Study on the Impact of Static Electricity on LTPS TFTs and Its Mechanism in Flexible OLED Devices Manufacturing Process

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Abstract

In the process of flexible organic light-emitting diodes (OLEDs) fabrication, the generation of static electricity is a very common phenomenon. In this study, a static electric field was applied to the back of OLED devices to observe changes in device brightness and measure the electrical characteristics of TFTs. The experimental results show that when a static electric field is applied to the back of the device, the brightness increases (with a negative charge) or decreases (with a positive charge). After the static electric field is removed, the brightness immediately returns to a level close to its initial state. Furthermore, the above phenomena are consistent with the effects of applying voltage to the back of LTPS TFTs. This paper demonstrates the impact of static electricity on OLED devices and reveals its underlying mechanisms through a study of TFT characteristic changes under a static electric field.

Author Keywords

LTPS, static electricity, TFT, mura.

1. Introduction

Electrostatic discharge (ESD) events have been proven to be a serious problem in the display industry, particularly in flexible organic light-emitting diodes (OLEDs)[1]. As is well known, flexible OLEDs contain many thin film layers that provide various pathways for electrostatic charges to enter the display body. At the same time, there is no glass substrate under the channel of the thin film transistor (TFT), only flexible films such as polyimide (PI), which exacerbates the impact of electrostatic charges on the TFT. Therefore, the issue of static electricity has undoubtedly attracted widespread attention in the OLED field.

Researchers have studied IGZO or amorphous silicon as TFT display devices, and found that display devices may experience display failure in the presence of static electricity[2]. However, these studies only focus on the generation of static electricity and have not delved deeper into its underlying mechanisms.

In this paper, the influence of positive static electricity and negative charge on the PI side of LTPS OLED display devices is systematically revealed. Meanwhile, by constructing a testing system, this phenomenon was associated with the drift of electrical characteristics of LTPS TFT when subjected to static electricity, explaining the mechanism of static electricity affecting LTPS OLED display devices.

2. Experimental Details

2.1 Device Fabrication

Flexible OLEDs are manufactured using traditional low-temperature polycrystalline silicon (LTPS) technology. After thermal curing, a polyimide film is first coated onto the glass substrate. Subsequently, a buffer layer composed of 300 nm silicon nitride (SiNx) and 300 nm silicon dioxide (SiO_2) is deposited. A 50 nm amorphous silicon layer is then grown via plasma-enhanced chemical vapor deposition (PECVD) and crystallized using an XeCl excimer laser beam. The PECVD technique is also employed to prepare the gate insulator (GI). Following this, gate metal is formed, and ion doping is performed on the top polycrystalline silicon layer. Diffusion annealing is subsequently conducted in a nitrogen environment. After depositing the intermediate layer, contact holes are patterned, and source/drain electrodes are deposited. Next, the OLED functional layers are sequentially deposited, including the hole injection layer (HIL), hole transport layer (HTL), RGB emission layer (EML), electron transport layer (ETL), electron injection layer (EIL), and a 15 nm-thick transparent cathode composed of Mg:Ag (1:9). A thin-film encapsulation layer with a SiO_2/polyimide composite structure (150 nm/2 μm thickness) is then prepared. Finally, the glass substrate is removed via laser lift-off (LLO) to obtain the flexible OLED device. [3]

2.2 Testing Equipment

The electrical characteristics of TFT were tested using Keysight 1500B and a 4-terminal probe station. The static electricity impact testing system for display devices uses a constant voltage DC voltage source and CA410 equipment to obtain brightness.

3. Result and discussion

As shown in Figure 1, the flexible OLED device produces dark mura at 0.03 nit. After 12 hours of generating this mura, this phenomenon disappears. The above results indicate that the cause of this mura is due to some kind of electrostatic influence.

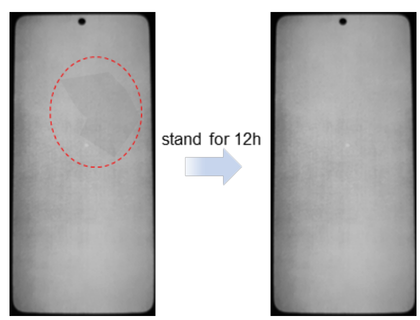

Figure 1. OLED devices affected by static electricity.

In order to understand the influence of static electricity types on OLED devices, a testing system as shown in Figure 2 was established. A small area on the PI side of the OLED display device was adhered with conductive tape, and different voltages were supplied to test its brightness during testing.

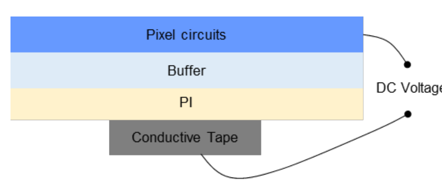

Figure 2. Schematic diagram of PI side voltage application

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The test results are shown in Figures 3 (a) and (b), respectively. When the PI side has a static electric effect of +60 V, the brightness of the area where the voltage is applied significantly decreases (Figure 3. (a)); When the applied voltage area is -60 V, the brightness of the applied voltage area will increase. Further using professional brightness testing equipment, as shown in Figure 3 (c), the brightness will decrease or increase at the moment of applying voltage. Both of the above phenomena recover instantly when the voltage is removed. This flexible OLED device is affected by external charges, as shown in Figure 3 (d), and has also been shown to vary linearly, R^2=0.98。

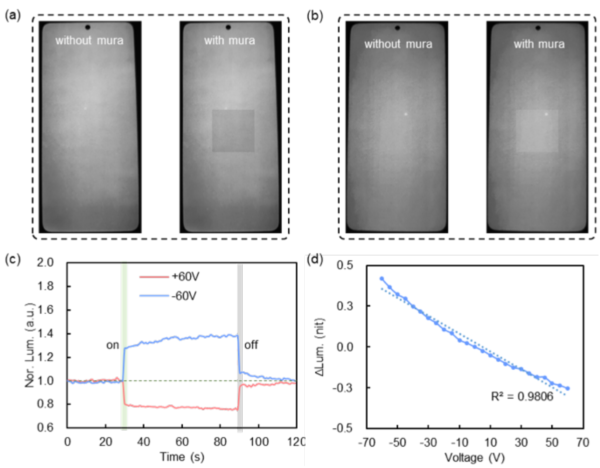

Figure 3. The brightness of the physical image varies with static motion: （a） +60 V, (b) -60V; (c) At 0.03 nit, brightness is affected by voltage. （d）Brightness variation induced by applied voltage changing with 0.03 nit initial brightness.

In order to investigate the formation process of electrostatic damage in flexible OLEDs, the typical transfer characteristic curve of TFTs was measured.

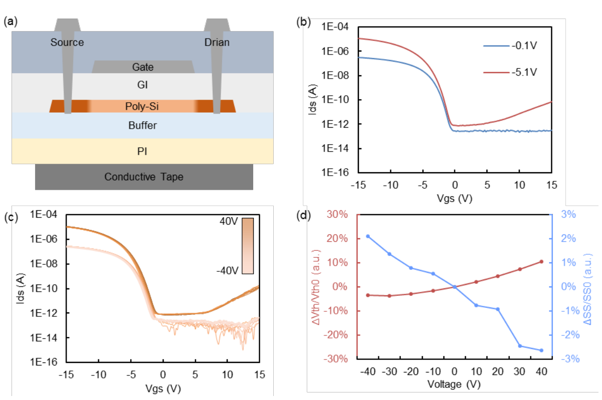

Figure 4.（a）, (b) Typical transfer characteristics curves of TFTs; (c) Transfer characteristics curves affected by PI side voltage. （d）The change rate of Vth and SS of TFT compared to the initial state under different PI side voltages.

As shown in Figure 4 (a), it is a schematic diagram of the PI back pressure of the LTPS TFT device. Figure 4 (b) shows the transfer characteristic curve of the TFT under normal and static free conditions at Vds = -0.1 and -5.1 V, indicating that the LTPS OLED device has no static effect phenomenon. Under normal circumstances, TFT has a threshold voltage (Vth) of -2.5 V and a subthreshold swing (SS) of 0.5 V/dec. As shown in Figure 4 (c), the transfer characteristics of TFT devices undergo significant changes when there is a voltage on the PI side, resulting in the phenomenon of Vth and SS changing with the PI side voltage in Figure 4 (d). Once the characteristics of TFT change, the output current will also change accordingly, so the generation of static electricity will cause changes in the brightness of OLED display devices.

4. Conclusion

In summary, a model of static electricity on flexible OLED display devices was established and validated by applying voltage on the PI side. The brightness and TFT electrical characteristics of OLED devices were experimentally measured as they vary with different voltages. The results indicate that the phenomenon of flexible OLED devices changing with brightness is strongly correlated with changes in TFT characteristics.

5. References

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