Research on the Process of Microlens Array Structure in Anti-Peeping Automotive Display

Yanqiang Wang*, Jing Yang, Zheng Liu, Tao Gao, Weifeng Zhou, Wenxuan Zhang, YuanZheng Guo, Qixiao Wu

***BOE AMOLED R&D Center, Chengdu, China**

Abstract

In recent years, AMOLED display has gradually become the mainstream product of automotive display with the advantage of controllable display angle, high brightness, different shapes, and so on. And anti-peeping technology in vehicle display has become a difficult point. In this article, we introduces the preparation of a hemispherical Lens through special design and processes to achieve an anti-peeping effect, while significantly enhancing the front brightness of OLED and better adapting to automotive display products.

Author Keywords

Automotive display, MLA, anti-peeping,

1. Objective and background

In recent years, with the electrification and intellectualization of automobiles, the display products have been increasingly applied in the automotive field, like Center Infotainment Displays (CID) with GPS, Dashboard Clusters or Digital Clusters (DC), Air-conditioning Controls, Head-up Displays and so on. Although OLED is suitable for most of these application requirements, but the most significant challenges are the life time, efficiency, and anti-peeping effects when OLED is applied in the automotive displays. So MLA (Micro Lens Array) technology not only substantially enhances the light extraction efficiency at the front viewing angle, but also achieves the purpose of improving viewing angles when used in conjunction with BM (Black Matrix), which is the anti-peeping effect. Consequently, it has become a primary focus of research and development for numerous display screen enterprises. But due to the inherent limitations of the thermal stability of OLED luminescent materials, the process temperature for MLA cannot exceed 100 ℃. We adopted the photolithographic process to fabricate MLA because it offers higher alignment precision and easier control over the profile of the MLA, compared to other implementation methods. In this study, we adopted a design what the MLA is matched one-to-one with each pixel in order to achieve the effect, both an anti-peeping effect and an enhancement in OLED efficiency. Additionally, we investigated the impact of MLA size and different aspect ratio designs of MLA on OLED efficiency and viewing angles.

2. Experiment

We adopt a top-emitting OLED device with RGB pixels as the light source on the substrate, and each RGB pixel designed to a different size. After the device is deposited and encapsulated, the touch-sensitive layer is integrated on the aforementioned substrate.

Then the MLA is fabricated above the touch function layer on the aforementioned OLD substrate. Firstly, we adopt an exposure process to fabricate a patterned high-refractive-index organic layer. The pattern of this layer is consistent with the pixels design layer shapes of the underlying OLED, shown in Figure 1. In addition, Figure 1a and Figure 1b respectively show the plan view and cross-sectional view of the MLA fabricated by the photolithographic process. Subsequently, an exposure process is used to fabricate a low-refractive-index flattening layer with slit coating, shown in Figure 2. The refractive index difference between the aforementioned high-refractive-index layer and low-refractive-index layer generally needs to be greater than 0.15.

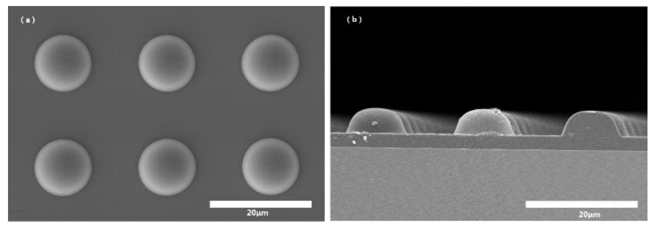

Figure 1. a. Lens SEM plan view；b Lens SEM cross-section view

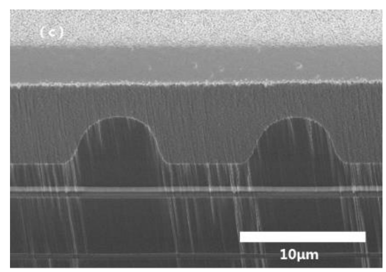

Figure2. low-refractive-index flattening layer SEM cross-section view

3. Result

When fabricating hemispherical MLA arrays uses photolithography, we have found three methods for forming hemispherical lenses. One method is achieved through light diffraction, another is through the thermal flow effect of materials, and the last method involves a combination of both. Currently, the first method is difficult to achieve large-sized lenses, and it is greatly affected by fluctuations during the photolithographic process. The second method is less affected by process fluctuations, but it is limited by the process temperature requirements of OLEDs. While pure thermal flow effects can produce a good profile, but they can also lead to insufficient material solidification, causing the material's chemical resistance to fall below standards. And the third method can obtain the advantages of both the aforementioned methods and can produce a more stable lens morphology. To achieve the desired aspect ratio and hemispherical morphology of the lenses, we adjust various process parameters such as exposure dose, curing temperature and time, soft bake, and second exposure dose during the photolithographic process. Through process adjustments, we have found that the three process stages of exposure, development, and curing have the most significant impact on the morphology of the lens. By optimizing the above

ISSN 0097-996X/25/5603-1650-$1.00 © 2025

three processes, we have found an optimal set of process parameters that result in the formation of a hemispherical morphology, as shown in Figure 1b. As shown in Figure 1b, the morphology of the high-refractive-index lens resembles a hemisphere or a portion of a hemisphere, and this morphology is related to its aspect ratio design. Specifically, when the aspect ratio (height to width) is 1:2, the lens takes the shape of a complete hemisphere. To achieve this hemispherical shape, we found that the high-refractive-index material is partially uncured during exposure. By adjusting the developing process, we can further control the size of the pattern. Finally, through the curing process, the cross-sectional morphology of the pattern is reshaped to achieve the hemispherical shape.

Then, we fabricated MLA with different aspect ratios on the substrate mentioned above and found that MLA with different aspect ratios result in different enhancements in the light extraction efficiency at the front viewing angle, as well as different L-Decay curves. Through simulations, we observed that by immobilizing the lens height and increasing the lens width, the L-decay slows down; conversely, by immobilizing the lens width and increasing the lens height, the L-decay accelerates, as shown in Figure 3. The width of the lens in Figure 3 is typically between 10-30μm, and the height of the lens is generally between 3-10μm. And the lens 1-4 have different widths, with Lens1 < Lens2 < Lens3 < Lens4. Lens 5-8 have different heights, with Lens5 < Lens6 < Lens7 < Lens8.

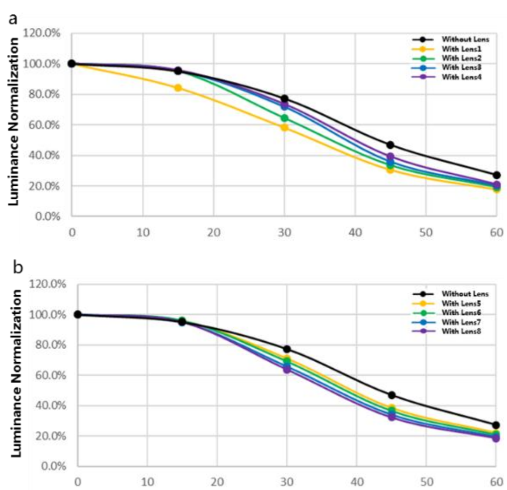

Figure 3. a. Effect of different lens widths on L-decay; b. Effect of different lens heights on L-Decay

Based on the aforementioned principles, we found the optimal lens design criteria by matching the size and shape of automotive pixels and continuously adjusting the size (D) and height (H) of the lens. The demo's specifications of the in-vehicle display product integrated with MLA is shown in Figure 4. As can be seen from the figure 4, the display content is not visible at large viewing angles in the anti-peeping mode. This design significantly increases the light extraction efficiency of the OLED by more than 90% at the front viewing angle and also greatly improves the anti-peeping angle, achieving a L-Decay@48 ° of less than 0.5% as shown in Figure 5. As shown in the diagram, the L-Decay attenuation at large viewing angles is accelerates with the lens applied, which is up to specifications which is the requirements for automotive anti-peeping. Simultaneously, due to the accelerated L-Decay attenuation, the color shift will also increase at the large view angle. So, since the brightness at large angles is relatively low, the impact on visual effects is minimal.

Name	12.3" Switchable Privacy OLED
Display	AMOLED(flexible)
Resolution	2400(H)*900(V)
Contrast Ratio	1000000:1
Luminance@ Perpendicular peak	1100nit
L decay(48 °/0 °)	0.30%

Figure 4. The demo of the display integrated with MLA

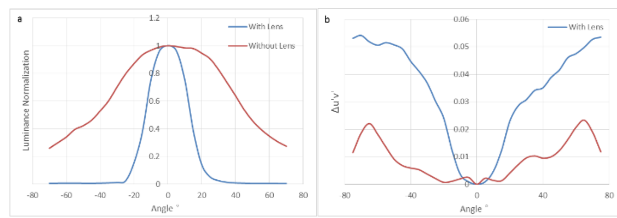

Figure 5. a L-Decay Curve；b Color Shift Curve

4. Conclusion

In this study, we investigated a process for fabricating Micro Lens Arrays by using photolithography. This method enables the creation of lenses tailored to the different RGB pixel sizes of OLEDs. By adjusting the aspect ratios of these lenses, we aim to enhance the efficiency of OLEDs and change L-decay curve. And the efficiency could be increased by over 90% by IVL (Integrated Visual Luminance) testing, so it can be significantly extending the life time of the OLEDs. Additionally, this approach accelerates the brightness decay at large viewing angles that is achieving a L-decay@48 ° of less than 0.5%. In summary, spherical-like MLA holds tremendous potential for future applications in automotive anti-peeping displays.

5. References

1. Tianhao Lu* , Xiaohu Li* , Qian Jin* , Che An*, Yutong Yan*, Ming Yang*, Wenqi Liu*, et al, "One-to-One Microlens Array with Pixel for Full-Color Organic Light-Emitting Diode Display " , SID Symposium Digest 1131-1134（2024）

2. Fen Chen , Jim Kuo"In-Vehicle Display Technology", Advanced Driver Assistance Systems and Autonomous Vehicles339-419 (2022)

3. Karlheinz BlankenbachAutomotive " Display Technologies Shine at Display Week 2020 ", Information Display 49-53(2020)