36.4 : A novel seamless tiling technology for high resolution OLED displays

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Abstract

A novel seamless tiling technology for high resolution OLED displays is described. This technology is mainly based on geometric arrangement of each pixels and optical path control of OLED displays. Computer simulations have been used to find and confirm the best conditions for seamless OLED displays. A 2 X 1 tiled, 72ppi resolution, 8" diagonal size AM-OLED seamless tiled display prototype was fabricated.

1. Introduction

Tiling display is one of the most useful and easiest ways of making large, high resolution screens. Some applications of tiled displays are CRTs, PDPs and LCDs. Typically tile displays are made by arranging multiple panels in the same plane as close as possible. Some advanced LCD tiled displays adopt optical components which control light path ways to eliminate boundary seam areas between two adjacent LCD panels [1].

OLED tiling technology is considered as one of the best ways to produce large size OLED displays. It was developed to overcome the size limitation of shadow mask which restrict the entire display size [2]. Overlapped tiled OLED structure was considered the cost effective approach to make large OLED screens [3]. In this paper, we present a method of tiling high resolution OLED panels without visible seams by geometrical pixel arrangement and optical path control of OLED panels. This novel method is especially suitable for high resolution OLED displays.

2. New tiling technology of OLED display

We considered overlapped tiling structure to eliminate pixel stream discontinuity between adjacent two panels (Figure 1). This structure can offer a seamless display in the normal direction. A transparent plate is introduced to prevent the reflection of incident light on the side edge of OLED panel 1.

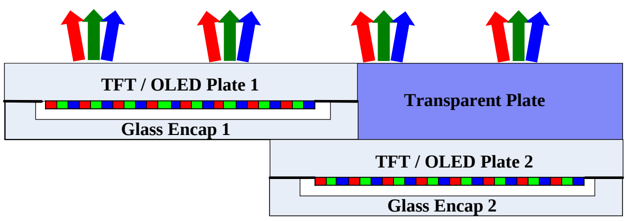

Figure 1. Schematic side view of overlapped panel tiling

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3. Optical simulation

3.1 Simulation design

Before fabricating the tile display prototype, several optical simulations were made using computer simulator for predicting the optical characteristics of the display and reducing the number of errors. All model design and optical simulation of this tiled display were performed using commercial software, RayWiz (Insideoptics Co. Ltd., Korea).

Among the many parameters obtained from the simulation, we consider "luminance" as a key identification factor. By definition, luminance means the amount of light that passes through or is emitted from a particular area, and falls within a given solid angle. Display luminance is dependant on the angle of observation, and also on the characteristics of different types of displays. A normal display has a gradual luminance change over the entire display area. But the tiled display may show discontinuous luminance change at boundary area of adjacent panels. Therefore, by monitoring that change, we can predict that how the seam area is seen by observers.

The preliminary simulation results show that rays from OLED panel 2 (down plate) are reflected at the side edge of OLED panel 1 (top plate) and this reflection causes a dark visible seam to oblique direction viewers. Based on these preliminary results, we intended to quantify these dark visible seams in detail by split simulation.

3 main items were considered as split parameters.

(1). Perfection of attachment between OLED panels and transparent plate

Due to the similar refractive index of glass (substrate of OLED panel) and transparent plate, most of the light rays pass through the contact interfaces of glass and glass or glass and transparent substrate. But if there is any air gap between the two dielectric materials, some of the light can be reflected off that surface. This reflection causes luminance decrease in the boundary area. We considered this factor in our simulation as 4 different cases seen in Figure 2.

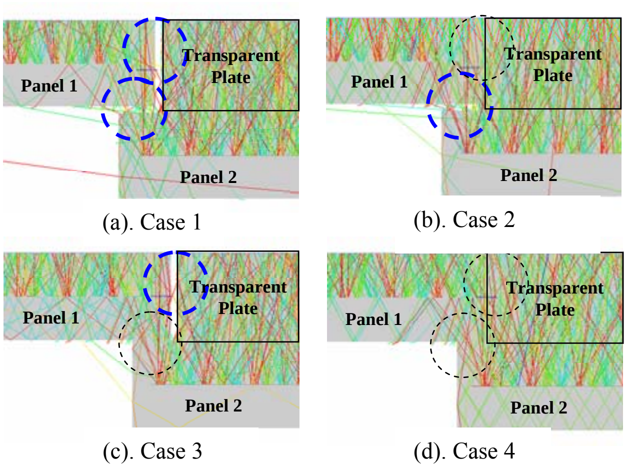


Figure 2. 4 cases of attachment condition. Blue bold circle represent the existence of air gap between facing two plate.

(2). Vertical gap between two emission layers

Vertical gap between two emission layers in each OLED panel is the total sum of the OLED panel glass substrate thickness and the glass encap (Figure 1). In this simulation, we considered both thickness of the panel and encap glass to be the same. Thickness of glass was incremented from 0.1mm to 0.7mm by 0.1mm.

(3). Observation direction changes.

We also monitored the luminance deviation relative to the observation angle. Normal direction observation was notated as 0^o. One observation direction, tilted to transparent plate, was defined as + direction, while opposite direction was defined as – direction. The oblique angle was 30^o and the insight angle of lights to the detector (observer) was limited to $\pm 15^o$.

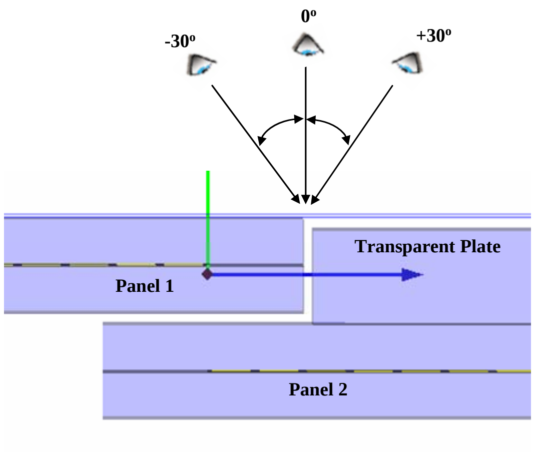


Figure 3. 3 observation directions.

3.2 Simulation results

Figure 4. shows the luminance distribution results at 0.5 mm the panel thickness. Luminance decreases can be seen as yellow vertical lines in the overlapping region of the two panels. The severity of luminance decrease is related to contact/non-contact status and observation direction.

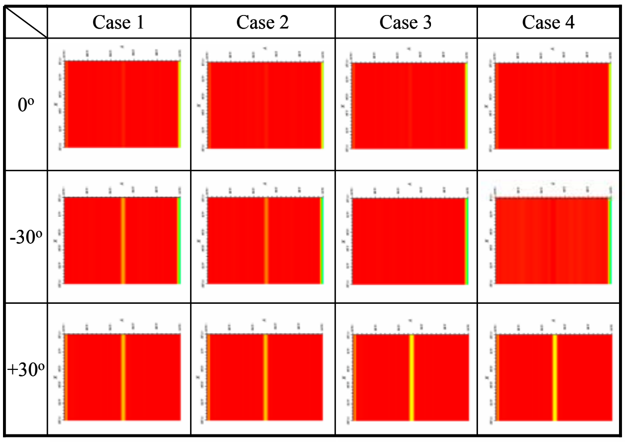


Figure 4. Luminance simulation results when the glass thickness is 0.5mm

The luminance decrease can be described as the decrease in relative intensity of non overlapped area. (Figure 5.)

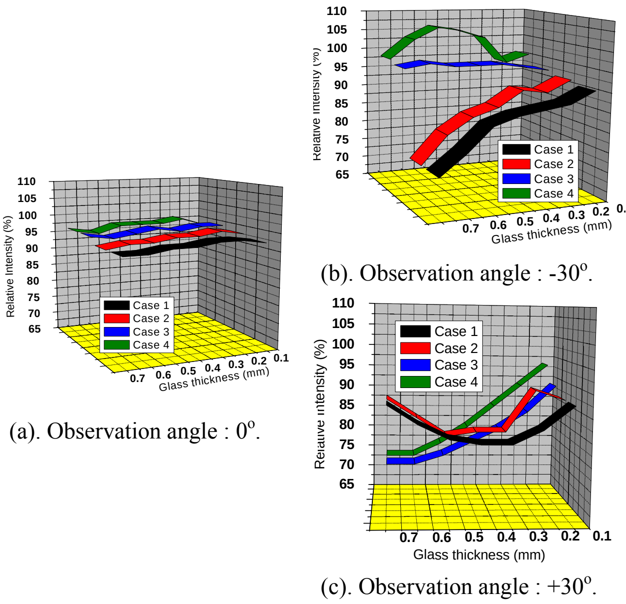


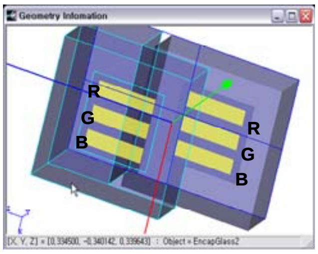
Figure 5. Luminance changes of different observation directions.

When the observation is performed at the normal direction (0^o) there is only little luminance fluctuation as shown in figure 5(a).

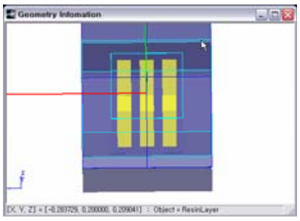
Figure 5(b) is the result of -30^o viewing angle. In this case, if there is no vertical air gap (case 3, case 4), changes in luminance is relatively small. But in the case of a vertical air gap being present (case 1, case 2), the luminance is gradually reduced as the glass thickness grows.

In the case of +30^o observation (figure 5.(c)), case 3 and case 4 shows linear decrease of luminance with increasing glass thickness. But in case 1 and case 2, luminance decrease is reversed after passing a certain glass thickness. But in all cases, the rate of luminance change versus glass thickness change is very large.

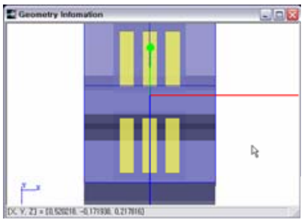
The reason why the degree of luminance decrease of +30° direction is bigger than that of -30° direction is shown in figure 6. If the observation angle is tilted to OLED panel (in figure 3), the pixels overlap and there is no discontinuity. (Figure 6.(b)). But in the opposite direction, there is the empty region in the pixel stream which causes local luminance decrease. This decrease is directly proportional to the gap between the two light emitting surfaces. (Figure 6 (c)).



(a). Perspective view



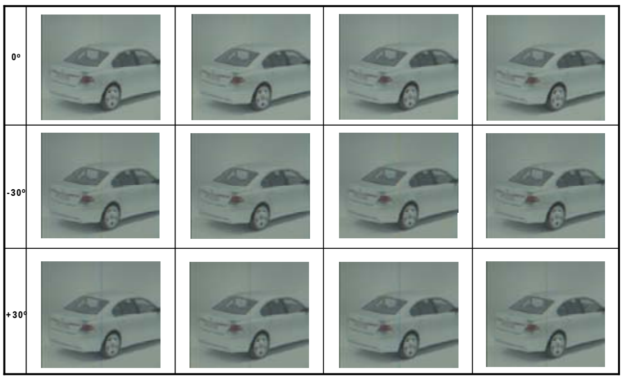
(b). -30° observation



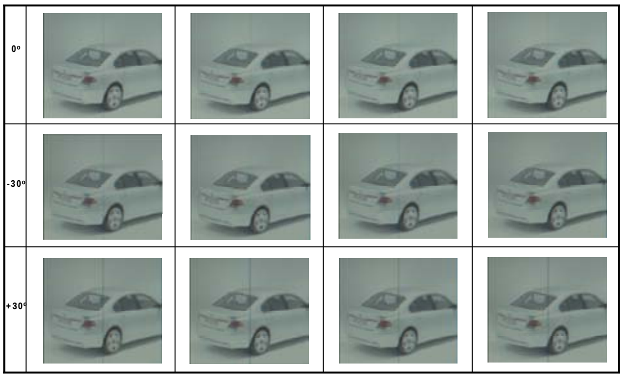
(c). +30° observation

Figure 6. Geometry views of pixels

Several image simulations were performed to predict the image on a real display device. Figure 7 (a) and Figure 7(b) are the image simulation results when the glass thickness is 0.3 mm and 0.7mm respectably. We can confirm that the dark line (luminance decrease) on images in thicker gap is darker than that of thinner gap.



(a). Glass thickness : 0.3 mm



(b). Glass thickness : 0.7 mm

Figure 7. Image simulation results

From these and several other computer simulation results, we conclude that two methods to reduce the dark seam line in display images are reducing the horizontal gap between the light emissive layers of both OLED panels and eliminating the air gap between the transparent plate and OLED panels.

4. Prototype fabrication

From these results we devised a new transparent thin film encapsulation method to reduce the horizontal gaps and admitted a new transparent, elastic material as an additional transparent plate to eliminate air gaps. Each OLED panel was made by general AM-OLED panel fabrication process except the encapsulation step. Thin film encapsulation process is made by forming alternative organic and inorganic layers on OLED panels. The entire film layer thickness is less then 10 ㎛, so the gap between two light emission surfaces is almost same to the glass thickness of OLED panel 2 (in this work, 0.7mm).

A 2 X 1 tiled OLED display was fabricated by arranging two OLED panels and one transparent plate as shown in figure 8. This transparent plate consisted of silicone rubber which was temporally or permanently attachable to the glass surface. Additionally, its elasticity can be helpful in eliminating small air gaps between the OLED panels and transparent plate. On this transparent plate, a normal polarizer film was introduced to prevent the reflection by incident lights.

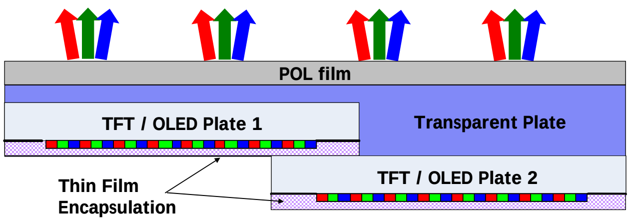


Figure 8. Schematic side view of proto type.

The photographic images of our prototype are shown in Figure 9 and a brief specification is in Table 1.

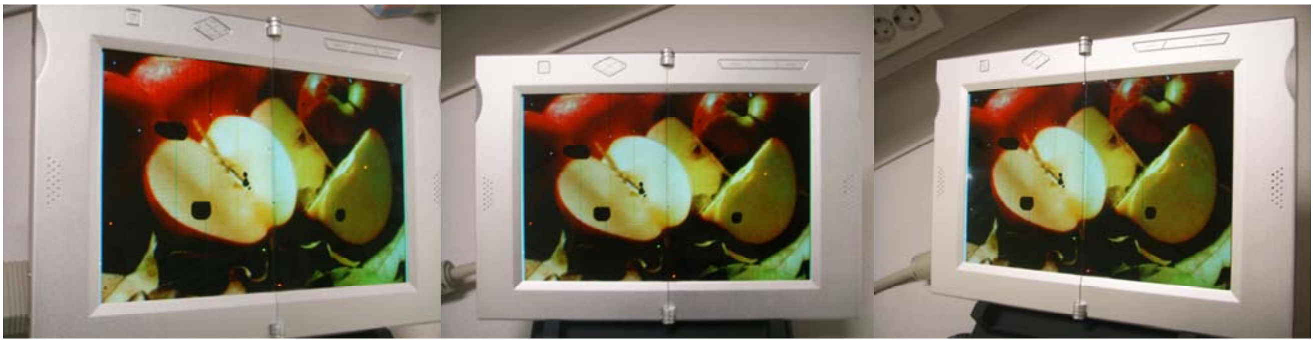


Figure 9. Images of prototype at left oblique, normal, and right oblique direction

This prototype shows a faint shadowing seam line in the normal direction view and both oblique direction views. This weak seam line might be the influence of imperfect attachment between OLED plate 1 and transparent plate.

Display size	172.8mm X 107 mm (8” diagonal)
Number of pixels	480 X RGB X 300
Resolution	72ppi
Pixel size	357 ㎛ X 357 ㎛
Pixel to pixel pitch	46㎛
Aperture ratio	40.5%
Driver type	Active matrix α-Si TFT
Encapsulation method	Thin film encapsulation

Table 1. Prototype display specifications.

5. Conclusion

Through computer simulations and prototype fabrication, we confirmed the feasibility of tiling high-resolution AM-OLED displays without dark seam lines. Glass slimming and edge grinding can be applied to further reduce the horizontal gap, and the refractive index of the transparent plate is tunable by careful selecting and modifying plate materials. We believe that a perfectly seamless OLED display can be developed by applying these improvement points. This novel tiling technology might be a promising solution not only for manufacturing large size OLED displays but foldable OLED displays.

6. References

[1] Paul A. Bayley, Niall A. Gallen and Anthony C. Lowe, "*A 68-inch SVGA 4x4 Tiled Display*" SID Symposium Digest, Vol. **35**. pp. 1550-1553, 2004.

[2] S. Terada, G. Izumi, Y. Sato, M. Takahashi, M. Tada, K. Kawase, K. Shimotoku, H. Tamashiro, N. Ozawa, T. Shibasaki, C. Sato, T. Nakadaira, Y. Iwase, T. Sasaoka and T. Urabe, "*A 24-inch AM-OLED Display with XGA Resolution by Novel Seamless Tiling Technology*", SID Symposium Digest, Vol. **34**. pp. 1463-1465, 2003.

[3] Mark Aston, "*Design of large-area OLED displays utilizing seamless tiled components*", J. Soc. Inf. Display, Vol. **15**, pp.535-540, 2007.