High Performance OLEDs with a New Device Structure

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Abstract

We report the fabrication of a new inverted OLED devices having potential to be used for both AM-OLED and lighting applications.

1. Introduction

The performance of OLED display strongly related to its cell structure. Careful selection and proper combination of materials provide the high quality display devices. Among recent OLED displays, top-emitting structure is known to provide the best display characteristics mostly due to its high aperture ratio and wide color gamut[1]. For this reason, the top-emitting structure has been adopted even for LTPS-TFT based backplane system in spite of its sophisticated cell structure and narrow processing window.

The major challenge to fabricate the top-emitting structure includes the optimum formation of electrode system. Since the emission center is confined in between the highly reflective metallic mirrors, the shape of emission spectrum and the efficiency are strongly affected by the thickness of both organic and metallic layers.

In this paper, we present a new way to fabricate top-emission structure without introducing extra-layers but simply turning the conventional device structure upside down.

2. Experimental

An OLED cell was fabricated using LiF/Al as a reflective cathode material and IZO as transparent anode material. Unlike to conventional OLED devices, the cathode layer was formed first, followed by deposition of ETL (LG 201), EML (LG 503: Green dopant), HTL (NPB), HIL (LG 101) and IZO (shown in **Figure 1**). Since the reflective cathode was formed on top of the glass substrate, the light emits through the transparent IZO layer, not through the glass substrate.

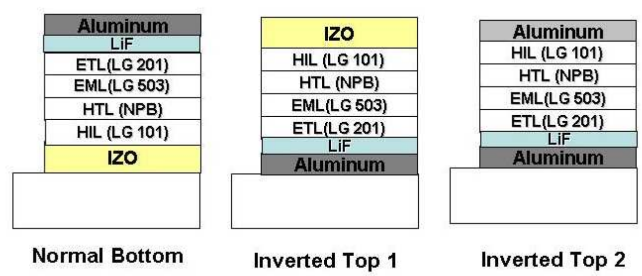

Figure 1. Device structures of normal and inverted OLEDs.

Two reference single layer devices were also fabricated using Alq3 and LG 201 as electron transporting materials to compare the difference in electron injection ability of electrodes depending on their building order and the kind of electron transporting materials.

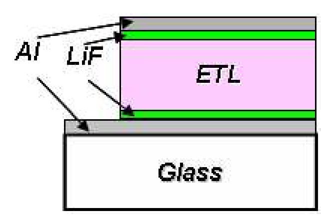

Figure 2. Structure of an electron only device.

LiF/Al bilayer structure was used as an symmetric electrode for the electron only devices (shown in **Figure 2**).

3. Results and discussion

LiF/Aluminum bilayer structure has been recognized as the most efficient and stable cathode. According to a widely accepted working mechanism, the “hot” vaporized aluminum atoms provide enough energy to cause the chemical reaction with lithim fluoride molecules to liberate the low-work function lithium atoms as follows[2];

$$3\ \mathrm{LiF} + \mathrm{Al} \rightarrow 3\ \mathrm{Li} + \mathrm{AlF_3}$$

Therefore, the inverted top device shown in Figure 1 should have poor electron injection ability since the inverted building order does not provide the chance to liberate the lithium atom. However, the inverted device operates even at lower driving voltage than that of a normal device (shown in **Figure 3**).

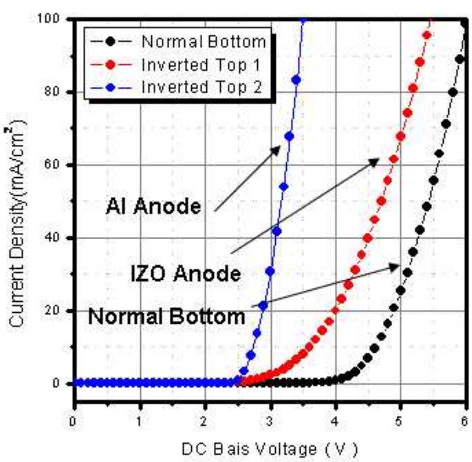

Figure 3. I-V characteristics of inverted devices.

By utilizing a unique property of LG 101, low work function aluminum was substituted for IZO as an anodic material[3]. As a result, the driving voltage decreased further. Below 4 volts, more than 100 mA/cm^2 of current density was injected into the device. Interestingly the electron injection behavior of single layer devices differs dramatically depending on the electron transporting materials (**Figure 4**). When Alq_3 was employed as the electron transporting material, the electron injection took place only from the top cathode. On the other hands, the introduction of LG 201 as the electron transporting material made it possible to inject electrons from both top and bottom cathodes. From this result, it become clear that the chemical structure of electron transporting molecule (LG 201) is playing the key role in the inverted structure.

An additional advantage of the inverted device is the current efficiency. As shown in **Figure 5**, the device having the Inverted Top 1 structure provides more than 40 cd/A of current efficiency with CIE color coordination of (0.25, 0.69). Considering that the emission originates from a fluorescent material, not phosphorescent one, and the cavity effects comes from the refractive index difference between IZO and air, the number is quite impressive.

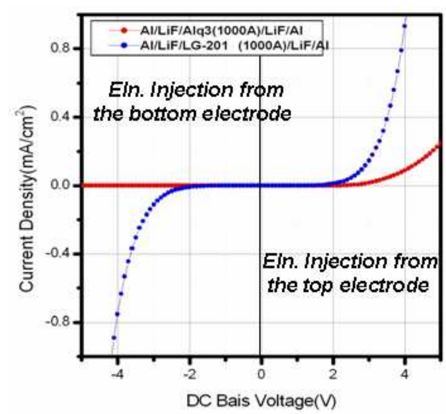

Figure 4. Electron injection behavior of single layer devices.

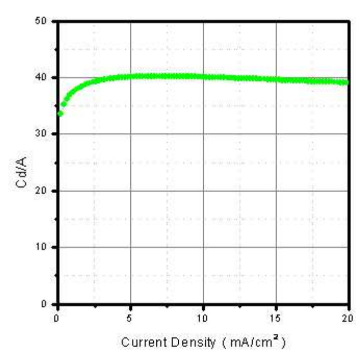

Figure 5. Current efficiency of the Inverted Top 1 device.

Also the device lifetime is also comparable to that of the normal bottom type structures.

4. Summary

High efficiency and low voltage devices with inverted structure were fabricated. All the materials used for the inverted device are air stable and easy to handle. The mechanism for electron injection from the bottom cathode is not clear yet but closely related to the chemical structure of LG 201, the electron transporting material. When aluminum was used as an anode material, further voltage reduction was observed.

5. References

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2. H. Heil, J. Steiger, M. Gastel, H. Ortner, H. Von Seggern and M. Stoβel, *Journal of Applied Physics*, Vol. 89, p 420 (2001).
3. Unpublished result. Since the LG 101 generates electron-hole pairs by charge transfer mechanism at the interface of LG 101-hole transporting layer, hole injection barrier caused by workfunction difference between anode and HIL (LG 101) does not have meaning anymore in our system. As a result, low work function metal such as aluminum or even calcium can be used as an anode material.