# Research Progress on the Influence of Black Organic Materials on OLED Display Residual Images

Yunqiang Yang*, Dongliang Yu*, Wenzhi Fan*, Zhonglong Yu*, Weiteng Zhang*, Weiqi Xu*, Ying Shen*

* Hefei Visionox Technology Co., Ltd, Hefei, China

## Abstract

***Organic Light-Emitting Diode (OLED) is a depolarizer technology that constructs a color filter stack structure on thin film packaging to replace the traditional core material polarizer with a color filter on encapsulation (COE). In recent years, this technology has been widely used in flexible displays, folding mobile phones, wearable devices and other fields. It has the advantages of wide color gamut, low power consumption, and low thickness. However, the BPDL coating in the COE structure will lead to the low brightness residual image of the display panel, which has become an urgent problem to be solved. In this paper, the correlation between the phenomenon of residual image and the BPDL coating is first explained, and the interaction between materials and processes is concerned. Secondly, the surface morphology and interface morphology of the materials were characterized and evaluated by SEM, AFM, TEM and other methods, and the mechanism of the residual image problem was summarized, and the results showed that the surface roughness and the strength of plasma treatment of BPDL materials were the main factors affecting the residual image. Finally, the methods to improve the residual image problem are discussed, including the optimization of BPDL materials, the adjustment of process gases and parameters, etc. By optimizing the BPDL material and adjusting the process gas and parameters, the residual image problem was effectively improved.***

## Author Keywords

Organic Light-Emitting Diode; residual image; black pixel design layer; flexible display.

## 1. Introduction

With the rapid development of technology, portable electronic devices such as smartphones and tablets are undergoing unprecedented changes[1]. In this revolution, OLED displays have quickly become the choice of the high-end market due to their thinness, flexibility, and vivid colors[2]. However, despite the significant progress made in OLED technology, the technology still faces high power consumption and thicker thickness during use, which is not conducive to application on foldable products. In order to overcome these difficulties, in recent years, a depolarizer technology called COE has emerged, which is widely used in flexible displays, folding mobile phones, wearable devices and other fields. It has the advantages of wide color gamut, low power consumption, and low thickness.

In order to reduce the reflectivity, the current OLED panels using COE technology use a black pixel design layer (BPDL), which is an organic black photoresist with an acrylic system, which can effectively absorb external light and prevent it from being reflected by the anode coating, resulting in increased reflectivity. OLED is driven by the active matrix AM, and the pixels are controlled independently of each other. The degradation difference between pixels will cause the brightness information of the previous picture to be retained on the new picture when the OLED display is switched to the image, and this image adhesion phenomenon is easy to capture by the human eye, which is called the afterimage phenomenon of OLED display. The brightness degradation of OLED is caused by the performance degradation of organic light-emitting materials and thin film transistor TFTs, and a large number of studies on the afterimage phenomenon of OLED are more focused on TFTs. In this paper, the residual image phenomenon caused by the interaction between the BPDL coating and the luminescent material in COE technology is analyzed. This paper analyzes the mechanism of this type of residual image, which provides a new idea for the suppression of OLED residual image.

## 2. Residual image&BPDL technology Analysis

### 2.1 Residual image of OELD display

Figure 1 shows a schematic representation of the ideal OLED display and the actual afterimage phenomenon that occurs. The OLED displays black or white for a period of time and then switches all of these pixels to gray. Ideally, the OLED should switch to this gray brightness quickly in a very short period of time, as shown in Figure 1(b), but due to the degradation of interpixel performance, the black area is originally displayed. The brightness is higher than ideal after switching to gray, while the white area that was originally shown is less bright than ideal, as shown in Figure 1(c).

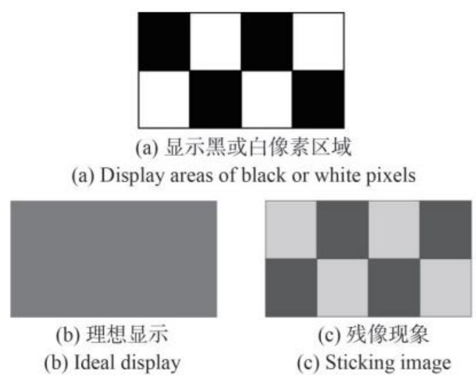



**Figure 1.** Sticking image of OLED display

### 2.2 The Structure of BPDL Display

In OLED displays, the PDL layer is mainly used as a pixel definition layer to control the aperture ratio and separate the R/G/B pixels to prevent crosstalk and leakage. In the OLED display of COE technology, the conventional PDL coating layer needs to be replaced with the BPDL layer, as shown in Figure 2(b), the main purpose of which is not only to play the role of conventional PDL, but at the same time, the black material can effectively absorb external light, thereby blocking the current light.


ISSN 0097-996X/25/5603-1755-$1.00 © 2025

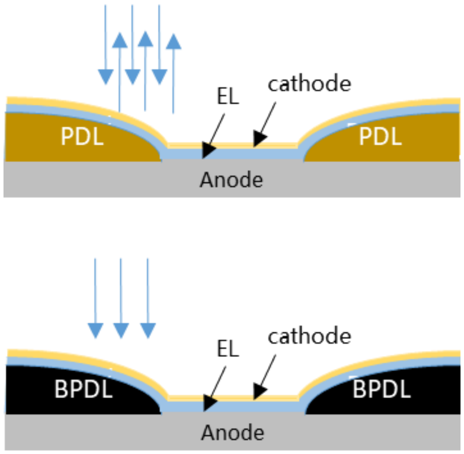



**Figure 2.**The Structure of BPDL Display

Limited by the level of global BPDL material development, at present, BPDL materials that can be applied to commercial use, after the completion of the curing process, there are obvious organic glue residues in the anode pixel region, as shown in the SEM of Figure 4, the organic glue residue will affect the luminous efficiency of the EL film, so the world's major panel manufacturers will add plasma process treatment to remove the residue of organic glue after the curing is completed, that is, the current process of BPDL film Flow is the photo→oven→curing penetrating to the anode to be reflected, resulting in an increase in reflectivity.

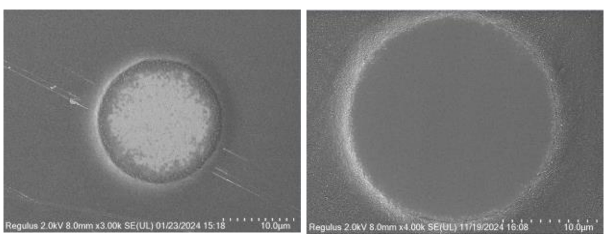


**Figure 3.** The difference between the residue before and after plasma treatment

## 3. Experienement

The experiment was carried out on the Visionox G6 generation line, and the process is shown in Figure 3: the organic layer BPDL is fabricated on a glass substrate by a yellow light process, followed by evaporation and packaging processes. Photoresists are mainly composed of resins, solvents, photoreceptors, and additives. The yellow light process mainly includes four main processes: gluing, exposure, development, and curing. The gluing process is to evenly coat the organic glue on the substrate by using a nozzle nuzzle, and then use vacuum vacuum drying (Vacuum Dry) and a heating table to bake SB (soft bake) to remove most of the solvent in the photoresist, fix the morphology of the organic glue, and enhance the adhesion to the substrate. The exposure process is to use a lithography machine to selectively expose the organic glue, and transfer the pattern on the reticle to the photoresist. The development process is a process in which the unexposed part of the photoresist (negative adhesive) or the exposed part (positive adhesive) is dissolved by the developer to form a specific design pattern. The curing process uses a heating furnace layer to heat multiple substrates to completely remove the solvent and make the photoresist fully cross-linked and cured.

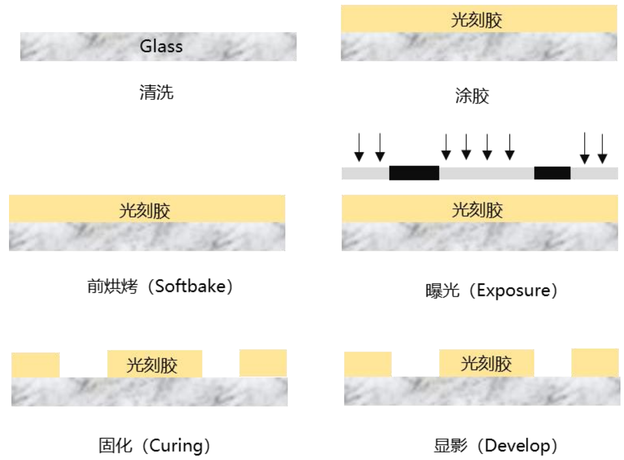
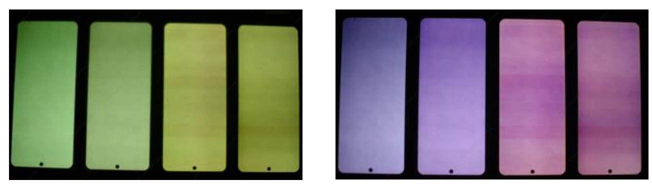



**Figure 4.** Process flow of lithography (Negative photoresist)

## 4. Simulation and Results

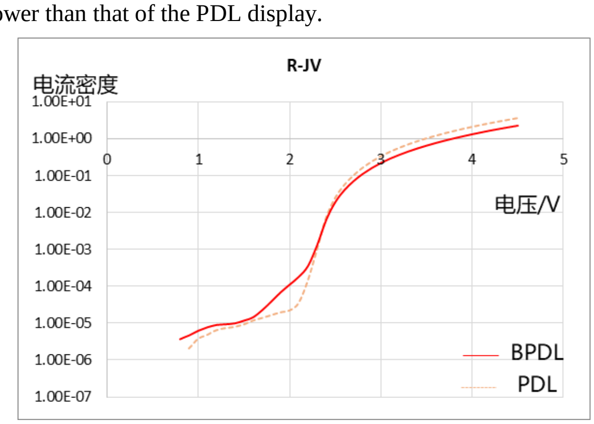
Comparing the afterimage performance of PDL and BPDL displays, the test method is to use a black and white interval screen, light up at high brightness for 1 minute, and switch to gray screen and linear mode, as shown in Figure 4, it can be seen that there is obvious afterimage on BPDL displays. The results show that this type of afterimage has no correlation with the TFT of the display driver circuit, mainly with the OLED device of anode-light-emitting material-cathode.



(a) Low-brightness display (b) Linear display screen

**Figure 5.** The residual image performance of PDL and BPDL displays

Comparing the IV curves and luminous efficiency of PDL and BPDL displays in the R/G/B screen, the results are shown in Figure 6, when the voltage is the same in the low-brightness screen, the BPDL display requires a higher current, which indicates that the luminous efficiency of the BPDL display in the R/G/B screen is lower than that of the PDL display.



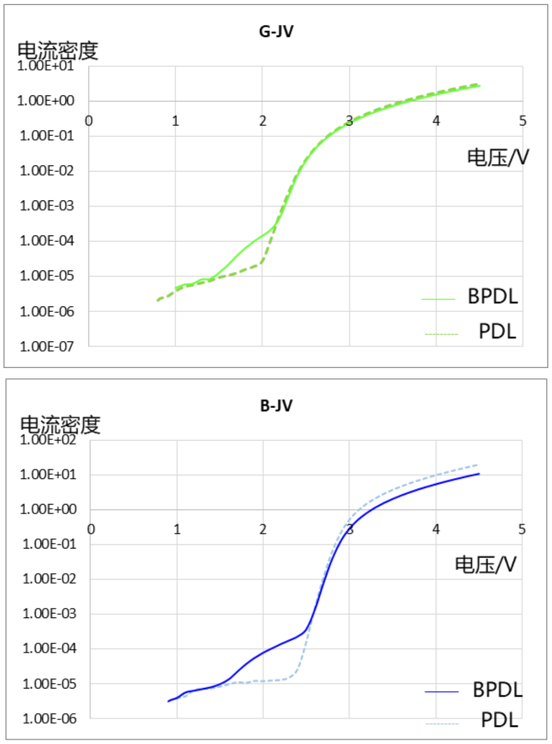
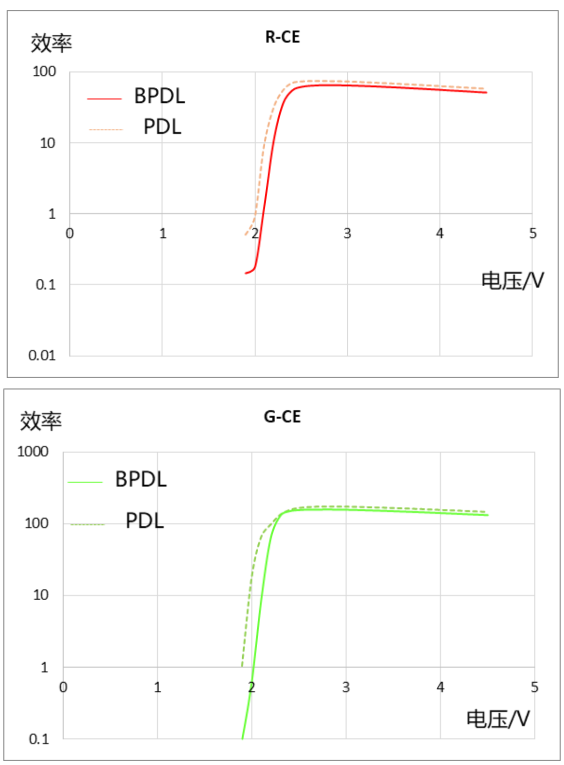



**Figure 6.** The current and voltage curves on the R/G/B screen



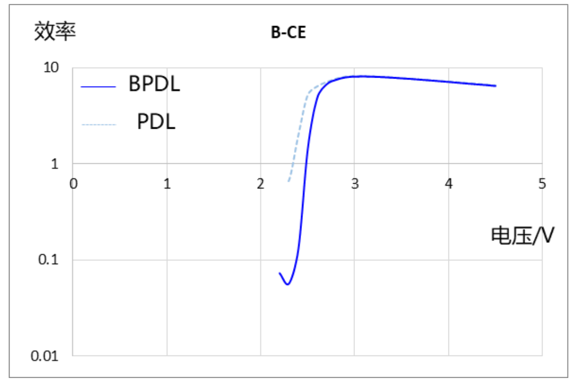
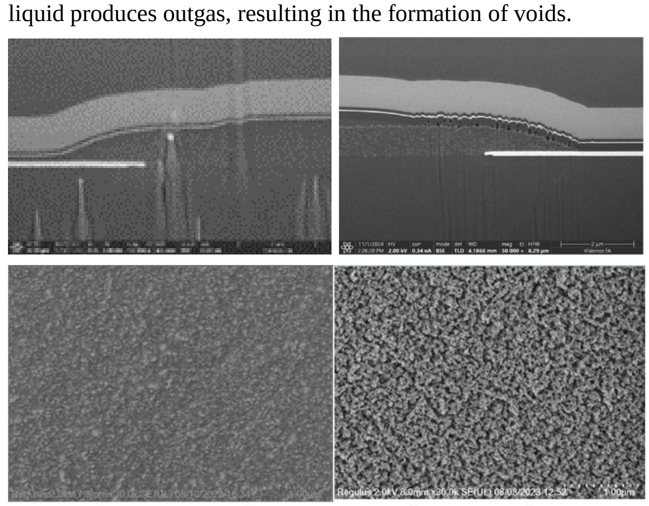




**Figure 7.** Efficiency in the R/G/B screen

In view of the comparison of the residual image performance of DL and BPDL displays, it is speculated that the difference in efficiency between BPDL and PDL displays is mainly caused by the interface difference between BPDL coating and light-emitting materials. The film structure and topography of the display were characterized using scanning electron microscopy (FIB-SEM, model LYRA3 XMH ) and transmission electron microscopy (TEM, model JEM-2010). Compared with PDL display, there is an obvious void in the pixel taper corner of BPDL display, and when this void is eliminated by adjustment, the residual image effect of the display has been significantly improved, and there is reason to believe that the poor afterimage effect of BPDL display is mainly caused by the void at the taper. Further experiments were carried out to verify the cause of the formation of the void, and the results were mainly caused by BPDL plasma, and the void at the taper could completely disappear when the plasma treatment was removed. With the advancement of the BPDL process, it can be found that when the BPDL film layer is treated with plasma, the surface morphology of BPDL changes from the original dense structure to the nano-porous structure, and the formation of the porous structure is mainly because the plasma is essentially an etching process, which will make the resin and other components of the BPDL organic material be etched, and the inorganic components in it are difficult to be etched, which leads to the formation of nano-porous morphology. Figure 8 shows the surface topography of BPDL organic materials as a function of the process. This porous morphology adsorbs the peeling solution of the subsequent film layer, and during the evaporation process of organic luminescent materials, the adsorbed liquid produces outgas, resulting in the formation of voids.



→Photo→Oven →Photo→Oven→plasma

## 5. Conclusion

Combined with the electrical performance and microscopic morphology test, the plasma process introduced by the BPDL coating layer makes the film layer change from a dense state to a nano-porous state, which adsorbs the stripping solution in the subsequent process, and in the evaporation process, the stripping solution is easy to outgas and cause cavities, which will cause the charge transfer to be significantly affected when the display is at low brightness, resulting in the occurrence of afterimage phenomenon.

## 6. Reference

1. Xu CX, Shu S, Lu JN, et al. 24-4: Foldable AMOLED Display Utilizing Novel COE Structure[C]/SID Symposium Digest of Technical Papers. John Wiley & Sons, Ltd, 2018. DOI:10.1002/sdtp.12548.
2. Franon M, Krauzman N, Mathieu J, et al. Diffraction at Infinity (Fraunhofer)[J. Experiments in Physical Optics, 2021 DOI:10.1201/9781003062349-9.
3. Iemmi, Claudio, and S. Ledesma. "Fraunhofer diffraction patterns generated by mixed Cantor gratings." Optics Communications 112.1-2(1994):1-8.
4. Schneider, John. "Understanding the Finite-Differenee Time-Domain Method." (2022).
5. Hecht, Eugene. "Optics, Global Edition, 5/E