High Performance Short Channel Oxide TFTs for Transparent Top Emission OLED TVs

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ABSTRACT

High performance TFTs with a short channel and good uniformity are required to mass-produce transparent top emission OLED TV. The uniformity of Vth and Ion are improved by controlling effective channel length. Negative Vth shift under NBTiS conditions is improved by optimizing light shield and buffer layers.

1 INTRODUCTION

Organic light emitting didoes (OLEDs) have attracted considerable attention to date because of a great advantage over liquid crystal displays (LCDs) in terms of the realization of a lively color, perfect black and wide viewing angle [1,2]. The oxide thin film transistors (TFTs) integrated with OLEDs are considered to be key technologies to offer more unique applications. Among them, coplanar self-aligned oxide TFT structures have been recently adopted as an optimal platform to overcome the hurdle in achieving high resolution and high driving OLED TVs. In addition, transparent displays have a variety of potential applications such as a signage and show window in the store. The transparent displays are made up of pixels to create colors and the clear section to make transparency. In practice, compact and high performance TFTs are preferred for maximum transparency of OLED TVs.

In this report, it has been demonstrated that high performance oxide TFTs with a short channel length can be efficiently fabricated and realized. In addition, the degradation origins of the oxide TFTs as well as possible ways to improve device uniformity and stability are discussed.

2 EXPERIMENT

The fabrication processes of TFTs for transparent top emission OLED TVs is almost the same as those of bottom emission TFTs except for the auxiliary electrode which functions as mitigating voltage drop of cathode. However, it causes numerous changes in the encapsulation process. First, a transparent glass instead of a metal as encapsulation materials is necessary to emit the light to the top direction. OLED devices are protected and passivated by dam and fill processes. Color Filter layers move to the position next to the encapsulation glass.

3 RESULTS

Two different configurations exist for OLED emission types, as shown in Figure 1. The OLED configurations are classified by the direction of light emission. The light emission occurs to the direction toward or against TFT substrate, which is called a bottom or top emission type, respectively. The top emission type is more suitable for transparent displays in view of occupying the transparent and emissive area.

The channel length is composed of the effective channel and 2ΔL, where 2ΔL is the diffusion length of oxygen vacancies from the n+ InGaZnO (IGZO) region to the channel formed during metallization and thermal annealing processes. In Figure 2, the TFT transfer curves, I_d-V_{gs}, are performed in order to collect V_{th} as a function of a channel length (2.5-8.5μm). It exhibits that the uniformity of V_{th} comes out to be 0.2V when the channel length of 6.5μm is used. The V_{th} experiences the shift towards negative side whereas the uniformity of V_{th} gets worse as the channel length decreases. Total resistance of the TFTs as a function of a channel length (3.5-8.5μm) is plotted in Figure 2 (b). The gate bias, V_{gs}, is varied from 3V to 15V. As a result, the 2ΔL of -0.6μm is extracted from the plot. Figure 3 displays the V_{th} shift of transfer curves after 4000 seconds of NBTiS under the stress conditions of V_{gs} = -30V, V_{ds} = 0V at 60°C as a part of the device reliability performance. The 4500 nit of visible light shines from the top or bottom of the TFTs. The V_{th} of the TFTs with the bottom emission configuration is shifted by -12.5V regardless of the light direction after 4000 seconds of NBTiS. Nevertheless, there exists only a V_{th} negligible shift for the top emission configuration when the light shines from the top whilst the V_{th} turns out to be -2.5V when the direction of incident light is reversed. Therefore, it confirms that the top emission type helps to improve the device stability relative to the bottom emission type.

We successfully demonstrate the top emission TFT device concept through the mass production of 55-inch FHD transparent OLED TVs. As shown in Figure 4, it is designed to have 4 sub-pixels of WRGB, the transparency of 40%, and peak white luminance of 400cd/m^2.

4 DISCUSSION

As described above, we confirm that the V_{th} shifts towards a negative direction and its uniformity becomes worse as the channel length gets shrunk. The uniformity of V_{th} gets widened from the channel length of 5.5μm. The V_{th} rolls off from around the channel length of 5.5μm as well. Throughout all the process optimization, the V_{th} roll off and 2ΔL have been significantly improved from our previous reference numbers. Therefore, it allows the one to extend the range of a channel length towards a short channel length side.

The NBTiS improvement observed here is explained as follows. The reflective and transparent anodes (see Figure 1) are employed for the top and bottom emission types, respectively. Therefore, the most of incident light from the top is reflected by the reflective anode in the case of the top emission configuration. On the other hand, when it comes to the bottom emission configuration the incident light mostly passes through the transparent anode interfering the TFT device performance. In addition, better reflective and opaque materials for light shield and buffer layers, respectively, are applied for the top emission type TFTs. As a result, NBTiS performance of the top emission TFTs using bottom light also shows the negative V_{th} shift (-2,5V) which is much less pronounced compared to that (-12.5V) of the bottom emission TFTs. It is because the most of the incident light is reflected out or absorbed through the light shield and buffer layers, respectively. The improved performance of NBTiS is attributed to the reduction of photo-induced electron and hole generation due to modification of light shield and buffer layers as described above.

5 CONCLUSIONS

Short channel oxide TFTs for top emission transparent OLED TVs have been investigated. It is demonstrated that the wider range of a channel length can be employed by minimizing 2ΔL. Plus, the NBTiS of the top emission TFTs for both top and bottom lights exhibits much better reliability performance compared to that of the bottom emission TFTs. Furthermore, we have successfully developed high performance short channel oxide TFTs for 55-inch FHD transparent OLED TVs on the Gen 8.5. It is designed to have 4 sub-pixels of WRGB, the transparency of 40%, and peak white luminance of 400cd/m2. This technology opens up the possibilities for the realization of high performance transparent OLED TVs and expansion of a variety of applications such as a signage and show window in the store..

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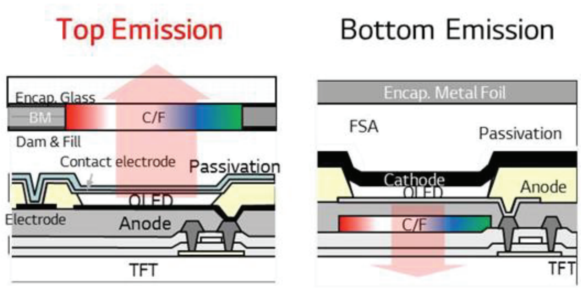


Fig. 1 Schematic cross-sections of top and bottom emission OLED structures

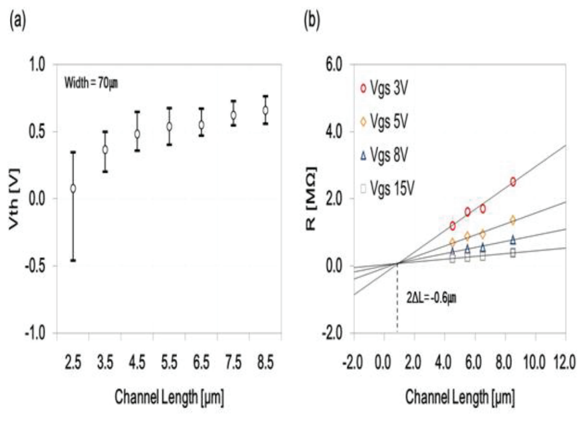


Fig. 2 Overall Vth uniformity with channel length of 8.5μm to 2.5μm and 2ΔL

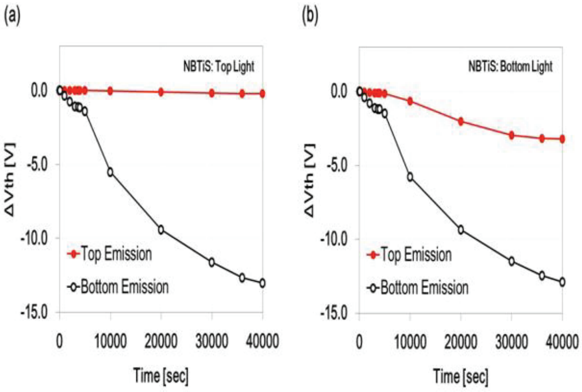
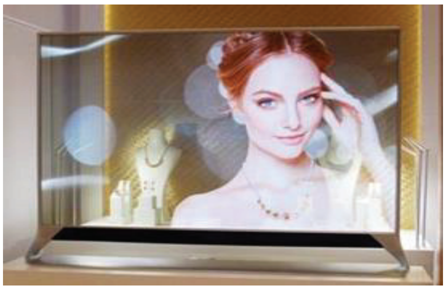


Fig. 3 NBTiS of bottom and top emission TFTs



Description	Panel Specification
Screen Type	W-OLED
Screen Size	55 inch / 139cm
Resolution	FHD (1920 x 1080)
Emitting Direction	Top Emission
Brightness	400/150 nit
Transmittance	40%

Fig. 4 Photograph and specifications of 55-inch FHD transparent OLED TVs