Transflective liquid crystal display with single cell gap and simple structure

Miyoung Kim[1], Young Jin Lim, Eun Jeong, Mi Hyung Chin, Jin Ho Kim, Anoop Kumar Srivastava and Seung Hee Lee[1]
[1]Polymer BIN Fusion Research Center, Department of Polymer-Nano Science and Technology, Chonbuk National University, Chonju, Chonbuk 561-756, Korea
Phone: +82-63-270-2343, E-mail: lsh1@chonbuk.ac.kr

Keywords : transflective liquid crystal display, single cell gap, wire grid polarizer

Abstract

This work reports the simple fabrication of the single cell gap transflective liquid crystal display (LCD) using wire grid polarizer. The nano sized wire grid polarizer was patterned on common electrode itself, on the reflective part of FFS (Fringe field switching) mode whereas the common electrode was unpatterned at transmissive part. However, this structure didn't show single gamma curve, so we further improved the device by patterning the common electrode at transmissive part. As a result, V-T curve of proposed structure shows single gamma curve. Such a dev ice structure is free from in-cell retarder, compensation film and reflector and furthermore it is very thin and easy to fabricate.

1. Introduction

Transflective liquid crystal display has attracted considerable attention because of its adequate visibility under the sunlight. Recently, several studies on the display characteristics of homogenous cells with compensation film driven by in-plane switching (named IPS) [1],[2] and driven by fringe-electric field have been reported. The performance of fringe-field switching (FFS) [3],[4] mode was found to be better than IPS mode as FFS mode shows high transmittance and wide viewing angle. Transflective LCD using wire grid polarizer at reflective (R) part was reported by Ge *et al.* [5], in which wire grid polarizer and electrode were used separately. Therefore this method increases thickness due to additional wire grid polarizer layer and also having a complicated cell structure.

In order to solve this problem, we are proposing, the nano sized wire grid polarizer, which is patterned on common electrode itself. The wire grid polarizer plays the role of electrode as well as reflector. The detailed electro-optic characteristics of proposed device have also been discussed.

2. Cell structure and Simulation Conditions

Figure 1 shows the simple cell structure of the transflective liquid crystal display with single cell gap. The width (w') of pixel electrode and distance (l) between them are 3 ㎛ and 4.5 ㎛ respectively. LC molecules in the cell are homogeneously aligned and the array electrode, which consists of pixel and nano sized counter electrodes, exists at the bottom substrate. Two polarizers are crossed to each other and an optic axis of the LC director coincides with one of the polarizer axis as shown in Figure 1(a) whereas the enlarged nano-sized wire grid polarizer is shown in Figure 1(b).

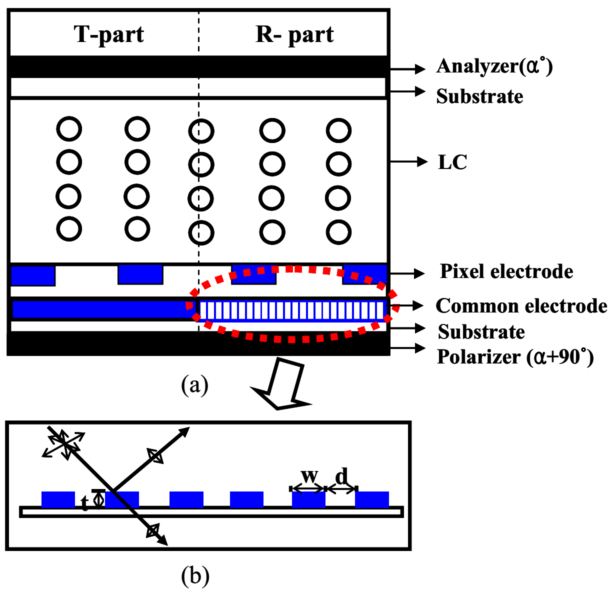
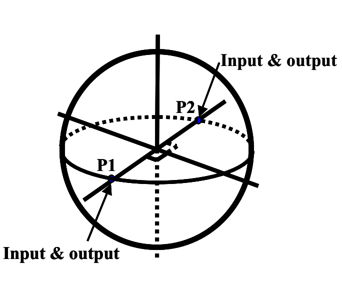


Fig. 1. (a) Simple cell structure of the transflective liquid crystal display (b) Enlarge view of wire grid polarizer at reflective part of common electrode.

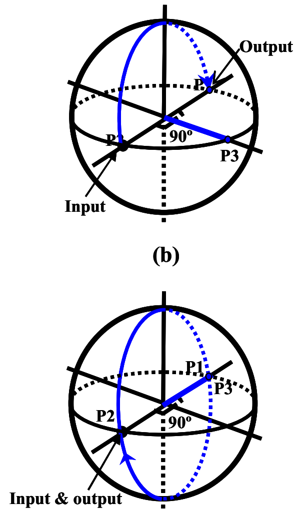
The thickness (t) of wire grid polarizer is ~50-500 nm range and the wire grid polarizer was grooved into 0.3 nm width (w) and 0.7 nm length (d) such that the summation of width and length is equal to one. If an unpolarized light enters on wire grid, the light component of electric field vector, parallel to the wire grid will be fully reflected by the wire grid polarizer [6]. For the calculations, the LCD master (Shintech, Japan) was used for the calculations. The LC with physical parameters, such as a dielectric anisotropy $\Delta\varepsilon$ = 8.2, and elastic constants K_1 = 9.7, pN, K_2 = 5.2, pN, and K_3 =13.3 pN were used, and the surface tilt angle of the LC was 2° with an angle, α, of 75° with respect to the horizontal component of the fringe-electric field. Here, a 2 X 2 extended Jones matrix was used to calculate the R and T [7].

3. Results and discussion

Figure 2 shows the polarization path on the Poincare sphere. P1 and P2 indicate the polarizer and analyzer respectively. In the R part of voltage off-state, the linearly polarized light comes through the analyzer and propagates along the slow axis of the liquid crystal director without changing its polarization state. This linearly polarized light transmitted through the wire grid polarizer. As a result, the light was absorbed by the polarizer and thus the R part appears black. In the transmissive (T) part of the voltage-off state, the linearly polarized light comes through the polarizer and then passes through liquid crystal layer without changing the polarization state. Thus it is blocked by the analyzer, showing a dark state. With above light path, the device is realized, normally black mode in both R and T parts, as shown in figure 2(a). It has been expressed by black spot on the Poincare sphere. In the presence of an electric field, all of the R and T parts are designed for an average twist angle of nearly 45°, therefore maximal reflectance and transmittance can be achieved as it can rotate the linearly polarized light by 90°, in the R and T parts, as shown in figure 2 (b)~(c).



(a)



(c)

Fig. 2. Polarization path on the Poincare sphere (a) dark state of FFS cell (b) polarization path of transmissive part with white state (c) polarization path of reflective part with white state

Figure 3 shows the maximal reflectance (R_{max}) and transmittance (T_{max}) as a function of $d\Delta n$. As indicated in Fig. 3, the reflectance and transmittance are almost constant and they were ~27% and ~30%, respectively with varying $d\Delta n$ values. In addition, the operating voltages (V_{op}) for all of the R parts and T parts are increased from ~ 3.5 V to 4.4 V, with increase in the $d\Delta n$ from 0.36 to 0.44 ㎛. The optimized cell retardation value of 0.42 ㎛ have been taken for analyzing the maximization of the light efficiency.

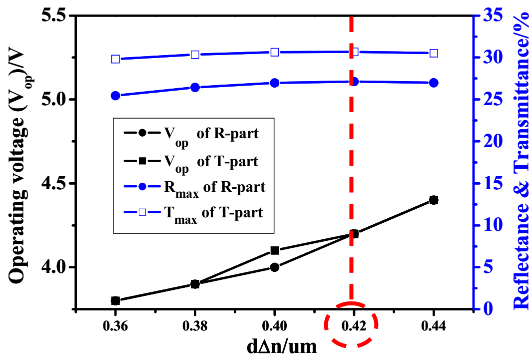


Fig. 3. Maximum reflectance, transmittance and operation voltages of each area as a function of dΔn.

With these cell parameters, we calculated a voltage-dependent reflectance and transmittance, (See Figure. 4). Unfortunately, two curves do not coincide with each other. Threshold voltage (V_{th}) of transmissive part is lower than V_{th} of reflective part. It is due to electric field of transmissive part is higher than electric field of reflective part. Hence further optimization is required to match both the curves so that it can be used as a single driving circuit.

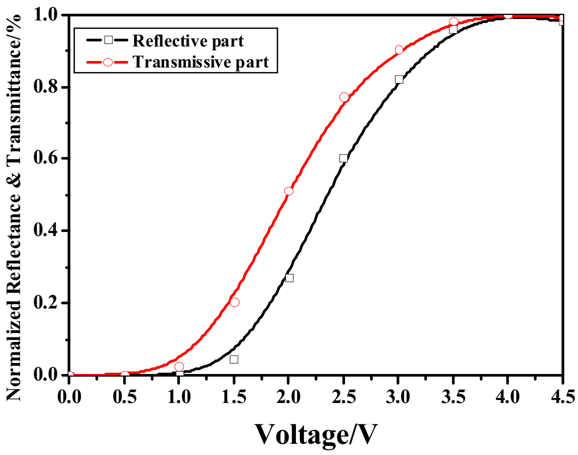


Fig. 4. Normalized voltage-dependent reflectance and transmittance curves

In order to achieve a single gamma curve, the electric field at the T part is required to be reduced. Hence we improved the proposed device by patterning the common electrode [7] at the T part as shown in Fig. 5.

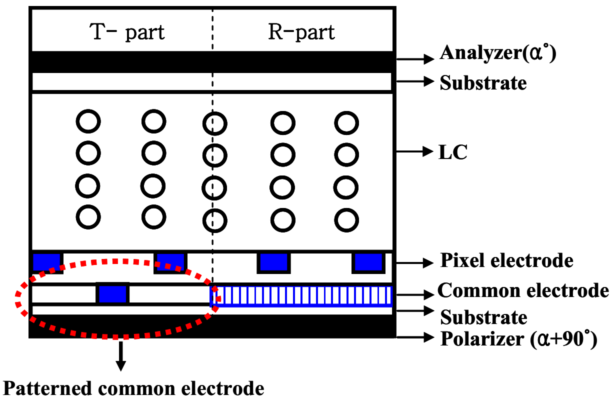


Fig. 5. Cell structure of FFS mode with patterned common electrode

We investigated the V-T characteristic of the device by changing the length of patterned electrode from 6 to 3 ㎛ while keeping the width of patterned electrode at 3 ㎛ at T part (See Fig. 6). The width and length of pixel electrode were same as mentioned before. The V-T and V-R curves do not show single gamma curve if *l* is equal to 4 ㎛ or 6 ㎛. However they coincide each other and show single gamma curve for l=3 ㎛.

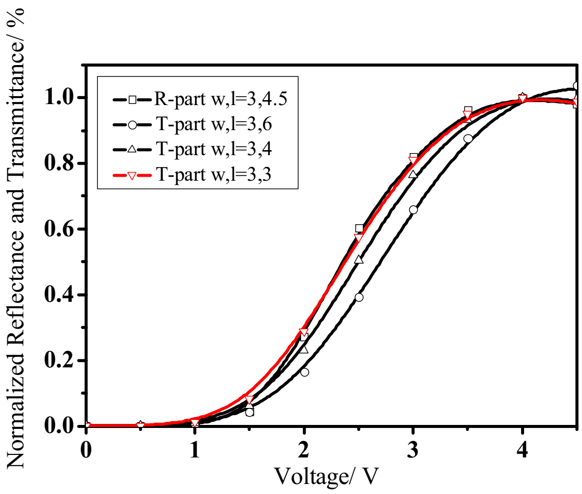


Fig. 6. Normalized voltage-dependent reflectance and transmittance curves as a function of different *l*.

4. Summary

In summary, the simple structure of the single cell gap transflective liquid crystal display (TRLCD) using wire grid polarizer in R-part has been reported. However, the V-R and V-T characteristics of proposed device did show single gamma curve. To obtain single gamma curve, we proposed improved cell structure with patterned common electrode in the T-part. The improved device show single gamma curve at particular length and width of 3 ㎛ at T part. The proposed device has simple and thin cell structure which does not require any in-cell retarder, compensation film and reflector.

5. Acknowledgements

This research was financially supported by the Ministry of Commerce, Industry and Energy (MOCIE) and Korea Industrial Technology

Foundation (KOTEF) through the Human Resource Training for Regional Innovation.

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