Viewing angle switching of Fringe-Field Switching (FFS) Liquid Crystal Display by Optimizing Pixel Structure

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Abstract

This Viewing angle control of fringe-field switching (FFS)-LCD using only one panel has been investigated. Viewing angle switching cell is composed of main- and sub-pixel, in which the former has a role of image expression and the latter has a role of viewing angle switching.

1. Introduction

A wide viewing angle is a main issue for liquid crystal displays LCD in the flat-panel display market because LCD has badly viewing angle characteristics due to anisotropic property of Liquid crystal. So its viewing characteristics depend strongly on the specific LC modes such as twisted nematic (TN) [1], vertical alignment (VA) [2], in-plane switching (IPS) [3], fringe-field switching (FFS) [4]. Several technologies have been developed to increase the viewing angle of LCDs.

Nowadays, as increasing the range of use for portable displays such as notebook computers, mobile phones, personal digital assistants, and tablet personal computers, display contents have been exposed to many people around or one person. So information on display has to be under the protection according to important degree of information or user's willing. Therefore, viewing angle switching display based on such concept is needed. Recently, several viewing angle switching displays which can controllable viewing angle have been studied and developed. [5-10] Most of viewing angle switching displays are composed of two cells or three polarizers. However, these displays have increase in thickness and cost and power consumption which is not proper to portable display. In this paper, we propose a new structure of viewing angle controllable LCD with one panel of FFS-mode, which has wide viewing angle characteristics.

2. Configuration and switching principle

In the proposed device, viewing angle switching FFS cell is composed of main- and sub-pixel in which the former has general FFS electrode structure and the latter has its common electrode that is additionally patterned partly on the upper substrate as shown in Figure 1.

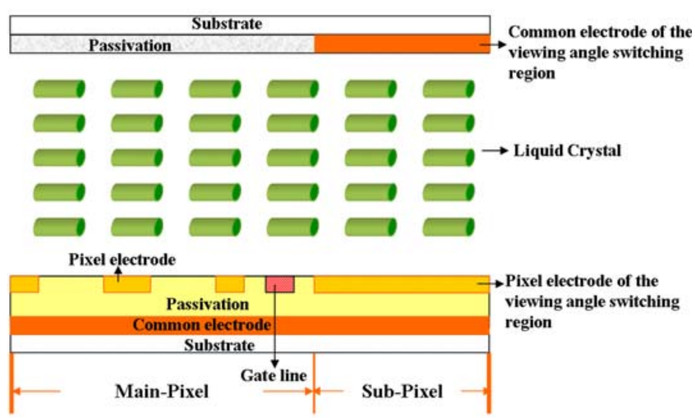

Fig. 1. Electrode structure of the controllable viewing angle FFS-LCD

Before applying voltage to the sub pixel, the device show wide viewing angle like that in the normal FFS mode, however, when the enough voltage is applied to the sub-pixel, the device becomes a narrow viewing angle. In the main-pixel, the LC rotates in plain by fringe-field and then white state is obtained. In the sub-pixel, the LC director tilts up in vertical direction due to vertical electric field, causing a light leakage in oblique viewing directions.

3. Results and discussion

In the FFS mode, the transmittance is proportional to $sin^2(2\ \psi(V))\ sin^2(\pi\ d\ \Delta n_{eff}(V)\ /\ \lambda)$, where Ψ is an angle between polarizer and LC director, dΔn is a voltage and viewing-angle dependent cell retardation value, and λ is an incident wavelength.

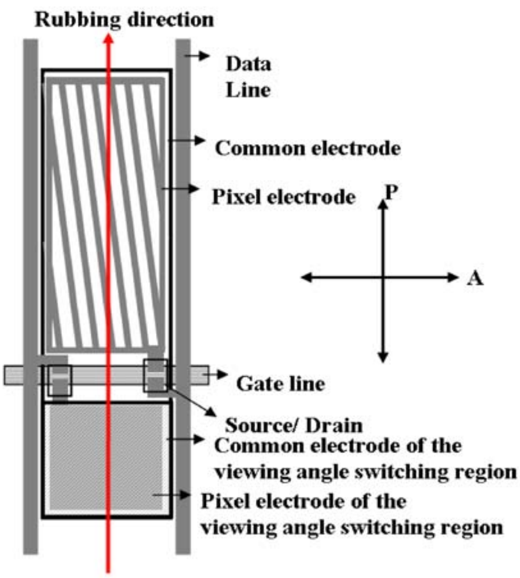

Fig. 2. Electrode structure of the controllable viewing angle FFS-LCD in the top view

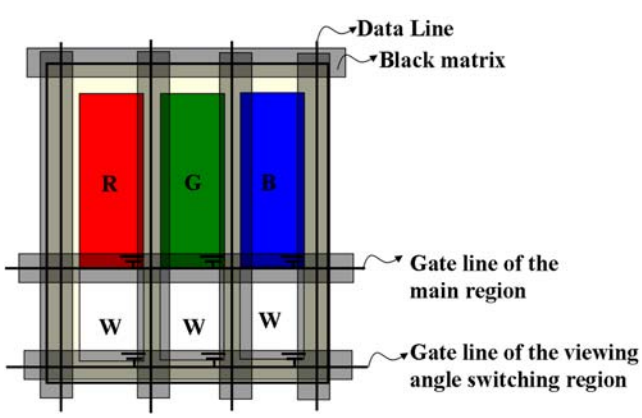

Fig. 3. Arrangement of color filter corresponding to Fig. 2.

Figure 2 shows electrode structure of controllable viewing angle FFS-LCD in the top view. Controllable viewing angle LCD is divided by main pixel for image expression and the extra pixel for viewing angle control. Here, two pixels are controlled by two data lines and one gate line. In the main pixel, the LC rotates by 45° by fringe-field and then white state is obtained. In the extra pixel, the LC director tilts up in vertical directions due to additionally patterned part of upper substrate such that there is no angle of Ψ. Therefore, in the extra pixel, although the LC director tilts up, the transmittance is not generated; however, the degree of tilt angle can be controlled by an applied voltage.

Figure 3 shows an arrangement of color filter in electrode structure of the figure 2. The main pixel is composed of red, green, and blue color filter and the extra pixel has a transparent resin. To achieve a narrow viewing angle for image protection, the LC director in the extra pixel tilts down but the degree of tilting can be adjustable along the pixels. In this way, when the LC tilts down, the image quality at normal direction is not changed but due to tilted LC, the light leakage in oblique viewing directions is generated due to mismatch of retardation between the LC and the compensation film. Using this light leakage, any type of information such as characters and image can be generated. This generates extra image over a main image in oblique viewing directions, that is, the original image is overlapped with made image when the voltage is controlled to the extra pixel for viewing angle control.

Figure 4 shows light leakage of the controllable viewing angle FFS-LCD at dark state in the narrow viewing angle mode and wide viewing angle mode. Light leakage is generated among the edge of the viewing angle control pixel, gate and data lines as shown in Figure 4(a). The reason is because of the LC director tilts downward in direction making 45° with respect to the crossed polarizers because applied voltage between common electrode and pixel electrode of the viewing angle control pixel affects near gate line and data line. In dark state, when light leakage is generated, iso-contrast ratio goes down in normal direction. Consequently, by using black matrix (BM) remove light leakages. Figure 4(b), (c) shows dark state and white state of the controllable viewing angle FFS-LCD using black matrix in both narrow viewing angle mode and wide viewing angle mode. Both narrow viewing angle mode and wide viewing angle mode show same transmittance distribution because using BM cover over light leakage of the

Figure 4(a). Both narrow viewing angle mode and wide viewing angle obtain perfect dark state as shown in Figure 4(b)

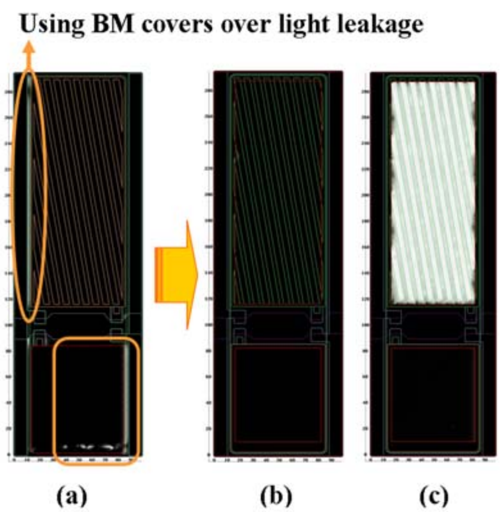

Fig. 4. (a) Dark state without black matrix and (b) Dark state and (c) white state of the controllable viewing angle FFS-LCD with black matrix for both narrow viewing angle mode and wide viewing angle mode.

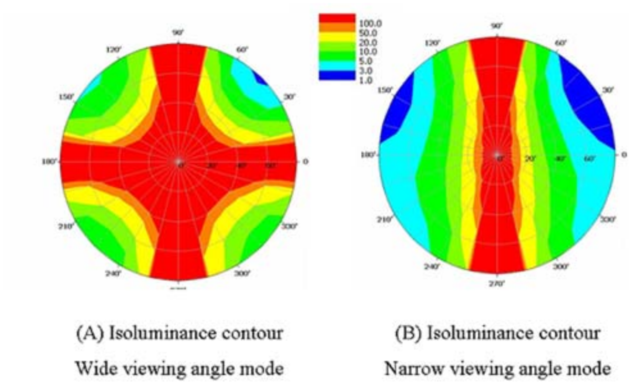

Fig. 5. Viewing angle properties of fringe-field switching (FFS) LCD

Finally, the iso-contrast ratio in wide and narrow viewing angle mode is calculated, as shown in Fig. 5. Considering a dark state, a light leakage is well controlled in a wide viewing angle mode but the light leakage does occur except for vertical directions in a narrow viewing angle mode. Consequently, the high CR is achieved in all viewing directions in the wide viewing angle mode whereas the region in which the CR is only 20 exists at 40° of polar angle at left and right directions in the narrow viewing angle mode. However, the CR of narrow viewing angle is still high in horizontal directions. Accordingly, we controlled viewing angle with made letters or images when the voltage is controlled to the extra pixel for narrow viewing angle mode instead of CR.

4. Summary

We proposed a new structure of the viewing angle switchable LCD composed of main- and sub-pixel, in which the former has a role of image expression and the latter has a role of viewing angle switching. Further, a perfect dark state is obtained in all pixel regions by using the black matrix on the region. Finally, we demonstrated a high image quality transmissive FFS LCD with viewing angle control function using only panel. Consequently, this device has advantage selecting the alternative of wide viewing angle mode or narrow viewing angle mode according to the person's environment of private business and purpose.

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6. References

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