The Introduction of Ink-Jet Printing Technology Progress

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ABSTRACT

Top emission RGB hybrid tandem OLED devices with first RGB devices in solution process and a second evaporated common blue device will be introduced in this paper. The blue emission of green and red tandem devices can be removed by introducing color filters for the panel application to reach high color gamut with DCI-P3 (CIE1976) in 98.3%. Through the addition of common evaporated process blue device onto the solution processed RGB devices, the power consumption ratio of RGB device of the panel will approach to close 1: 1: 1 based on the calculated results.

1 Introduction

OLED display production based on ink-jet printing (IJP) technology has attracted tremendous attention as JOLED showed the capability and progress in G5.5 factory production for the 21.6" 4K and 31.5" 4K panel in 204ppi and 140ppi, respectively.[1] However further optimization of inks, devices, printer, processes, pixel design and panel architecture is essential to outstand IJP from other technologies. In order to establish the next technology of medium and large size OLED business, BOE had focused in the development both in WOLED and IJP OLED at the same time for decade. 55" 4K and 8K IJP AMOLED panels had been demonstrated since 2018. [2] In this paper, a key development of top emission hybrid tandem solution RGB OLEDs (**Fig. 1**) enhancing the performance of panel will be introduced in this paper.

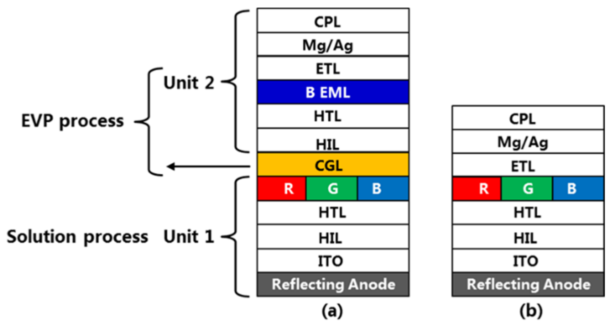

Fig. 1 Architecture of (a) top emission RGB hybrid tandem OLED and (b) single unit RGB OLED.

2 Experiment

The size of top emission substrate is 4cm×4cm with four light-emitting regions with 3mm×3mm emitting area. The substrate was cleaned with alkali and deionized water each 10 minutes and baked for 30 minutes under vacuum with 200°C. Then the substrate was exposed under UV radiation for 3 minutes to increase the work function.

The HIL, HTL and EML of solution unit were prepared by spin coating and baked in air for HIL and in nitrogen for HTL and EML respectively. The baking temperature of HIL/HTL/EML decreases gradually. Devices were then transferred to a vacuum thermal evaporator chamber (Vacuum < 5 × 10^{-5} pa) for following vapor deposition of CGL, evaporation blue unit, metal cathode and CPL.

Table 1. The hybrid tandem devices performance under 10mA/cm².

Device*		V (volt)	C.E. (cd/A)	CIE-x	CIE-y	Blue Index
R	Tandem	9.4	30.2	0.612	0.330	-
	Single	7.0	26.2	0.650	0.349	-
G	Tandem	10.4	66.1	0.229	0.592	-
	Single	8.1	67.2	0.259	0.688	-
B	Tandem	10.1	10.0	0.135	0.063	**158**
	Single	6.6	6.0	0.136	0.089	**67**

Table 2. The hybrid tandem devices performance under 10mA/cm² with color filter.

Device*		V (volt)	C.E. (cd/A)	CIE-x	CIE-y	Blue Index
R	Tandem	9.4	20.2	0.678	0.319	-
	Single	7.0	17.4	0.674	0.326	-
G	Tandem	10.4	50.0	0.209	0.692	-
	Single	8.1	54.8	0.221	0.722	-
B	Tandem	10.1	6.3	0.136	0.051	**123**
	Single	6.6	3.0	0.135	0.059	**51**

1. *. Single unit device fabrication based on spin coating process.

2. Current Efficiency and CIE-x y data were calculated with CF transmission spectra.

3 Results

The performances of R/G/B hybrid tandem devices and single unit devices are shown in **Table 1** and **Table 2**, in which the current efficiency and CIE coordinate were treated before and after with color filter (CF). The blue index (BI) of hybrid tandem blue device showed more than two times higher compared with that of the single unit blue device no matter treated with CF or not. The single unit solution processed blue device exhibited current efficiency of 3.0 cd/A and BI of 51 with CF. Due to the additional evaporated blue unit, the efficiency of the tandem blue device had been greatly improved, achieving current efficiency of 6.3 cd/A and BI of 123, about 2.4 times compared to the single unit blue device after treated with CF. On the other hand, the hybrid tandem red and green device efficiencies maintained a comparable level to single unit structures. After treated with CF, the hybrid tandem devices exhibited 20.2 cd/A with a CIE coordinate of (0.679, 0.320) for red and 50 cd/A with a CIE coordinate of (0.258, 0.692) for green respectively. The EL spectra of hybrid tandem devices are shown in **Fig. 3**. The blue peaks about 450nm in both green and red become very weak due to strong cavity effect, which may be the reason why red and green devices maintain high efficiency.

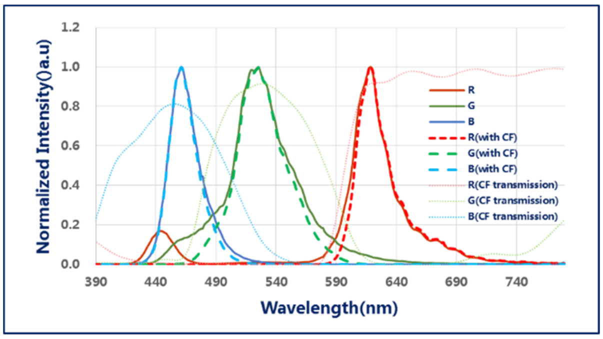

Fig. 3 Graph of spectra of R/ G/ B hybrid tandem device treated with and without R/ G/ B CF transmission spectra respectively, and R/ G/ B CF transmission spectra.

The operation lifetimes of hybrid tandem device and single unit device are shown in **Fig. 4**. Worse lifetime is exhibited in the tandem hybrid red and blue device, which may be caused by charge unbalance between hole and electron in the tandem structure. Processing and ink optimization will be introduced to improve hybrid tandem device lifetime in the next step.

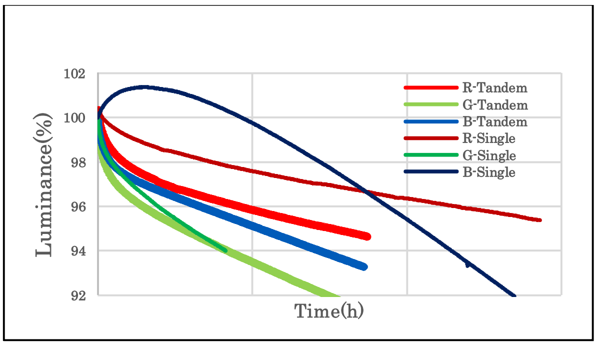

Fig. 4 Lifetime of hybrid tandem device and single unit device.

4 Discussion

Table 1 showed the performance of top emission RGB single unit and hybrid tandem devices. The driving voltage of hybrid tandem structure under 10mA/cm^2 increased 2.4V, 2.3V and 3.5V for red, green and blue device respectively, compared with the single unit device. The reason for the driving voltage gap of blue device is higher than red and green device is not clear now. It might be the interface deviation of material between EML and CGL. The blue emission of red and green hybrid tandem devices can be remove by color filter and reach higher color purity in (0.678, 0.319) and (0.209, 0.692), respectively. The color coordinate of blue hybrid tandem device also can be improved and reached in a CIE(x, y) = (0.136, 0.051) by color filter.

Table 3. Panel performance based on various panel architecture based on calculation.

Panel Architecture*	Device Performance on Panel					27" @200nit,	
	Color	cd/A	BI	CIE x	CIE y	Power(W) (0.308,0.327)	Color Gamut (DCI-P3)***
Single RGB OLEDs (w/ AR film)	R	24	-	674	0.326	11.9	93.4%
	G	70	-	0.221	0.722	9.0	
	B	3	51	0.135	0.059	19.8	
	W	18.7	-	0.308	0.327	40.7	
Hybrid Tandem RGB OLEDs (w/ AR film)	R	22	-	0.678	0.319	12.4	97.8%
	G	55	-	0.209	0.692	12.4	
	B	7	123	0.136	0.051	9.4	
	W	27.2	-	0.308	0.327	34.2	
T/E 3 Units Tandem WOLED** (w/ POL)	R	1.8	-	0.672	0.322	116.5	97.4%
	G	10.9	-	0.283	0.670	63.1	
	B	1.3	24.6	0.142	0.054	51.3	
	W	66	-	0.308	0.327	51.1	

* w/ color filter.
** The perfoemance based on the device with 66cd/A, CIE(x, y)= (0.298, 0.327)
*** Area coverage ratio with CIE1976 satandard.

It is well known that low blue device efficiency is the bottle neck keeping solution process technology from commercial applications. Low blue efficiency results in high power consumption in a real display panel. As shown in **Table 3**, we simulated EL power consumption in 27 inch display panels which applies the single structure or the tandem OLED. When at white screen of CIE coordinate of (0.308, 0.327) and luminance of 200 nits, the power consumption of tandem EL structure is 84% of single unit's because of the blue efficiency markedly increase. Moreover, the power ratio of blue device reduced from 48.6% to 27.5% for single unit device and hybrid tandem device, respectively. It means the loading of blue device will be lower during the panel operation.

5 Conclusions

Based on the calculation, Inkjet OLED panel used top emission hybrid tandem RGB devices combined with proper color filters might reach a power consumption reduction with 40% and color gamut with DCI-P3 in 97.8% and showed more balanced RGB power ratio under CIE coordinates (0.308, 0.327).

References

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