Simulation study for seamless imaging of OLED tiled display

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ABSTRACT

A new OLED tiling technology for seamless imaging is described. The visible seam line of display is eliminated by modification of pixel structure and optical treatment. This seamless viewing is realized for not only normal direction view but oblique view. All of those effects are confirmed by several computer simulations.

1. INTRODUCTION

Tiled display, which is composed of several individual display panels, is one of the most useful and easiest ways of making large size screen. Because of these capabilities, tiled display is used for applications which need large screens. Those tiled displays can be made with CRTs, LCDs and PDPs. Because it is formed by connecting two or more display panels together, tiled display has discontinuity of screen which occurs at the boundaries of adjacent display panels, and is presented as a seam line on the display screen. To reduce or eliminate that boundary seam line, some advanced LCD tiled displays adopt optical components which control light path ways [1].

OLED tiling technology is considered one of the best ways to produce large size OLED display. It was developed to overcome the size limitation of the shadow mask which restricts the entire display size [2]. Overlapped tiled OLED structure is also considered as a new approach to producing large OLED screens [3]. In our previous work, we have suggested the novel method of tiling OLED panels which is appropriate for 72 ppi resolution OLED displays [4]. In this paper, we describe more sufficient ways to reduce the visible seam lines which were deducted from several optical simulations and suggest modifications to our previous tiled display structure.

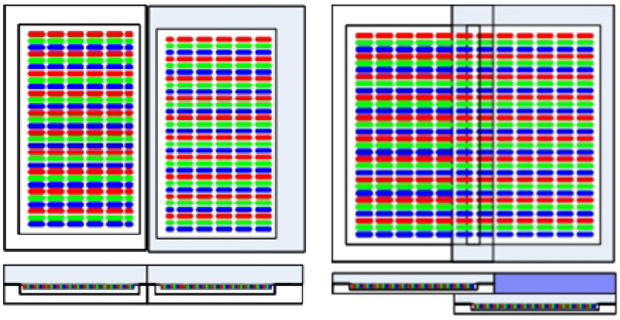
2. Consideration of simulation model

2.1 Display resolution

Because the distance between display screen and the viewer is different, the required resolution of mobile size display differs from that of large size displays, such as TVs. Generally, large size displays require lower resolution than that of mobile displays. For example, a 42 inch diagonal Full HD TV has 1920 X 1080 pixels and its resolution is 53 ppi. On the other hand, a 2.6 inch QVGA (240X320) display, which is normally used in high end cellular phones, has 155 ppi resolution and its pixel pitch is only 165 ㎛. Because the purpose of OLED tiling is not only for making large size screen but also for mobile device displays with relatively higher resolution, we decided on 140 ppi resolution for our simulation model.

2.2 Tiling structure

There are two possible tiling structures of OLED displays. One is side by side tiling and the other is overlapped tiling. In case of side by side method, individual display panels are arranged in the same plane as close as possible. In the overlapped tiling structure, one panel's edge area is overlapped by another panel's edge. The light from the bottom panel is passing through the thin, transparent edge of the top panel. This overlapping method is only possible for OLED displays because of its thinness.

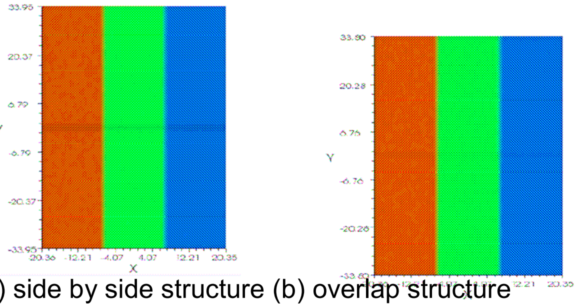


(a)Side by side structure (b)Overlap structure

Fig. 1 Schematic diagram of two possible OLED tiled displays

For the preliminary consideration, we compared these two structures by computer simulation. All model design and optical simulation in this paper were performed using commercial software, RayWiz (Insideoptics Co. Ltd., Korea). Among the many simulation output parameters, we considered “luminance” as a key identification factor. By definition, luminance is the amount of light that passes through or is emitted from a particular area, and falls within a given solid angle. By monitoring the luminance change, we can predict that how the seam area is seen by observers.

As shown in figure 2, there is a thick dark black line in the case of side by side structure. In comparison, the overlap structure shows only a faint, gray seam line on the screen. In the case of overlap structure, in the normal view angle, two panels can be arranged to make zero pixel to pixel gap between the two panels. As a result, there is only small amount of luminance decrease in the boundary area.



(a) side by side structure (b) overlap structure

Fig. 2 Simulation images of two structures

Therefore, we chose overlap structure as the basic concept of our tiled display. Additionally, we adopted a transparent plate on the down panel to maintain a flat display surface.

3. Simulations for oblique direction view

Due to specific structural features of overlap tiling, oblique direction view must be different from normal direction view. We monitored the luminance deviation relative to the observation angle. Normal direction observation was notated as 0^o. One observation direction, tilted towards the transparent plate, was defined as positive(+) direction, while the opposite direction was defined as negative(–) direction. The oblique angle was 30^o and the insight angle of lights to the detector (observer) was limited to $\pm 15^o$. (Figure 3)

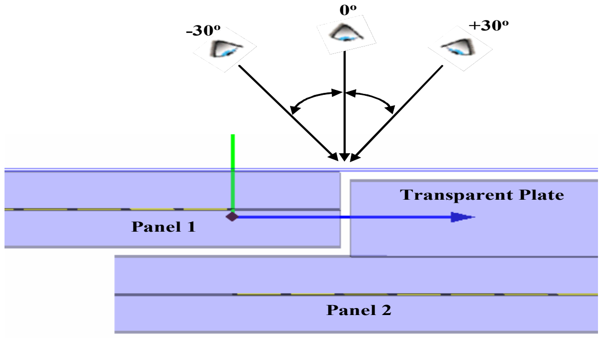
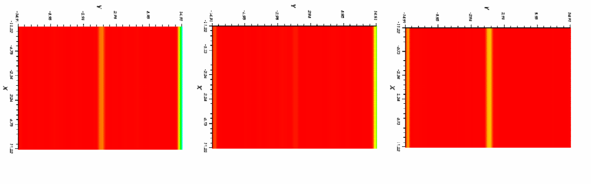


Fig. 3 Observation directions

Figure 4 shows the luminance distribution results of each viewing direction. Luminance decrease can be seen as yellow vertical lines in the overlapping region of the two panels. In the normal direction view, there is uniform luminance distribution which means the observers can not see any seam line on the screen. On the other hand, in the oblique direction viewing, the luminance decrease occurred on the display, showing a darker line in the $+30^o$ direction than the -30^o direction.



(a) -30^o (b) 0^o (c) $+30^o$

Fig. 4 Luminance distributions of 3 different viewing angles

3-1. Negative observation direction

The luminance change observed in the negative viewing direction is mainly due to the light reflection on the boundary area of OLED panel 1 and transparent plate.

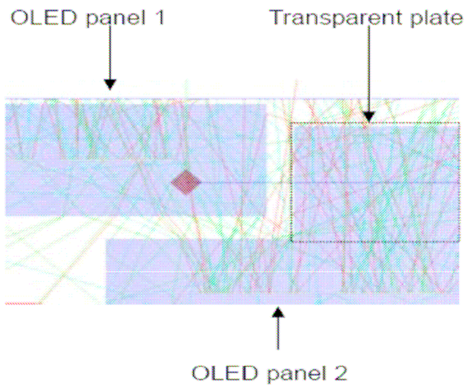
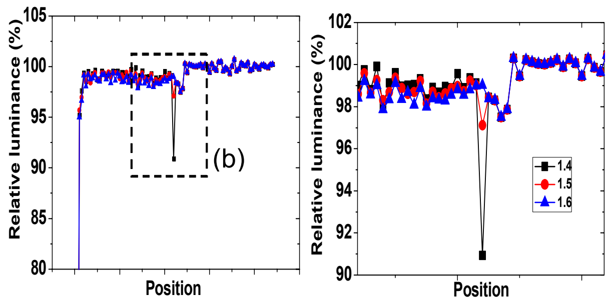


Fig. 5 Computer simulation results of ray reflrction tracing

If there is no air gap between OLED panel 1 and the transparent plate, the degree of light reflection is smaller than that of the opposite case. In this simulation, we considered air gap existence as well as the refractive index of transparent plate. Three different refractive index values (1.4, 1.5 and 1.6) were considered for the simulations. Figure 6 shows the influence of refractive index when there is no air gap between the two dielectric objects. This observation was made from -30^o viewing angle and the panel thickness was 0.5mm. When the refractive index is 1.4, the degree of luminance decrease was 9.1%. But when it was 1.6, there is only a 0.9% decrease in luminance on junction area. From those results, we can infer that the larger refractive index of transparent plate induces a smaller luminance decrease when two dielectric plates are attached. But if there is any air gap between the two plates, the degree of luminance decrease is not influenced by the difference in refractive index.

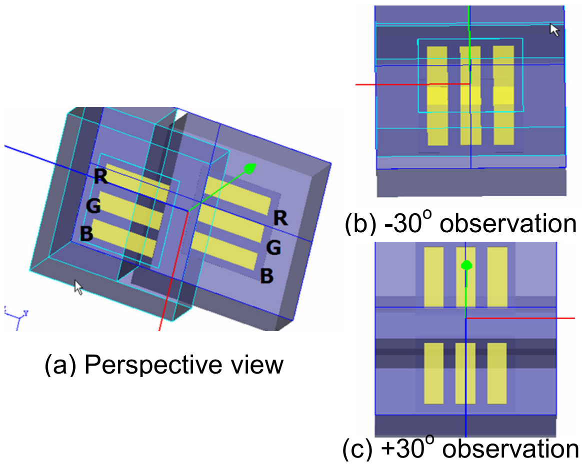


(a) All area (b) selected area

Fig. 6 Cross section plot of relative luminance

3-2. Positive observation direction

The cause of the larger luminance decrease for the +30° direction compared to that of -30° direction is shown in figure 7. If the observation angle is tilted to OLED panel 1, the pixels overlap and there is no discontinuity. But in the opposite direction, there is the empty region in the pixel stream which causes local luminance decrease.



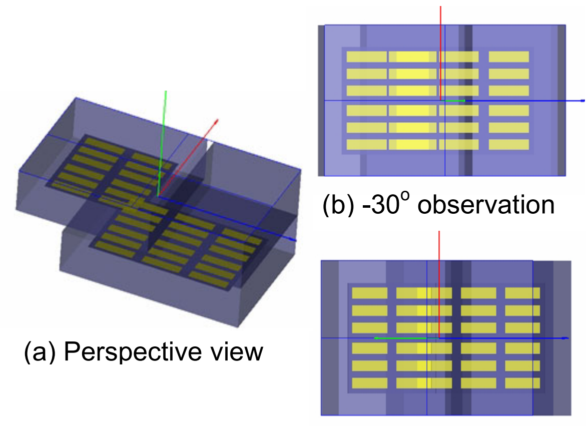
(a) Perspective view

(b) -30° observation

(c) +30° observation

Fig. 7 Geometry views of existing display structure

To eliminate or reduce the luminance decrease, we adopted an additional pixel line on the OLED panel 2, which is located under the last pixel line of OLED panel 1. Figure 8 shows the geometry views of our new display structure which has the additional pixel line. There is no discontinuity of pixel stream in the positive viewing direction, as well as in the negative viewing direction.



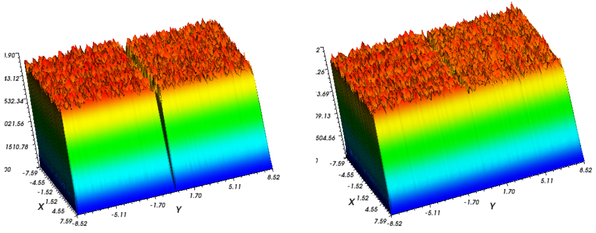
(a) Perspective view

(b) -30° observation

(c) +30° observation

Fig. 8 Geometry views of new display structure

Simulations have confirmed the effectiveness of this structure. All of observation was made from +30° viewing angle and the panel thickness was 0.5mm. Figure 9 shows the simulation images of luminance distribution from both existing structure and new structure. The dark deep valley which is shown on the existing structure represents the rapid luminance decrease on the boundary area. It no longer appears in the new structure.



(a) Existing structure (b) New structure

Fig. 9 Luminance 3D graphs of each display structure

Fig 10 shows the cross section line plot of luminance distribution. The luminance decrease of the new structure is only 9.2 %, compared to 89.8% for the existing structure.

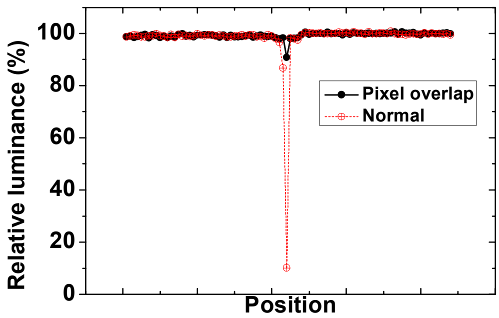


Fig. 10 Cross section line plot of each display structure

Fig 11 is the image simulation results of the two structures. In the case of our new structure, the dark seam line is almost invisible.

(a) Existing structure (b) New structure

Fig. 11 Image simulation results of each display structure

4. Conclusion

Through computer simulations, we confirmed the possibility of eliminating the overlapped tiled display's dark seam line which could be seen from the oblique viewing direction. We have verified these results by using a 140ppi display model, whose resolution is high enough for mobile device displays. In future studies, we plan on performing more detail simulations and fabricate a prototype display device to confirm our simulation results.

6. REFERENCES

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