reflectance.

1. Introduction

Reflective liquid crystal displays (LCDs) was used for the mobile applications because of light-weight and low power consumption. However, in dark environments, the reflective LCDs do not have good image quality. Therefore, the transflective liquid crystal display (LCD) has begun to be applied to the mobile applications because of their superior performances in both indoor and outdoor environments. The pixels of transflective LCDs are generally divided into transmissive and reflective subpixels. The multi gap structures [1,2] were widely used to compensate the optical path difference between two subpixels. Recently, new configurations of transflective LCDs having a single cell gaps and two different modes [3] and a single cell gap and a single LC mode [4,5] were reported to overcome the complex fabrication process of the multi gap design. For the transflective LCD having a single cell gap and a single LC mode, the additional fabrication processes are needed due to the patterned retardation layers. In this work, we proposed a configuration of transflective LCD [5] and a simple fabrication process for the photo-patterned retardation layer by applying a photoalignment technique [6]. The transmittance and reflectance of proposed LCD were quite similar to each other.

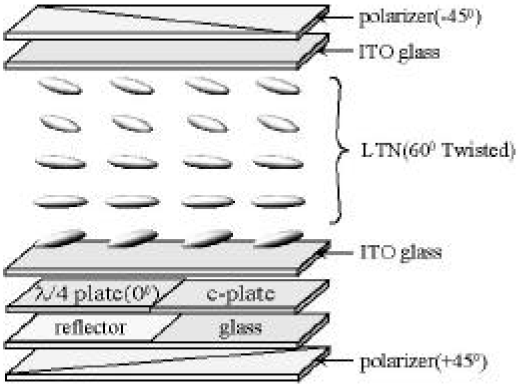
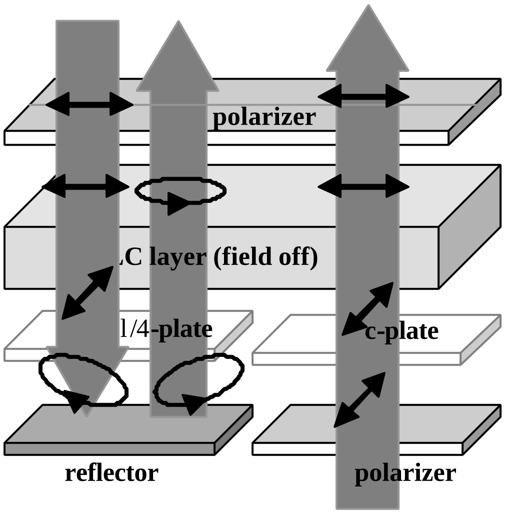


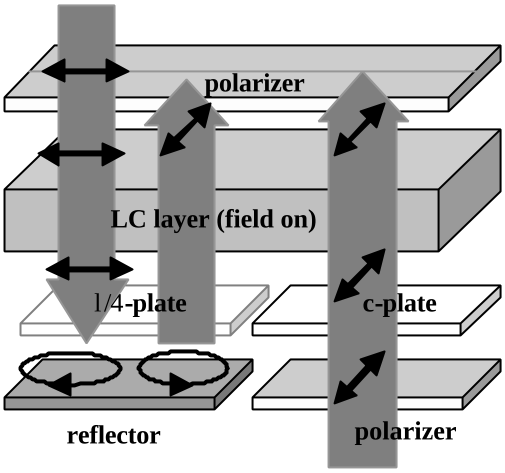
Fig. 1. The structure of our transflective LCD

2. Operation Principle

The structure of our transflective LCD is shown in Fig. 1. The configuration of LC is low-twisted nematic mode with the twist angle of 60^{O}. The optic axes of the front and back polarizers are aligned perpendicular to each other. The retardation layer has both the quarter wave plate and c-plate. The operation principle of our transflective LCD is described in Fig. 2. In the transmissive part, an input light from a backlight unit is converted into a linearly polarized light by a back polarizer. The linearly polarized light passes through the c-plate without experiencing any optical retardation. The polarization state of the input light is rotated through the LTN layer in the field-off state, and the light is then transmitted through the front polarizer. Under an applied voltage, the wave guiding effect becomes disturbed. Above a certain saturation voltage, the LTN layer produces no optical retardation. The linearly polarized state of an input light is changed and blocked by the front polarizer. In the reflective part, an input light from the front panel is converted into a linearly polarized light. The

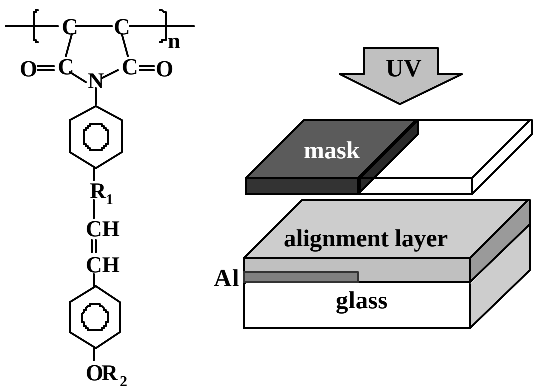


Off state (Bright)



On state (Dark)

Fig. 2. The operation principle of our transflective LCD



(a) (b)

Fig. 3. (a) The structure of photo-polymer and (b) the UV exposure scheme

polarization state of the input light is rotated through the LTN layer. In our configuration, the output polarization direction and the optic axis of a quarter wave plate are not parallel. Therefore, the outcoming light emerging from the quarter wave plate is elliptically polarized. The phase of light is changed by π due to the reflector. Moreover, the outcoming light is guided in the LTN layer and is transmitted through the front polarizer. Accordingly, a bright state is obtained under no applied voltage. Above a certain saturation voltage, the LTN layer produces no optical retardation. In this case, the polarization of the input undergoes only λ/2 of the optical retardation due to the quarter wave plate and the reflector. Thus, the outcoming light is blocked by the front polarizer and a dark state is obtained.

3. Experiments

The transflective LC cell was made using two glass substrates deposited with indium-tin-oxide (ITO). The polyimide of AL1051 (Japan Synthetic Rubber Co., Japan) was coated onto the ITO and thermally treated at 200°C for 1 hour. The polyimide film was rubbed unidirectionally to produce uniform planar alignment. The two substrates were assembled to make an angle of 60° between two rubbing directions. The cell thickness was maintained using glass spacers of 1.8μm thick. The MLC6012 (Merck) doped with S-811 was injected into the cell by capillary action at room temperature. For the fabrication of the patterned retardation layer, UV curable liquid crystalline material LC242 (BASF) was used. The reflector used in this study has two regions, transmissive and reflective parts. Aluminum (Al) was deposited on the reflective part of the substrate. A photo-reactive polymer having the structure shown in Fig. 3 (a) was coated onto the reflector and baked at 150°C for 30 minute. The linearly polarized UV was irradiated on the photopolymer with a photomask as shown in Fig. 3 (b). The irradiated UV energy was about 5 J/cm^2. The UV curable liquid crystalline material dissolved in chloroform was spin-coated on the photo-patterned polymer and cured by an additional UV irradiation at 20mW/cm^2 for 10 minute. The reflector was attached

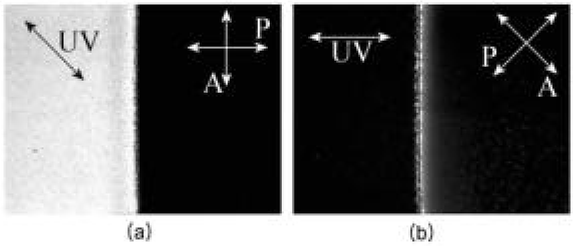


Fig.4. The photographs of patterned retardation layer.

on one side of the LTN cell and two polarizers were attached to outer sides of the LTN cell.

4. Results and Discusstion

We performed numerical simulations to design the optical configuration of our transflective LC cells and to obtain the EO characteristics within the extended 2×2 Jones matrix formalism [7]. The material parameters used for numerical simulations were the elastic constants, $K_1 = 11.6\times10^{-12}$ N, $K_2 = 5.5\times10^{-12}$ N, $K_3 = 16.1\times10^{-12}$ N, the ordinary refractive index $n_o = 1.4620+5682/\lambda^2$, the extraordinary refractive index $n_e = 1.5525+9523/\lambda^2$, the dielectric anisotropy $\varepsilon_a = 8.2$, and the rotational viscosity $\gamma_1 = 0.192$ Pa · sec. Here, λ is the wavelength of the incident light in nm. The effects of the twist angle and the cell gap on the EO characteristics were reported previously [8]. Based on the numerical results, the cell gap of 1.8 μm and the twist angle of 60° were selected to obtain the optimized EO characteristics.

We used the cell gap of 1.8 μm thick. The gap is much smaller than that for the first minimum, 3.4 μm, by the Gooch-Tarry criterion [9] of $\sqrt{3}\lambda\phi/\pi\Delta n$ where λ, ϕ and Δn are the wavelength of the incident light, the phase retardation, and the birefringence, respectively. In this relatively thin geometry, our transflective LC cell shares some common features with the mixed-mode TN mode with a relatively low twist of 45° [10] where polarization guiding effect and the optical retardation are used for reflective-type applications. In our case, the twist angle is optimized for both the reflective and transmissive parts and only the guiding effect is considered.

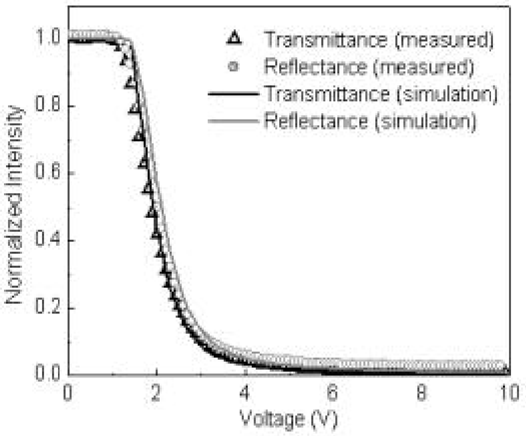


Fig. 5. The EO characteristics of our transflective LTN cell. Open symbols and lines represent the experimental results and numerical simulations, respectively

For fabricating a patterned retardation layer, a photopolymer having a photoreactive side chain was used as an alignment layer for the UV curable liquid crystalline material. As shown in Fig. 3 (a), the photoactive group is attached to the polymaleimide backbone. As an alignment layer, this polymer induces homeotropic and planar LC alignment in the unexposed and the UV exposed areas, respectively. As shown in Fig. 3 (b), the UV light was illuminated on the photopolymer with a photomask. The UV curable liquid crystalline material was coated on the patterned layer and photocured by an additional UV exposure. The photo-patterns on the photopolymer were transferred to the crosslinked nematic liquid crystalline networks. As a result, the retarder having both the homeotropic and planar alignment was produced as shown in Fig. 4. The homeotropic part shows a dark state in any direction of the optic axis. On the other hand, the planar part shows a dark or a bright state depending on the direction of the polarizer. The measured optical retardations were 1.6 and 0.1 in the homeotropic and planar parts, respectively.

Fig. 5 shows the experimental EO results and numerical simulations for the 60°-TN transflective cell as a function of the applied voltage. The transmissive and reflective intensities were normalized to examine the essential features of the EO responses in both the transmissive and reflective parts. The open symbols and the lines represent the experimental results and the numerical simulations,

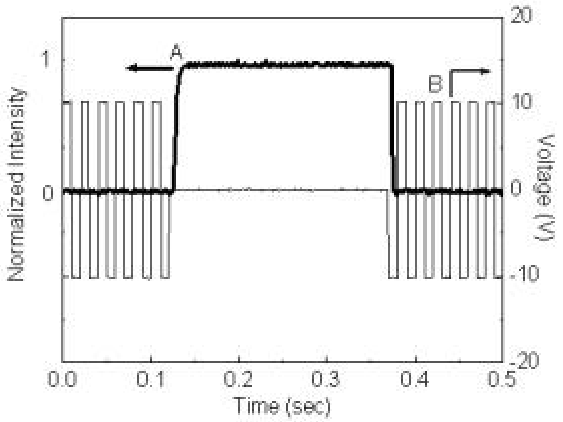


Fig. 6. The EO response times of our transflective LC cell. The lines A and B are the normalized EO response and the pulse input, respectively.

respectively. As shown in Fig. 5, it is clear that the EO characteristics of the transmissive and the reflective parts were similar to each other. This similarity has origin in our configuration and the polarization guiding effect of the LTN layer with the twist of 60°. In a single cell gap and a single LC mode, the threshold voltages and the response times of the transmissive and reflective parts are apodictically identical to each other. Moreover, we can reduce the difference in electro-optic characteristics between the transmittance and the reflectance by using a LTN configuration. In our proposed transflective LCD, the optical path of the input light in the reflective part is twice larger than that in the transmissive part. This is not possible if the optical retardation effect of the LC layer is involved. In our case, a single driving scheme can be employed to operate the device. The measured EO response times are shown in Fig. 6. The rising and falling times were found to be 5.8 msec and 0.8 msec, respectively. The switching times are fast enough for video-rate applications

5. Concluding Remarks

We have proposed a new design of transflective LCD in a single LTN configuration and a simple fabrication method of a retardation layer. The retardation layer was fabricated by one step of photo-patterning. The EO characteristics of the transmissive and the reflective parts were fould to be quite similar, and thus a single driving scheme can be used. The new design of our transflective LCD and the fabrication method of the patterned retardation layer are useful for mobile LCD applications.

6. Acknowledgements

This work was supported by Samsung SDI-Seoul National University Display Innovation Program.

7. References

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