Anode Protective Metal Structure for Increasing Lifetime in Micro-OLED

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Abstract

Al corrosion and short circuits often occur in the traditional preparation process of Micro OLED, which seriously affect its yield and performance. Here, we proposed a novel anode protective metal structure (APMS) designed to protect Al and reduce short circuits. The results show the APMS offers superior protection for Al and anode, reducing the defect rate by 2.67% compared to conventional structure. Furthermore, the image sticking level was improved one level and the lifetime of device was extended by 4.87%.

Author Keywords: Micro OLED; Al migration; Layer Horizon Control; metal protect

1. Introduction

Micro OLED as a next-generation display technology, have been widely used in virtual reality and augmented reality due to their small size, high refresh rate, and ultra-high pixel per inch display (PPI). However, achieving such ultra-high PPI not only demands precise control over sub-pixel gap, but also requires the prioritization of the leakage protection between sub-pixels. To address lateral leakage between sub-pixels, Micro OLED adopts an undercut structure, which requires the extra layer horizon control (LHC) to improve vertical leakage caused by cathode puncture. During the fabrication of anode and LHC, two problems have been identified. First, in the traditional anode fabrication process, the anode is formed before the LHC, in which Al is often used as the middle layer of the anode. During the definition of the anode area, the etching gas and cleaning solution will directly contact the exposed Al on the side wall of the Anode, leading to Al corrosion and even migration occurs, ultimately resulting in damage or surface defects on the anode, as illustrated in Figure 1(a)[1]. Second, in the LHC fabrication process, the LHC covers the anode. To ensure complete removal of the LHC from the anode surface, plasma generated by etching gases is used to bombard the anode surface for LHC etching. However, the etching process is uncontrollable and poses a risk of over-etching. This inevitably damage the anode interface lattice, which enhances grain boundary scattering and leads to a reduction in carrier mobility [2]. Therefore, when power is applied to the Micro OLED, Al migration and damaged anode may burnout, as shown in Figure 2(a). This often causes a short circuit with the corresponding cathode, pulling down the scanning voltage of the pixel row due to the lower potential of the cathode. Consequently, this results in line defects on the Micro OLED display, significantly affecting its performance, as shown in Figure 2(b).

To address these two problems, we designed a special structure of coated anode [3]. The process involves first creating a LHC, then etching recessed anode patterns into this layer, and finally fabricating the anode within the recessed structure. The APMS is shown in Figure 3(a). In this structure, the protective metal is in the outermost layer of the anode sidewall, and its high tolerance and stability can provide coated protection for Al. Additionally, the protruding part of the recessed structure serves as the LHC prior to the anode fabrication. Therefore, the APMS can avoid Al corrosion when defining the anode region, as shown in Figure 1(b). The APMS overturns the traditional approach, where the anode is fabricated first and the LHC is added later to compensate for height differences (as shown in Figure 3(b)). The APMS provides a new idea for the application of unstable metals in the OLED display field.

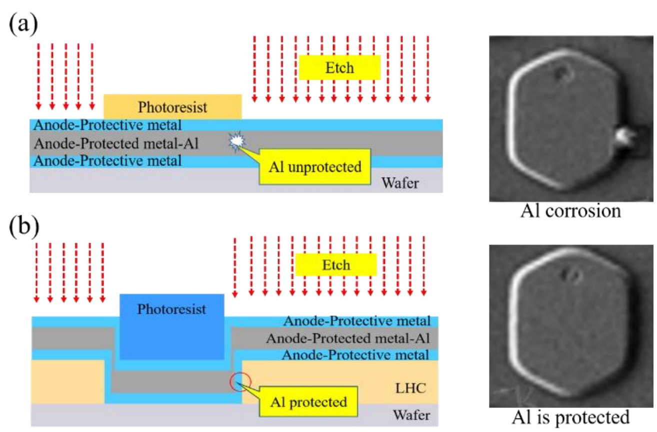

Figure1. (a) Al corrosion occurs without protection. (b) Al is protected from corrosion.

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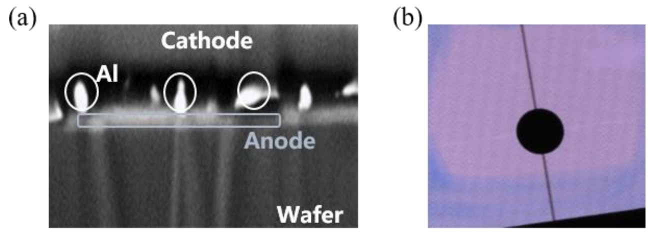

Figure 2. (a) Cathode and anode melting short circuits. (b) line defects.

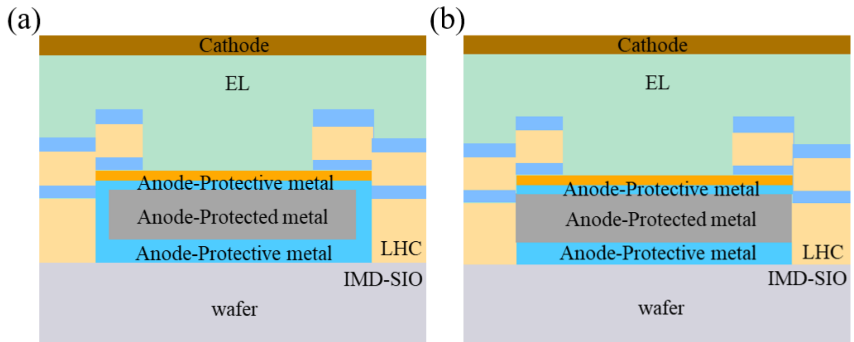

Figure 3. (a) APMS. (b) Traditional structure.

2. Results and discussion

The STEM of APMS was shown in Figure 4. The Al on the anode sidewall was completely coated by protective metal, which effectively avoided the Al corrosion in the process of dry etching and liquid cleaning.

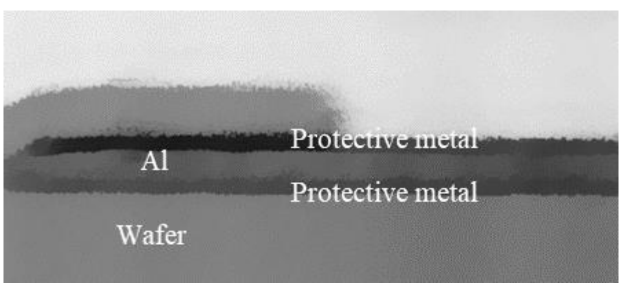

Figure 4. STEM graph of the APMS.

To verify the impact of the APMS on the optical and electrical performance of the Micro OLED, the IVL test was employed for analysis. As shown in Figure 5, the median current density of the Micro OLED using traditional structure was 1.001, while the median current density of the Micro OLED prepared by the APMS was 1.096, showing an improvement of 9.49%.

Next, the relationship between current and brightness of Micro OLED was analyze using IVL. As shown in Figure 6(a), starting from the 6.5V voltage, the current of the Micro OLED with the APMS was significantly better than that of the traditional structure. According to Ohm's law, the impedance of Micro OLED with APMS is better than that of traditional structures. Furthermore, as shown in Figure 6(b), the brightness of Micro OLED based on the APMS was also better at the same voltage.

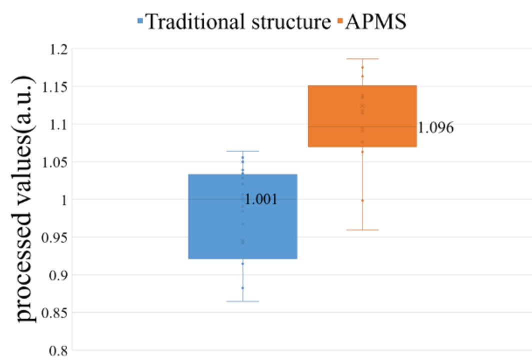

Figure 5. Box graph of Micro OLED current density at 8.5V. The data were specially processed.

The spectrum of Micro OLED with different structure is shown in Figure 7(a). There was no obvious difference between the traditional structure and the APMS in the absolute spectra. However, after normalizing the spectrum, as shown in Figure 7(b), the blue light convergence of the Micro OLED with the APMS was inferior, but the half-peak width of green light exhibits a narrower, the wave peak of green light was higher, and its visual efficiency was improved.

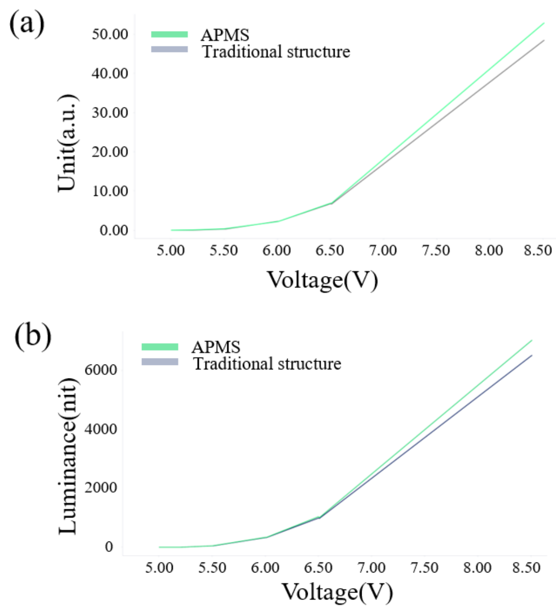

Figure 6. (a) The current-voltage relationship graph of Micro OLED. (b) The brightness-voltage relationship graph of Micro OLED. The data were specially processed.

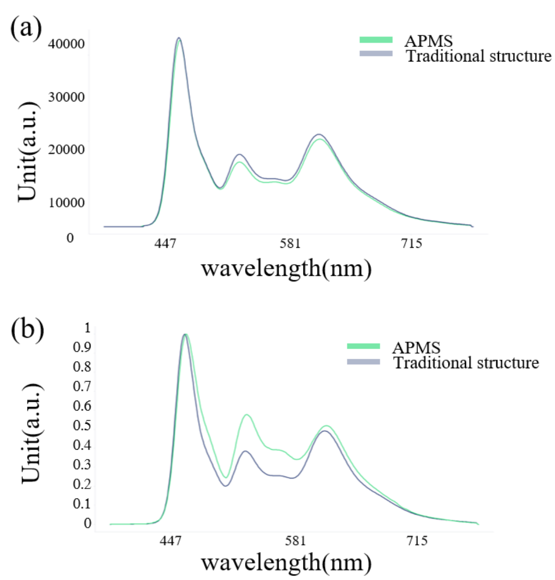

Figure 7. (a) The spectrum of Micro OLED with different structures. (b) Normalized spectrum of Micro OLED with different structures.

To confirm the improvement of the APMS on the burnout defects of Micro OLED, the yield and reliability of the structure sample preparation were evaluated. The results shown in Table 1 indicated that burnout defects in Micro OLED with the APMS decreased by 2.67% compared to the traditional structure, and the image sticking level improved one level. Moreover, the lifetime was improved 4.87% within 240h as shown in Figure 8. This demonstrated that the APMS improved the yield and performance of Micro OLED, which can further reduce the production cost.

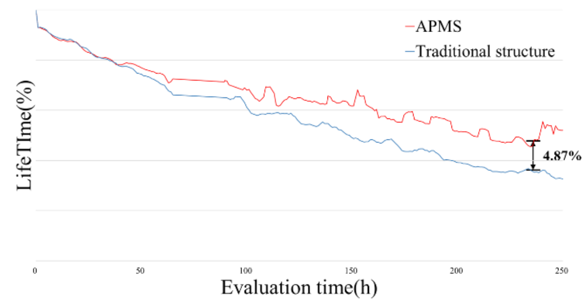

Figure 8. The Lifetime of Micro OLED with different structure.

Table 1. The defects and evaluation level of Micro OLED.

Evaluation type	Traditional	APMS
Burnout defect proportion	5.50%	2.33%
Image sticking level	Level 2	Level 1
Lifetime-240h	-	+4.87%

Notes: The Level of the image sticking is from good to poor, and the level is from 1 to 4.

3. Conclusion

In the field of OLED displays, we proposed a APMS designed to increasing the lifetime. By fabricating the recessed structure first, followed by the anode, we achieved effective protection for Al and anode. The results show that the defect rate of Micro OLED based on APMS was reduced by 2.67% compared with the traditional structure, the image sticking level was improved one level, and the lifetime was increased by 4.87%. Moreover, the reliability and performance of Micro OLED with the APMS were superior to traditional structure. We believe that the APMS can provide a new approach for the research and application of Micro OLED.

References

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