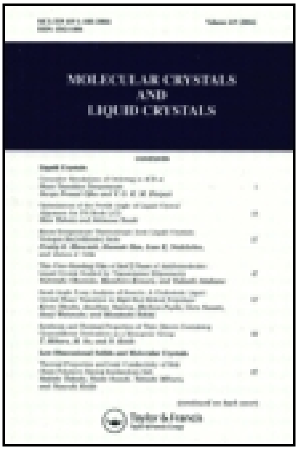

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Circular Polarized LCD

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Circular Polarized LCD

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Novel LCD, which transmits circularly polarized light, is reported. The circular polarized light enables us to see the LCD screen through polarized sunglasses. It is developed for outdoor application, such as mobile computing, car navigator, and so on. The circular light is achieved by placing additional quarter wave film upon the screen.

Keywords: LCD; outdoors; mobile computing; circular polarization

INTRODUCTION

When we watch the liquid crystal display (LCD) through sunglasses, sometimes we get a unusual dim screen. In such cases, we observe remarkable screen-brightness change if we put our heads a little to one side or another. Such sunglasses have a polarized characteristics. The polarized sunglasses is widely used for drivers, fisherman, and so on to remove reflected light. As the transmitted light from the conventional LCD has linear polarization, the amplitude of transmitted light through polarized sunglasses depends on a relative angle between optical axis of LCD exit-polarizer and that of the sunglasses. Unusual light absorption can be minimized if the optical axis of the LCD exit-polarizer is parallel to that of the polarized sunglasses. One of the authors once proposed such optical geometry with combination of multi-domain technology[1]. However, it cannot be a final solution because if the observer puts his head a little to one side, again, he will recognize unusual brightness change.

CIRCULAR POLARIZED LCD

The unusual LCD screen brightness change is resolved if the LCD transmits circularly polarized light. The simplest way to achieve circular polarized LCD is put quater-wave film on the LCD exit-polarizer with its optical axis at an angle of 45 degrees to that of the LCD exit-polarizer. To simplify, we assume normalized transmitted light from conventional LCD, quater-wave film, and transparent polarized sunglasses as follows.

$$TransLCD = \begin{pmatrix} -\sin(a) \\ \cos(a) \end{pmatrix}$$

$$QuaterWave = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 + i\cos(2(a+\frac{\pi}{4})) & i\sin(2(a+\frac{\pi}{4})) \\ i\sin(2(a+\frac{\pi}{4})) & 1 - i\cos(2(a+\frac{\pi}{4})) \end{pmatrix}$$

$$SunGlass = \begin{pmatrix} \sin^2(\beta) & -\sin(\beta)\cos(\beta) \\ -\sin(\beta)\cos(\beta) & \cos^2(\beta) \end{pmatrix}$$

Where α and β are the transmission axes of the LCD exit-polarizer and sunglasses, respectively. Both α and β are measured from Y axis. The optical axis of the quater-wave film should be placed at an angle of 45 degrees to α. The definition of α is shown in Fig.1.

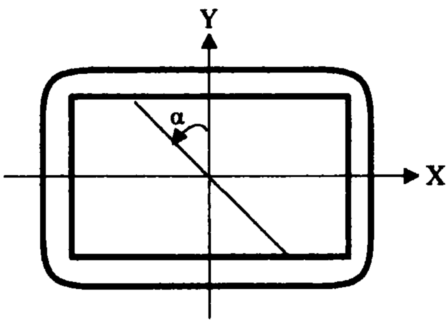

FIGURE 1 LCD screen coordinates X,Y and the transmission axis of the exit polarizer.

Fig.2 shows the brightness changes as a function of |β| for conventional linear polarized LCD and proposed circular polarized LCD. |β| is a relative angle between LCD Y axis and transmission axis of the polarized sunglasses. For the case of linear polarized LCD, there are three curves are plotted for different α. α=0 is the best case for conventional linear polarized LCD. However, α=0 assumption is not practical for conventional twisted nematic (TN) LCD or super twisted nematic (STN) LCD because of the restriction of symmetrical viewing characteristics. Multi-domain TN LCD, or electrically controlled birefringence (ECB) LCD enables us α=0 geometry. Well known TN is shown as α=-45 degree case. When we watch TN screen through polarized sunglasses and we incline our head from right side to left side, screen brightness changes of its maximum to minimum. As an example of STN, IBM PC110 case is also shown in Fig.2. Through polarized sunglasses, PC110 screen is nearly black out. On the other hand, circular polarized LCD brightness through polarized sunglasses is constant against β, and half of the brightness of the LCD without polarized sunglasses.

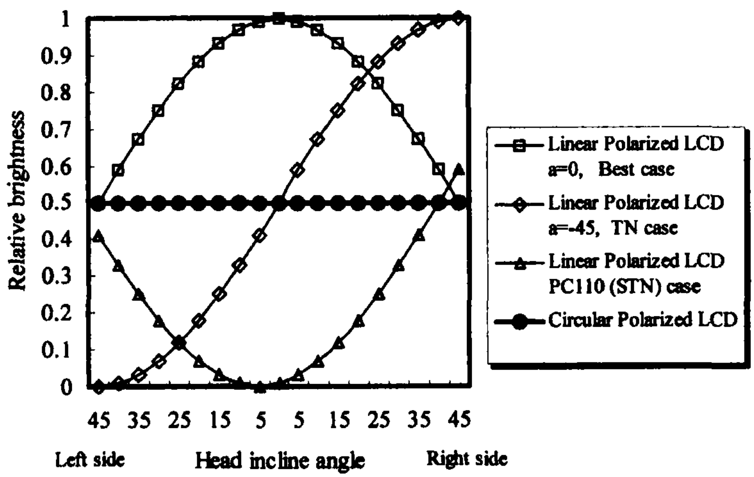

FIGURE 2 Brightness change vs. Head incline angle.

In conclude, the authors propose circular polarized LCD for outdoor application for its constant brightness through polarized sunglasses. Circular polarized LCD is achieved by placing quater-wave film on the LCD exit-polarizer with its optical axis at an angle of 45 degrees to that of the LCD exit-polarizer. Without sunglasses, the existence of the quater-wave film brings no side effect.

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Reference

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