Gradient refractive index ITO for high contrast OLEDs

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Abstract

Improving the visual contrast in OLED displays is another important issue to address with a significant technological implication. The use of a gradient refractive index anode shows promise for contrast improvements in OLEDs. This talk will discuss the progress in developing gradient refractive index TCO anode for application in high contrast OLEDs.

1. Introduction

In a conventional structure of the OLEDs, the metallic cathode is typically used and has a high reflection to the ambient light. As such, the contrast of the devices is very low and the visual image of the OLEDs is poorly legible. This work will discuss the use of a gradient refractive index transparent conductive oxide anode for application in high contrast OLEDs. The gradient refractive anode provides a circular polarizer-free and also a cost effective approach for achieving high contrast OLEDs. The technology can be easily integrated to the existing mass production process for device fabrication.

Much effort has been focused on developing OLEDs with low reflectivity under the ambient light. For example, a circular polarizer film is used to improve the visual contrast. This is a very simple solution for improving the contrast of OLEDs. However, the use of polarizer results in higher costs and also increases the thickness of OLED displays. When using such a circular polarizer in flexible OLED displays, this becomes a genuine concern.

In addition to the use of a circular polarizer for enhancing the visual contrast of the emissive displays, a variety of black cathode structures have also been developed to minimize the light reflection at organic/cathode interface [1-3]. For example, a reflection-less OLED with a multilayer black cathode structure of LiF/Al/ZnO/Al was reported [1]. In this multilayer black cathode, the zinc oxide film was deposited by thermal evaporation. It acts as an optical absorbing layer to reduce the ambient light reflection from the metallic cathode. The use of a high conductive black carbon film in multilayer cathode system also was demonstrated by Renault et al [2]. This black cathode consists of a thin electron injector layer of magnesium, an optically absorbing and electrically conductive carbon layer and a thick aluminum layer. Black Layer™ is another example of multilayer electrode which consists of a phase change layer to form a low reflectivity cathode for OLEDs [4]. There are other methods using additional light absorbing layers of a variety of different materials. These methods essentially address the reducing of reflected ambient light by incorporating a low reflectivity composite cathode [5-8].

2. Results and discussion

A high contrast OLED can also be fabricated using a gradient refractive index anode to reduce the reflectance of the ambient light from the device. The concept is based upon on using an anode with a gradient or graded refractive index anode to minimize the ambient light reflection from OLEDs and hence to enhance the visual contrast. For example, a gradient refractive index anode which consists of a region with highly oxygen deficient indium tin oxide (ITO) and a normal ITO layer with high work function can be applied for application in OLEDs to reduce the ambient reflection. The highly oxygen deficient ITO film is electrically conducting and optically absorbing. The oxygen deficient ITO layer is inserted between the anode and the rigid or flexible transparent substrate serving as an optical destructive layer for reducing the ambient light reflection from the OLEDs.

A typical structure of a high contrast OLED consists in order of a rigid or flexible transparent substrate, an oxygen deficient ITO, an ITO anode, an organic stack of the hole-transporting and emissive layers, and a normal metallic cathode. The gradient refractive index anode can be fabricated using ITO or a combination of other materials, enables to reduce sufficiently the ambient light reflection from mirror-like surface of the metallic cathode in OLEDs through light absorbing and optical destructive interference.

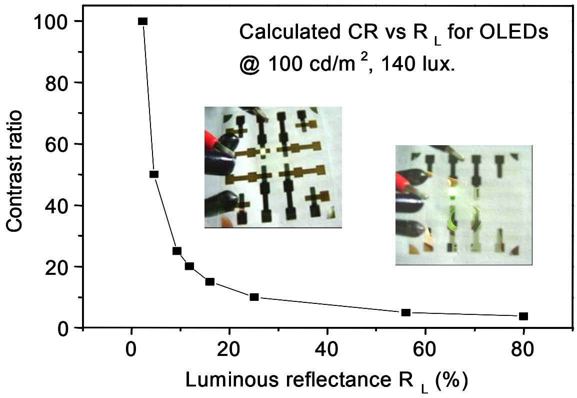

Fig. 1. G Calculated contrast ratio as a function of luminous reflectance for the OLEDs at 100cd/m2 under 140 lux of ambient illuminance.

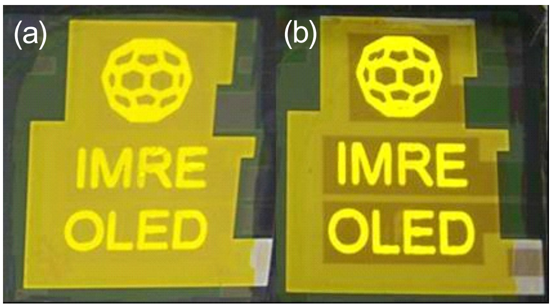

Fig. 2. Under an indoor ambient light, e.g., 140 lux, a conventional OLED (a) has a contrast ratio of ~ 5:1 operated at a brightness of 100 cd/m2. At the same operation conditions, a contrast ratio of more than 80:1 can be obtained for an OLED made with a gradient refractive index ITO anode.

Figure 1 shows the calculated contrast ratio as a function of luminous reflectance for the OLEDs at 100cd/m2 under 140 lux of ambient illuminance. Figure 2 shows the photographs taken for a control device with a bare ITO anode, the OLEDs made with a gradient refractive index ITO anode, respectively. High reflective cathode in a control device can be evidently seen in Figure 2(a), the dark electrode shown in Figure 2(b) clearly demonstrates the effect of ambient light deduction in devices. It is obvious from Figure 2 that the presence of a gradient refractive index anode reduces the reflection of the OLEDs.

It is demonstrated that a conventional OLED with an inherent weakness of high reflectivity from mirror-like cathode can be overcome by employing a gradient or graded refractive index ITO. The results indicate that the OLEDs with a gradient refractive anode can provide a substantial enhancement in visual legibility and the contrast ration of the OLEDs under the ambient light environment.

3. Summary

The use of a gradient refractive index ITO anode is capable of reducing the ambient light reflection from the reflective cathode to enhance the contrast of OLEDs. The ITO with different refractive indices can be easily engineered by varying the deposition conditions during the film preparation. Although ITO is still one of the most widely used anode materials for OLEDs, other alternatives suited for OLEDs may also be used for making gradient refractive transparent electrode for high contrast OLED displays using this technique. This technique provides a cost-effective approach for achieving high contrast emissive displays.

4. Acknowledgements

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5. References

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