See-Through LCDs Using Transparent Light-Guide Plates

W.-S. Choi, J.-H. Lee, J. Yeon and J. -B. Yoon

School of Electrical Engineering and Computer Science, KAIST,
373-1 Guseong-dong, Yuseoung-gu, Daejeon 305-701, Republic of Korea

ABSTRACT

See-through black and white (B/W) liquid crystal displays (LCDs) were implemented by using a transparent light-guide plate (LGP) and a color-filterless film compensated super nematic (FSTN) LC panel. In addition, feasibility of further development as full color see-through displays are proven by an initial work conducted with a color light source. It is expected that this work will is applicable to various future display devices.

1. INTRODUCTION

See-through displays are considered as one of the promising devices for future displays. Recently many researches have been conducted to develop see-through displays in projection displays [1-2] and Organic Light Emitting Diodes (OLED) displays [3], such as Head-up Displays (HUD) navigation systems for automobiles and advertising signboards.

Projection HUD is a technology that projects images from projector to a combiner which is transparent so as to display images, while showing front side view. However, Projection HUD has limits on portability owing to complex optical systems. Another good candidate of see-through displays is OLED display, but it still has issues on reliability and relatively high cost. In addition, transparent OLED has yet to mature to be applied to commercial displays.

LCD technologies, meanwhile, have become fully developed and used extensively from wide TVs to mobile devices, so realization of see-through LCDs is more plausible than others. In conventional LCDs, however, low transmittance of color-filters and optical films in backlight units (BLU) hinder LCDs from being developed into the future displays.

In this paper, we proposed two types of see-through LCDs, a transmissive and a reflective type. To realize these displays, a color-filterless film compensated super nematic (FSTN) LCD module and a transparent LGP which was fabricated by backside 3D lithography and plastic replication [4] were used.

2. CONFIGURATION AND PRINCIPLE

Figure 1 shows a schematic view of the proposed two types of see-through LCDs. One is a transmissive see-through LCD, which consists of a color-filterless film compensated super nematic (FSTN) LC panel (PE12864WRF-018-H-Y1 from Powertrip), two absorptive polarizers (arrow marks denote polarization axis of polarizers), and a transparent Polydimethylsiloxane (PDMS) LGP (Fig. 1(a)). The other is a reflective see-through LCD, which has the same components as the transmissive type except a reflective polarizer placed on the bottom surface of the LC panel.

The principle of the transmissive see-through LCDs is similar to that of the conventional LCDs where on and off state are determined by applied voltages to the LC panel. The major difference is that users are able to see backside views through the device due to the transparency of the LGP, which makes it see-through display (Fig. 2).

For the reflective type device as shown in Fig. 3, the LGP was placed on the LC panel. In on-state, lights from a source located at the side of the LGP were reflected at the reflective polarizer, and went toward viewers while backside views of the device were absorbed by the upper polarizer (Fig. 3(a)). Contrarily in off-state, backside views of the device can be shown to users, whereas the lights from a source escaped downward (Fig. 3(b)).

In realization of the proposed devices, the transparent LGP having inverse-trapezoidal shaped micropatterns was designed by LightTools® simulation (Fig. 4). Details were presented in Ref. 5. The spatial luminance distribution of the designed LGP (32mm by 60mm) with four 0.65cd LEDs is shown in Fig. 5. Considering the simulated average luminance of 820 nit and light utilization efficiency (LUE) of two polarizers (38%), the front luminance of the see-through LCDs is expected to reach up to approximately 300 nit, which is comparable to the conventional LCD (approximately 500 nit [6]). Figure 6 shows the fabricated LGPs, and the backside image is clearly seen with little distortion. Further improvements will be obtained by optimization of the pattern distribution which has effects on luminance and transmittance.

3. DEMONSTRATION

Figure 7(a) shows a module consisting of a LC panel and the fabricated LGP, and the printed words of “KAIST” are clearly seen through the module. When a light source was applied to the LGP, the transmissive type device was implemented; pixels for letters of “3DMEMS” programmed as off-state were dark, and the others of on-state were transparent and bright (Fig. 7(b)). In the case of the reflective see-through LCD, the letters were displayed with non-transparent bright pixels in on-state, while the remaining pixels were transparent as off-state (Fig. 7(c)).

Figure 7(d) implies the feasibility of full color see-through LCDs using the proposed scheme. As an initial step, the blue LEDs were applied to the reflective type device, and the blue letters were successfully displayed. Therefore, the proposed device can be evolved into full color displays by applying field sequential color illumination. Undesirable bluish off-pixels in the LGP can be improved by adjusting LED coupling between the LGP and blue LEDs precisely.

Full color see-through LCDs are on the verge of realization, and it will be applied to variety of applications from HUD navigation systems for automobiles to future table computer screens.

4. CONCLUSION

Transparent displays are one of the promising future displays, and it is on the edge of becoming reality by the proposed see-through LCDs. Numerous applications such as HUD navigation systems, advertising signboards and future table computer screens are expected. Moreover, its applications can be more expanded when full-color flexible see-through LCDs are realized.

5. ACKNOWLEDGEMENT

This work was supported by KAIST Institute for Information Technology Convergence. The transparent LGP used in this work was a result from the project which was supported by Samsung Advanced Institute of Technology (the authors would like to thank H.-S.Lee, H.Song, and H.-Y.Choi).

6. REFERENCES

[1] T. P. Caudell and D. W. Mizell, “Augmented reality: an application of heads-up display technology to manual manufacturing processes,” Proc. the 25th Hawaii International conference on System Science, Vol. 2. pp659-669 (1992)

[2] T. Nakatsuru, Y. Yokokohji, D. Eto, and T. Yoshikawa, “Image Overlay on Optical See-through Displays for Vehicle Navigation,” Proc. IEEE and ACM ISMAR’03, pp286-287 (2003)

[3] P. Gorrn, M. Sander, J. Meyer, M. Kroger, E. Becker, H. Johannes, W. Kowalsky, and T. Riedl, “Towards See-Through Displays: Fully Transparent Thin-Film Transistors Driving Transparent Organic Light-Emitting Diodes,” Adv. Mater. 18, pp738-741 (2006)

[4] J.-H. Lee, H.-S. Lee, B.-K. Lee, W.-S. Choi, H.-Y. Choi, and J.-B. Yoon, “Simple LCD Backlight Unit Comprising Only a Single-sheet Micropatterned Polydimethylsiloxane (PDMS) Light-guide Plate,” Opt. Lett., 32, pp2665-2667 (2007)

[5] H.-S. Lee, J.-H. Lee, B.-K. Lee, W.-S. Choi, H. Song, H.-Y. Choi, and J.-B. Yoon, “Monolithically Fabricated Micropatterned Light Guide Plates for Sheet-less Backlight Unit,” Proc. IDW’07, pp661-664 (2007)

[6] AJSM De Vaan, “Competing display technologies for the best image performance,” Journal of the SID, vol.15, no.9, pp657-666 (2007)

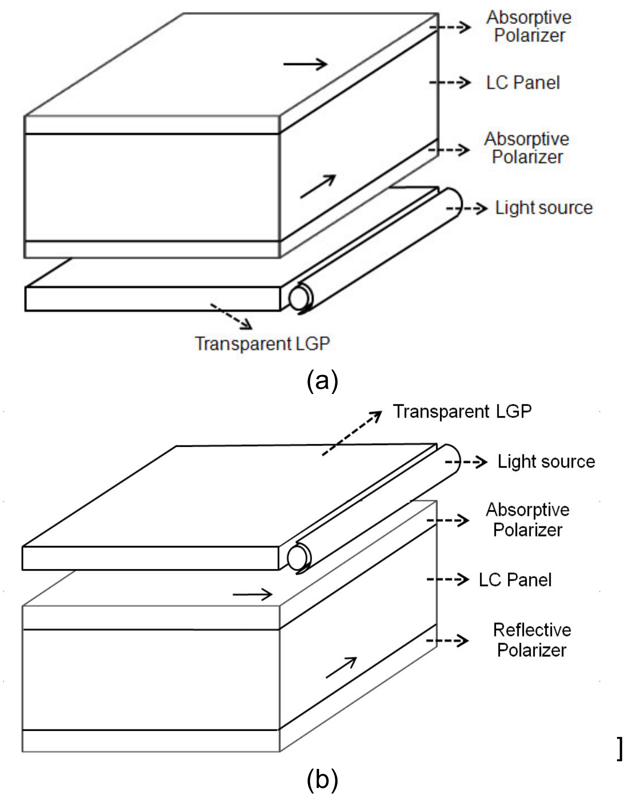


Fig. 1. Configurations of the proposed two types see-through LCDs of (a) transmissive type and (b) reflective type.

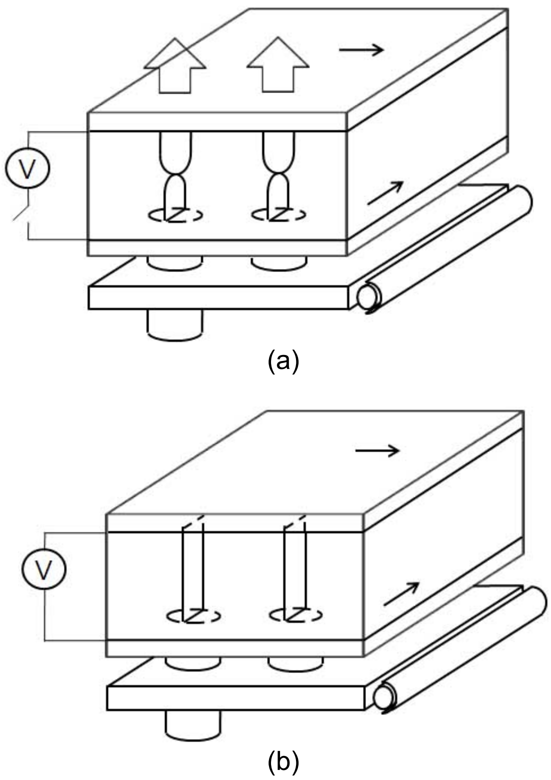


Fig. 2. The principle of transmissive see-through LCDs : (a) on-state and (b) off-state.

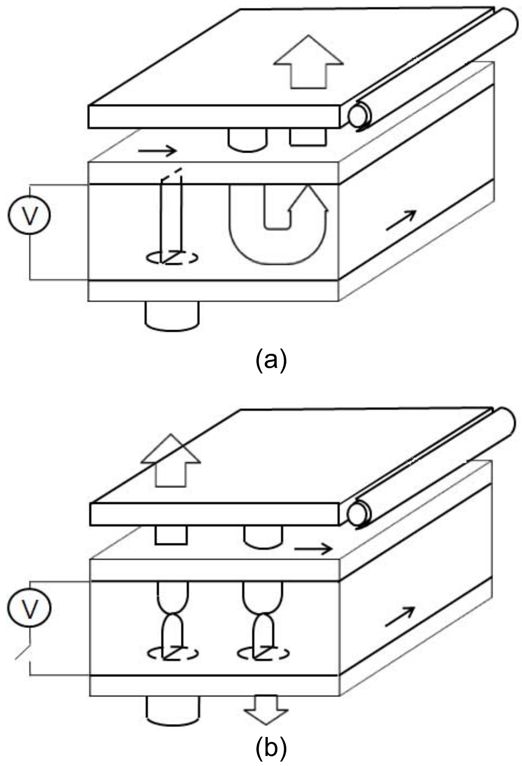


Fig. 3. The principle of reflective see-through LCDs: (a) on-state and (b) off-state.

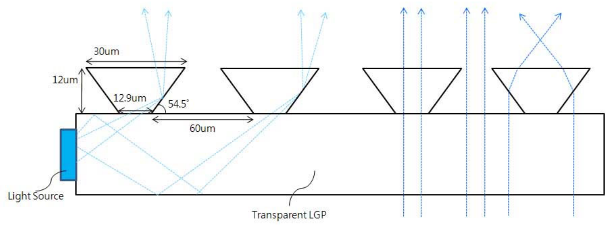


Fig. 4. The design of the proposed transparent LGP.

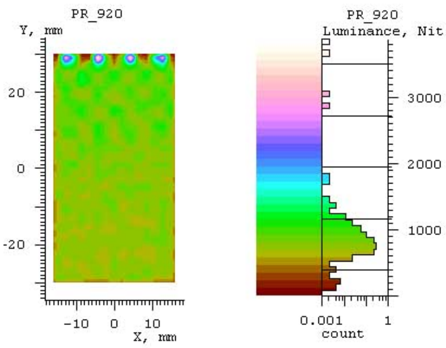
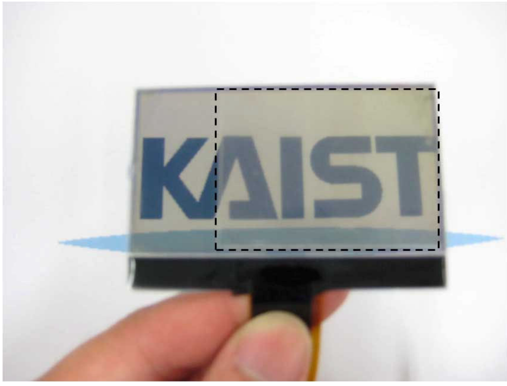
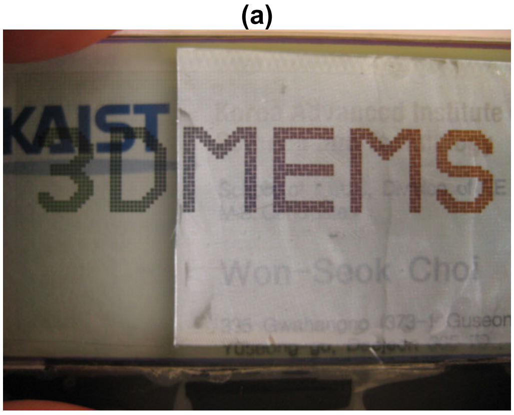


Fig. 5. Spatial luminance distribution of the designed LGP by LightTools® simulation.

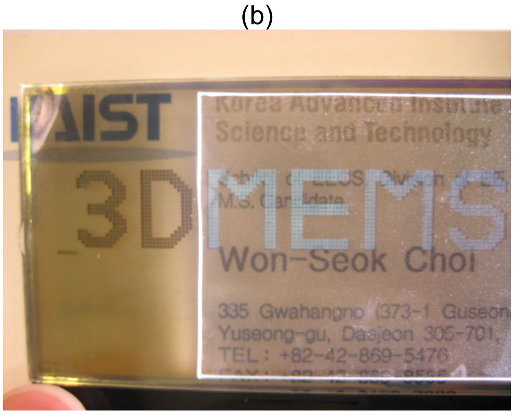
Fig. 6. Photograph of the fabricated transparent LGP on the printed letters (dotted box).



(a)



(b)



(c)

(d)

Fig. 7. Implementation of the See-through LCDs. (a) Module comprising a LC panel and the fabricated LGP. B/W see-through LCDs operating in (b) transmissive mode and (c) reflective mode. (d) Color see-through LCDs in reflective mode with blue LEDs as a light source.