A Novel Electrically Switchable White Privacy Display Device

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Keywords: e-Privacy LCD; White privacy display; Privacy and share mode.

ABSTRACT

This paper introduces an e-Privacy display, electrically switchable between wide viewing angle (share) mode and narrow viewing angle (privacy) mode. Pixel electrodes are divided into two domains, one part is the normal display area, and the other part is the privacy area. By controlling the privacy area electrode, viewing angle switching can be realized.

1 Introduction

Now privacy display can be divided into black privacy display and white privacy display. The black privacy display is to reduce luminance at ⩾45° viewing angle, it looks black obliquely in privacy mode [1]. The black privacy display is dual cell display structure, which is composed of a normal display cell and a view angle switching cell. And dual panel is thicker and more expensive. The white privacy is to improve black picture luminance at ⩾45° viewing angle in order to reduce contrast ratio [2], and it looks white obliquely in privacy mode. As shown in Fig. 1, a type of white privacy display is by adding CF-side ITO electrode [3]. CF ITO and COMMON electrode at TFT side can form vertical electric field. The vertical flip of the liquid crystal would lead to side view light leak and therefore contrast ratio reduction greatly with view angle increment similar to the TN mode. The vertical electric field and the electric field of FFS are in the same plane, which has the problems of image sticking and poor flicker and low contrast ratio as well as blurred and white-fogged display under front view.

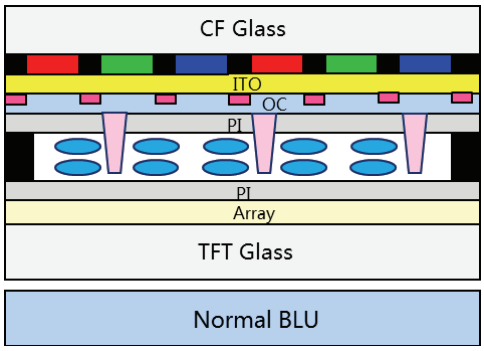
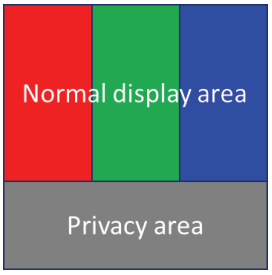


Fig. 1 CF ITO mode

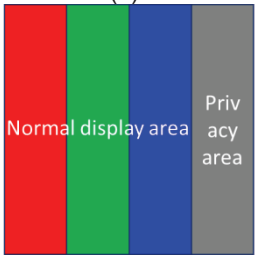
In this paper, we propose a new structure to realize white privacy. It's low cost and has no image sticking problem and good flicker and contrast ratio at 0 degrees.

2 Structure

As shown in Fig. 2, we divide display area into privacy function area and normal display area, the privacy area can be under the normal display area or on the right. Because part of display area is taken by privacy area, the structure will lose part of the transmittance. The privacy area is specially designed. When the liquid crystal rotates under the electrical field driving, the light from the backlight can pass through the liquid crystal layer. While at the front view light is blocked by special structural design, and only the oblique light can pass through normally, so that the front view contrast ratio (CR) is not affected, but the oblique contrast ratio is reduced and the privacy effect is realized. The electrode of the privacy function area is not connected with the electrode of the normal display area, and it can be controlled independently. When the privacy mode is turned on, the electrode of the privacy area is powered on. As shown in Fig. 3, in order to further improve the privacy effect, it is necessary to reduce the brightness by reducing the white voltage in the normal display area, and then the backlight brightness can be increased to compensate for the brightness loss.



(a)



(b)

Fig. 2 (a) Privacy area under normal display area and (b) privacy area on the right of normal display area in front view

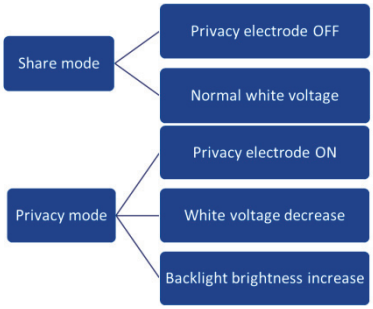


Fig. 3 Driving mode of share mode and privacy mode

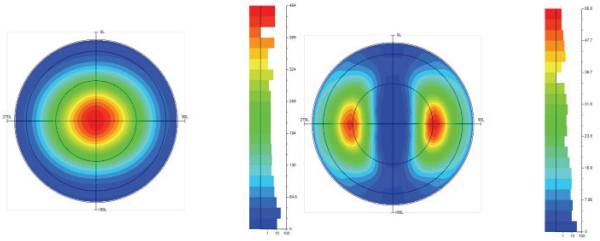
3 Simulation

We use Light Tools software for simulation. First we set privacy area beside the normal display area. Then an RGB color filter film with a certain transmittance rate is established in the normal display area. And a normal backlight is used. An angle receiver is used to collect the view angle brightness. We set color filter film T% as 0 to represent black state of LCD, and color filter film T% as 25% to represent white state of LCD. The CR of the privacy performance is expressed as Equation (1): the white state luminance of display area plus that of privacy area is divided by the black state luminance of display area plus that of privacy area.

Next, we studied the effects of different structures on the contrast ratio. We defined the space between two neighboring holes. We studied the number of holes, the size of holes, and the spacing between two layers of hole1 and hole2. As holes increase, oblique contrast ratio will decrease. The distance between two layers of hole affects the viewing angle CR. As distance increases, viewing angle CR of privacy will decrease. As shown in Fig. 4, left figure is white state and right figure is black state in privacy mode. As we turn on privacy mode, light leaks from both left and right side, and contrast ratio decreases. Through optimizing all the structures, we get a result of contrast ratio=2.8 at 45 degrees in horizontal direction based on the actual panel structure.

Fig.5 shows the visual effects of different contrast ratio, and it shows CR $<$ 2.0 has better privacy effect. Therefore, from Equation 1, we further reduce the oblique contrast ratio and improve the privacy effect by decreasing the white voltage in the normal display area. If the brightness of the normal display area decreases, the 45 degrees contrast ratio can reach less than 2.0.

$$\mathrm{CR} = \frac{\mathrm{L}_{\mathrm{white}} + \mathrm{L}_{\mathrm{privacy}}}{\mathrm{L}_{\mathrm{black}} + \mathrm{L}_{\mathrm{privacy}}} \quad (1)$$



(a) (b)

Fig. 4 Simulation results of (a) white and (b) black pictures

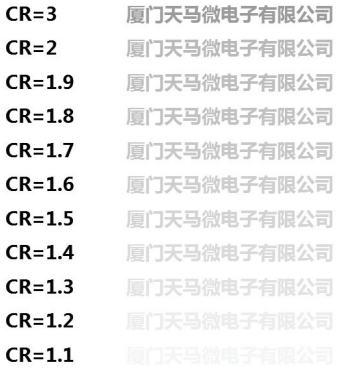
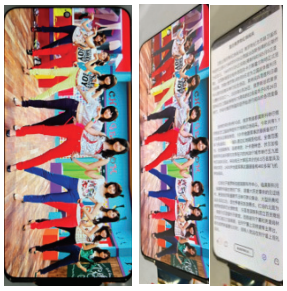


Fig. 5 Visual effect with different contrast ratio

4 Experimental Results

To test our design, we did experiment in our manufacture line. And we measured optical performance of our LCD panel. As shown in Figure 6, differences in actual production process, privacy mode has little effect in front view. And obvious privacy effect can be seen when we turned on the privacy area electrode. As shown in Figure 7 that the contrast ratio curve of privacy mode has obvious narrowing effect compared to share mode. And privacy area has no effect on the sharing area.

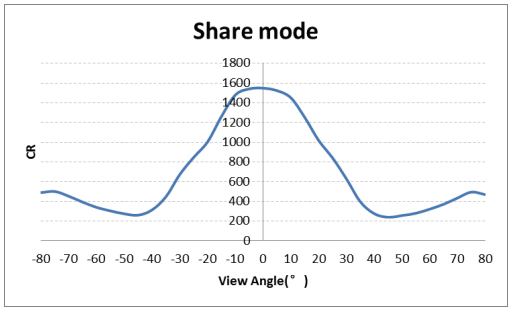
Table 1 contains the performance comparison between privacy display and normal display. We reduce the white voltage of normal display area from 5V to 3V, and the brightness of the normal display area decreases. Then we test the oblique brightness at 45 degrees of both white and black pictures. The contrast ratio is 2.0 at 45 degrees in horizontal direction. If the white voltage continues to decrease, the contrast ratio will be less than 2.0, which provides better privacy effect.



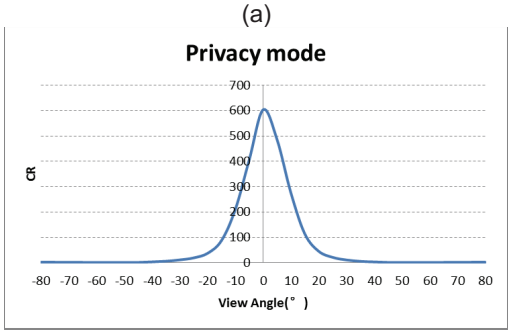
(a) Share mode

(b) Privacy mode

Fig. 6 Prototype 6.7inches FFS LCD



(a)



(b)

Fig. 7 Contrast ratio curve of (a) share mode and (b) privacy mode in horizontal direction

Item	Share mode	Privacy mode
Luminance (cd/m^2)	446.5	275.0
Darkness @45°(cd/m^2)	0.20	28.60
Contrast Ratio @45°	249.0	2.0
Transmission (%)	4.24	4.19

Table 1. Performance comparison between normal display and privacy display

5 Discussion

We have designed and manufactured a white privacy display panel. The contrast ratio is 2.0 at 45 degrees in horizontal direction. And our structure has no image sticking problem and good flicker and contrast ratio at normal view. To achieve better privacy effect, the contrast ratio value should be less than 1.3. We will continue to improve the structure of the privacy area.

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