Novel structure for a full-color AMOLED using a blue common layer (BCL)

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Abstract
We report a novel structure for a full-color AMOLED (Active Matrix Organic Light Emitting Diode) eliminating the patterning process of a blue emitting layer. The patterning of the three primary colors, RGB, is a key technology in the OLED fabrication process. Conventional full color AMOLED containing RGB layers includes the three opportunities of the defects to make an accurate position and fine resolution using various technologies such as fine metal mask, ink-jet printing and laser-induced transfer system. We can skip the blue patterning step by simply stacking the blue layer as a common layer to the whole active area after pixelizing two primary colors, RG, in the conventional small molecular OLED structure. The red and green pixel showed equivalent performances without any contribution of the blue emission.

1. Introduction
The potential of organic light-emitting diodes (OLED) make it possible to realize an ideal display for a new generation display in the flat panel display industry with its many advantages, such as low power consumption, thinner panel thickness, fast response time, and wide viewing angle. Recent development of the phosphorescent devices with an evaporation process showed very high efficiencies, which utilize both singlet and triplet states[1]. The small molecular OLED is completed by laying up a multilayer organic film including hole injection layer(HIL), hole transport layer(HTL), RGB emitting layer(EML), hole blocking layer(HBL), electron transfer layer(ETL), electron injection layer(EIL) by deposition process according to function of the respective layers and finally depositing the cathode electrode. When fabricating the small molecular OLED by the conventional vacuum process, we needs to screen or pattern red, green and blue colors, respectively, on the anodes for the RGB by shadow mask. Most of the major pixel defects are come from the three patterning step (RGB), such as, misalignment and particle problems in the whole vacuum process of the OLED fabrication. Especially for mass production of AMOLED with fine resolution and large-area, the elimination of a complicated step is very important to decrease potential defectives and increase the total yield. Here, we report a novel technology to reduce a one patterning step simply using the concept of a blue common layer (BCL) after pixelizing two primary colors, RG, in the conventional small molecular OLED structure. By confining the emission zone of the device and optimizing the structure for the red and green devices, we skipped the process of the fine patterning of the blue emitter by simply depositing the blue layer with an open mask as a common layer all over the active substrates. The red and green pixel showed equivalent performances to the conventional devices with phosphorescent emitters without any contribution of the blue emission. Furthermore, we verified the feasibility to employ the 'BCL' structure by fabricating 2", 17" full color AMOLEDs with conventional fine metal mask and recently developed LITI (Laser Induced Thermal Imaging)[2] technology.

2. Exeperiments
Phosphorescent small molecules were used as a dopant for red and green devices. Device structures for a comparison consists of ITO / HIL / HTL / Red or Green / HBL or BCL / ETL / LiF / Al as shown in Fig. 1. ITO with 4mm^2 of active area for the conventional test device was imaged with photolithography process. A soluble polymeric HTL or/and vacuum-deposited small molecule(NPB) were stacked on a UV-O_3 treated ITO and annealed on a hot plate. The red and green light-emitting layers containing phosphorescent dopant were deposited on the HTL. Balq or blue emitting layer and Alq_3 layers were deposited sequentially by thermal sublimation in

a vacuum of ~1×10^{-6} Torr and used as a hole-blocking and electron transporting layers, respectively. LiF and Al were deposited by thermal evaporation and used as the cathode of the device.

3. Results

The blue-stacked devices showed equivalent efficiencies and slightly improved lifetimes compared to a conventional phosphorescent emitters. We controlled the recombination zone close to the HTL/EML interface and the effective emission thickness within the EML thickness so as not to make a mixed blue emission because of the BCL stacking. The recombination and the emission zone are closely related to the nature of a host in the emitting layer. A phosphorescent host with good electron mobility made it possible to stack the BCL on the green and red EML without color shift from the blue contribution, while small peak of the blue was shown in the devices with a conventional CBP host. Fig. 2 illustrates the simulation result with the thickness of layers and host having different hole/electron mobility. We used an OLED simulator called 'Eluce' made by ourselves, which feasibility was already proven with conventional phosphorescent devices. The Simulation results of the devices certified that the recombination zone was near the HTL/EML interface and emission region was confined below 100Å of the EML thickness in case of triplet host having faster electron mobility (Case 3, $\mu_h < \mu_e$), which were confirmed by experimental data simultaneously. The efficiencies of the optimized red devices reached 6 Cd/A (3.6 lm/W) at 500 Cd/m^2 without color shift from the stacked blue emission (CIE x=0.67, y=0.32), and 50 Cd/A (25 lm/W) at 500 Cd/m^2 (CIE x=0.34, y=0.62) for the green devices. The blue devices with thickness of 10~20nm showed a reasonable efficiency more than 5 Cd/A at 500 Cd/m2 (CIE x=0.14, y=0.18). Finally, we fabricated 2" and 17" full color AMOLEDs with conventional shadow mask method and the LITI technology to verify the two step patterning process of the 'BCL' structure. Just only two steps of red/green patterning followed by whole deposition of blue enabled us to make the devices simply of a reasonable color gamut and efficiencies quite identical to that of test devices. In addition to the bottom emission structure of the 2" and 17" devices, we verified that the BCL technology could be realized in fabricating a top emission structure. Recently, we demonstrated a 302ppi device of top emission at SID 2005 with the BCL structure.

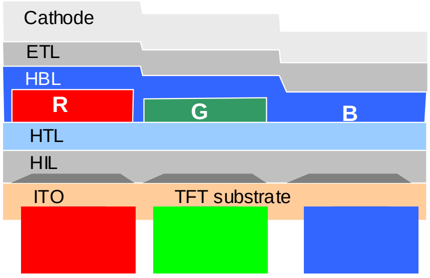

Fig. 1. Full color AMOLED with BCL structure.

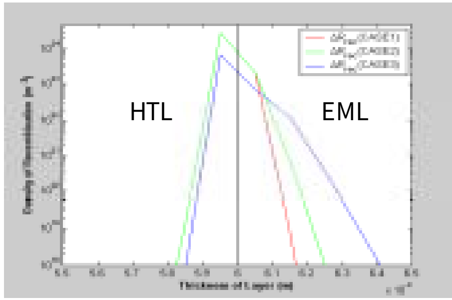

Fig. 2. Calculation of recombination zones with different mobility of hosts

(case 1: μ_h [10^{-7} cm^2/Vs]<μ_e [10^{-5} cm^2/Vs]

case 2: μ_h [10^{-5} cm^2/Vs] = μ_e [10^{-5} cm^2/Vs],

case 3: μ_h [10^{-5} cm^2/Vs] > μ_e [10^{-7} cm^2/Vs])

4. Conclusion

We can skip the patterning step for the blue emitter among three RGB emitter process using a common mask, which means that we can expect more than 30% improvement of product yield during the fine patterning process in OLED fabrication without adding more process or technology. It will be helpful to increase the productivity and accelerate the penetration of the AMOLED into flat panel display market.

5. References

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