Switchable Viewing-Angle Control Film for Self-Emissive Displays

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Abstract

Viewing angle controllable display changes the viewing angle between wide and narrow viewing angles modes as needed for many applications such as display information protection or peeping prevention. An active switchable film structure (SFS) composed of a fix barrier layer and a switchable barrier layer was proposed to control the divergence angle of a light source in this paper. The switchable function in the SFS is achieved by the patterned micro-structure filled with dye doped PDLC (polymeric dispersed liquid crystal) mixture. The active privacy switch self emissive display was demonstrated by combining the SFS on an OLED display. Such active switch viewing OLED structure is proposed to apply in the automobile application for safety improvement.

Author Keywords

Active privacy control; polymeric dispersed liquid crystal (PDLC); dye-doped PDLC; micro-structure; switchable viewing angle control; active peeping film

1. Introduction

Automotive display is widely adopted in electronic instrument cluster for car information or center information display for controls functions and audio systems. Recently car entertainment display for passenger seat is also discussed. Such entertainment display potentially distracts driver while driving and thus increase the risk of safety issue. To prevent such safety risk, there are regulations prohibiting drivers from watching moving pictures while driving. Therefore, to secure safety regulations while providing entertainment for passengers is necessary.[1] Viewing angle switching function, as shown in Fig. 1, or the car entertainment display is needed. However, the solution for LCD and OLED display is limited due to the challenges in ensuring safety and conformance to legal regulations.

Switchable backlight luminance angle technology such as E-Privacy solutions for LCD display is one of potential approach to switch the viewing angle of the display. E-Privacy display that electrically switching backlight luminance viewing angle from wide viewing angle mode to narrow viewing angle mode has been introduced in LCD display.[2] Such technology provides good information protection function for laptop personal computer displays.[3]

Two parallel alignment liquid crystal cells that employing a twisted nematic liquid crystal (TN-LC) film to control display viewing angle was also proposed. In the TN-LC film, the refractive index distribution can be controlled at viewing angles by applying a vertical electric field so that the light can be controlled using crossed polarizers in a specific left viewing angle direction based on polarization optics.[5]

In this study, a switchable barrier stack was designed to control the angular luminance distribution and for a self emissive display such as OLED or micro-LED display.

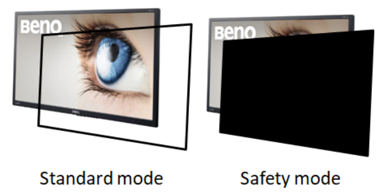
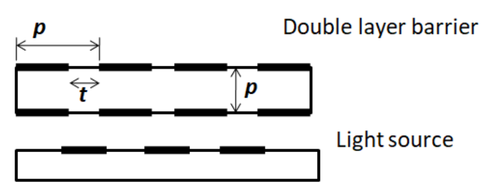


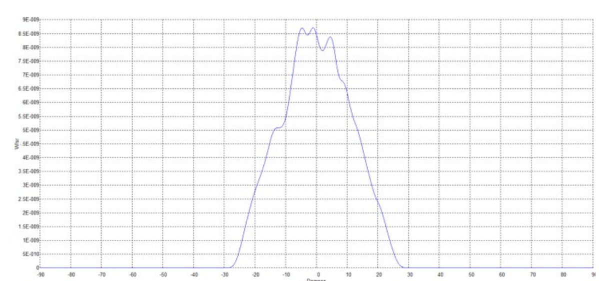
Fig. 1. Illustration or viewing angle control for an entertainment display. In the safety mode, luminance distribution of driver side is limited.

2. SFS Layer Stack Design

Parallax barrier is a promising approach for autostereoscopic display. The viewing zones are decides by the clear and opaque area design of the gratings. A double layer of parallax barriers structure was designed to further limit the viewing angle of the luminance light source. Therefore, a pair of same period grating structure where pitch of ***p*** and open area of t was split by gap ***p***, as shown in Fig. 2(a). Optical properties was modeled by optimized ***p*** and ***t*** by software TracePro**(TM)** and the narrow viewing angle result was obtained as shown in Fig. 2(b).



(a)



(b)

Fig. 2 (a) Schematic diagram of the double layer barrier with on a self emissive display and its (b) luminance angle on a patterned light source.

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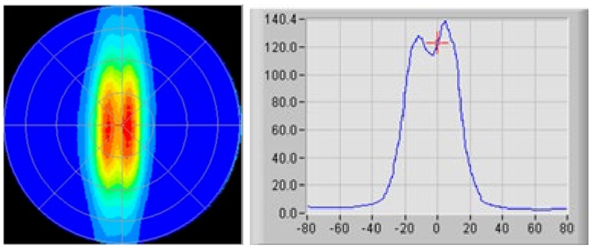
A double 5X5cm double layer barrier of ***p*** of 120um and ***t*** of 50um was fabricated by laser etching process and attached on a Lenove 11inch OLED pad for further Evaluation. The narrow luminance angle of 350deg was obtained by CONO Scope**(TM)**. The angle luminance cone and cross section plot was shown in Fig. 3 (a) and (b) respectively. The measurement results agrees with previous simulation result well.



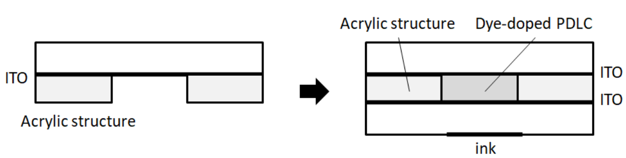
(a) (b)

Fig. 3. The angle luminance (a) cone and (b) cross section plot of a double later barrier on an OLED panel. Viewing angle

3. SFS Manufacturing Process

The top barrier of the double barrier was replaced by switchable barrier for switchable viewing angle control. Dye-doped PDLC is one of the light valve material usually used in optical shutters and smart privacy smart window products. [6] Such material behaves clear state to dark exhibit interesting electro-optical properties because they can switch between an opaque light scattering off-state to a transparent on-state by the application of an electric field. A dye doped PDLC with optical properties of the transmittance from 3% to 40% was obtained for the following device examination.

Micro grooves of 30um width and 25um depth copper mold was made the precession CNC lathe machine and UV embossing process to duplicate micro grooves on ITO film, as shown in Fig. 4 (a). Next, the dye-doped PDLC was sandwiched between embossed micro grooves film and a ITO film. Finally, the ink was printed on the opposite side of the back side corresponding to dye-doped PDLC area, as shown in Fig. 4 (b). SFS film was fabricated after UV exposure.

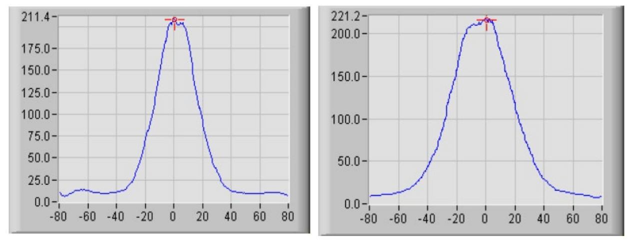


(a) (b)

Fig. 4. The process of switchable grating film: (a) UV embossing process duplicate micro-grooves on ITO film and then (b) dye-doped PDLC with sandwiched with a ITO film with. After UV exposure, dye-doped PDLC can be switched by external voltage source.

4. Optical Performance Evaluation

Brightness of cross section view obtained by CONO Scope**(TM)** on viewing angle control state (no external voltage applied) and normal viewing mode (60V AC voltage applied) was obtained and shown in Fig. 5 (a) and (b), respectively. Same brightness levels were obtained at center viewing angles in viewing angle control mode and normal viewing mode. At large viewing angle, i.e. 40deg, the brightness contract is about 5. The SFS control the viewing angle significantly.



(a) (b)

Fig. 5 The brightness cross section view of the SFS on Lenove 11inch OLED panel. When the viewing angle control is (a) ON and (b)OFF, respectively.

The photo in viewing angle control mode and normal viewing mode at center viewing angle was taken and shown in Fig. 6 (a) and (b) respectively. In the SFS area, red square area, there's no significant brightness difference between modes.

Viewing angle control - ON Viewing angle control - OFF

Fig. (6) Front view as SFS film on OLED panel and viewing angle control (a) ON and (b) OFF.

The photo form side view in viewing control mode and normal viewing mode was taken and shown in Fig. 7 (a) and (b) respectively. It's not easy to identify the image content in the SFS area in viewing angle control mode. The image of the normal viewing mode can be identified easily.

Fig. Side view as SFS film on OLED panel and viewing angle control (a) ON and (b) OFFmodes.

5. Conclusion

An active switchable film structure (SFS) composed of a fix barrier layer and a switchable patterned made by dye-doped PDLC layer was proposed to control the viewing angle of self emissive display such OLED or microLED displays. The SFS can be fabricated by UV embossing process and filled with dye-doped PDLC material. The switchable function and its optical performance of SFS on OLED is studies. The SFS keeps the center brightness level and more than 5X brightness difference at viewing control mode or normal viewing mode, respectively. Such SFS is a potential approach for self emissive viewing angle control.

6. References

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