

# Research on the High-Temperature Lifetime Stability of Tandem Devices

Juewen Zhao\*, Kailong Wu\*, Zhao Li\*, Fang Wang\*, Lin Yang\*, Yu Gu\*,  
Chao Dai\*, Ming-Chou Wu\*

\*Wuhan China Star Optoelectronics Semiconductor Display Technology Co., Ltd., Wuhan, China

## Abstract

We found that the CGL of our tandem devices is not stable enough. n-dopant and p-dopant may react at the interface of n-CGL and p-CGL, which will cause lifetime suddenly drops accompanied by a rapid increase in voltage under ultra-high temperature conditions. Therefore, we have developed a new CGL structure which makes our tandem OLED can operate stably at 110°C with a very small V-shift voltage.

## Author Keywords

Tandem; OLED; CGL; Lifetime; Stability

## 1. Introduction

With the gradual maturity of the Organic Light Emitting Diodes (OLEDs) manufacturing process, the applications of OLED gradually increase in the fields of: wearables, mobile phones, tablets, laptops, and vehicles. As the application scenarios of OLED expand, consumers' demand for OLED displays is also growing. In recent years, tandem OLED have received a lot of attention in display fields such as mobile phones and vehicles due to its advantages of low power consumption, high brightness and long device lifetime. The tandem OLED connects two or more light-emitting units in series through the CGLs (Charge Generation Layers), which is a crucial component in tandem devices. When a voltage is applied across the tandem device, the CGL can produce both holes and electrons. These charges are then injected into the adjacent light-emitting units. In general, the CGL has a p-n organic heterojunction structure and is composed of a hole transport layer doped with p-type dopants (p-CGL) and an electron transport layer doped with n-type dopants (n-CGL). As p-type dopants, transition metal oxides such as molybdenum trioxide (MoO<sub>3</sub>) and tungsten trioxide (WO<sub>3</sub>) or deep-lying lowest unoccupied molecular orbital (LUMO) materials such as F4TCNQ, HATCN, and NDP-9 are used.[1] On the other hand, as n-type dopants, alkali metals and their carbonate composites are mainly used.[2] A CGL that works stably under high temperature and large current density is of great importance for achieving stable tandem devices that can meet the demands of various application scenarios. It was reported that due to the strongly reducing Li dopant and the strongly oxidizing F4-TCNQ dopant, chemical reaction between Li-doped Alq<sub>3</sub> and the F4TCNQ-doped NPB layer leads to the formation of neutral complexes at the interface, which leads to CGL degradation.[3]

Here, in this work, we examined degradation characteristics of CGL under electrical and thermal stress at the same time. We have found that there are some defects in the CGL we are currently using, which causes tandem devices more prone to failure than single devices under harsh environments. We studied the causes of the defects and made improvements, and finally greatly enhanced the stability of tandem devices at high temperatures.

## 2. Results and Discussion

### 2.1 The Lifetime of Tandem Device under Ultra-high Temperatures

Ignoring the higher costs of tandem devices and some unresolved issues, their higher peak brightness, lower power consumption and longer lifetimes have been favored by many consumers. However, with the increase in product types and application scenarios, consumers' demand for display screens has increased, especially in extreme environments. Therefore, we have studied the working conditions of tandem devices in extremely high temperature environments. Figure 1 shows the lifetime and the corresponding delta-V curves of our tandem devices at 110°C and a current density of 10 mA/cm<sup>2</sup>. It can be seen that the lifetime suddenly drops accompanied by a rapid increase in voltage, which means that display abnormalities may occur in extreme environments. Solving this problem is important for improving the quality of our products.

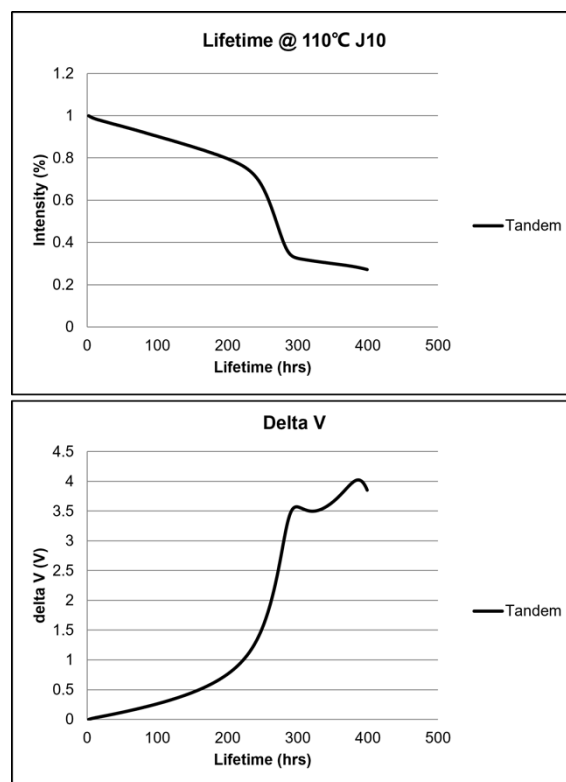


Figure 1. The lifetime and delta V curves of tandem device at 110 °C and a current density of 10 mA/cm<sup>2</sup>

### 2.2 CGL Degradation Analysis

First, we confirmed that the glass transition temperatures ( $T_g$ ) of all materials in the tandem devices are higher than  $110^\circ\text{C}$ , which can rule out rapid degradation of the tandem devices at  $110^\circ\text{C}$  caused by material phase transitions. As is well known, the n-dopant and p-dopant in CGL, due to their strong redox properties, will undergo chemical reactions to form neutral compounds, thereby affecting the performance of the tandem devices. To study whether our tandem devices' CGL has similar phenomena and whether it is related to the rapid degradation at ultra-high temperatures, we conducted two simple comparative experiments.

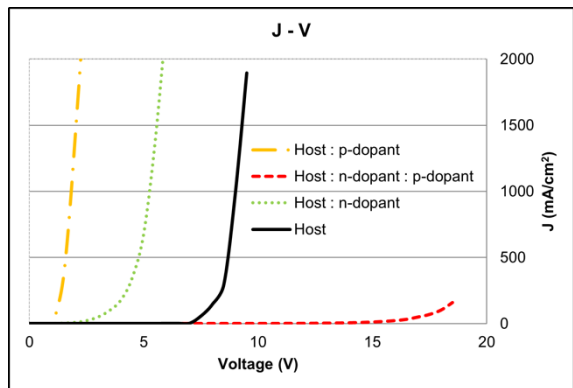


Figure 2. J-V curves of 4 films

As shown in Figure 2, we prepared 4 simple single-layer devices and tested their J-V curves. When n-dopant or p-dopant is separately doped into the host material, the conductivity of the thin film increases. However, when n-dopant and p-dopant are jointly doped into the host material, the conductivity of the thin film drops sharply, which may be due to the occurrence of chemical reactions, resulting in some traps or other neutral compounds that hinder conductivity. The above results indicate that the contact between n-dopant and p-dopant at the n-CGL/p-CGL interface of our CGL is unstable, which may be the reason for the rapid degradation of the device at high temperatures.

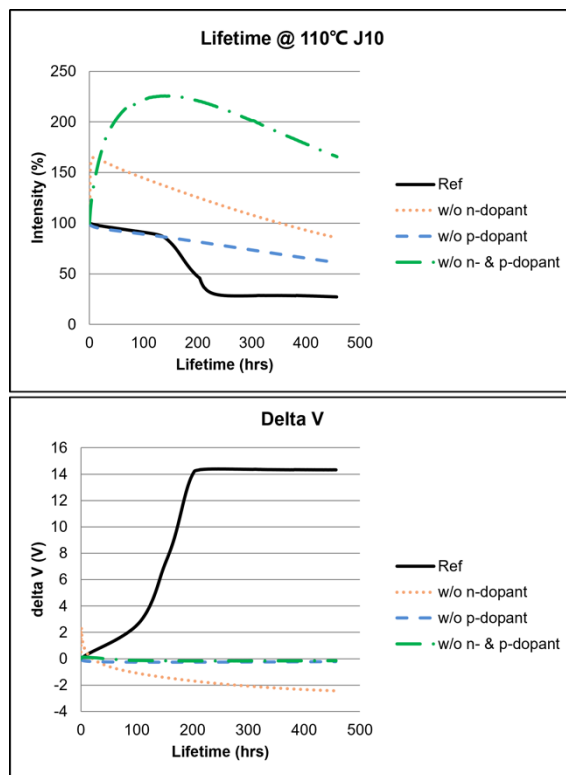
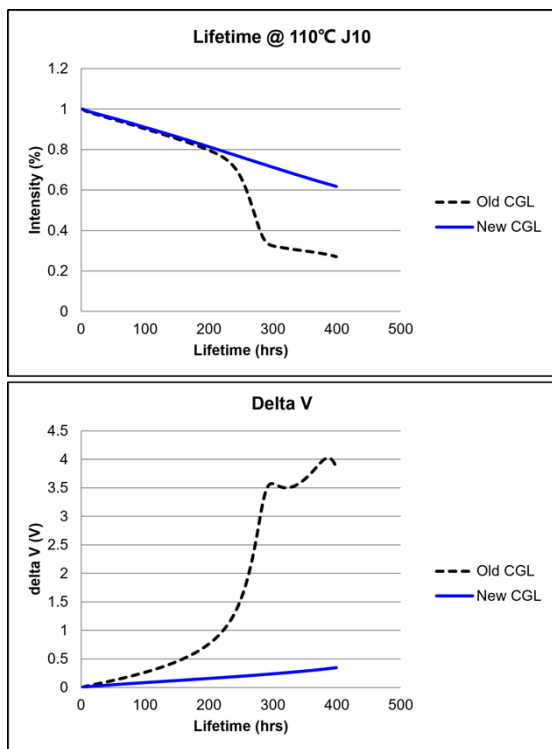


Figure 3. J-V curves of 4 films

### 2.2 CGL Degradation Analysis

Although removing n-dopant or p-dopant can make CGL more stable, the operating voltage of the device is very high, which is unacceptable. Therefore, we have re-developed a new CGL that can improve the high-temperature lifetime stability of the device without sacrificing the voltage. As shown in Figure 4, the device based on the new CGL has a normal brightness decay at  $110^\circ\text{C}$ , and the voltage only rises slightly, which enables our tandem device to be applied in more scenarios.



**Figure 4.** The lifetime and delta V curves of new CGL based tandem devices at 110 °C and a current density of 10 mA/cm<sup>2</sup>

### 3. Conclusion

We found that our tandem device's lifetime suddenly drops accompanied by a rapid increase in voltage under ultra-high temperature conditions. Through analysis, we identified the cause of this phenomenon as the instability of CGL. Eventually, we developed a new and more stable CGL, which can improve the high-temperature lifetime stability of the devices without sacrificing the voltage, which enables our tandem device to be applied in more scenarios.

### 4. References

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