Blue OLEDs using Quantum Well Structure and Exciplex Effect with Double Emissive Layer.

Ju-An Yoon¹,²,³, You-Hyun Kim¹, Nam Ho Kim¹, Song Eun Lee², Woo Young Kim¹,²,³
¹ Department of Green Energy & Semiconductor Engineering, Hoseo University, Asan, South Korea
² Department of Information Display, Hongik University, Seoul, Korea
³ Department of Engineering Physics, McMaster University, Hamilton, Ontario L8S 4L7, Canada

Abstract
Blue Organic light-emitting diodes (OLEDs) with quantum well structure using ADN and Balq were fabricated and characterized with emitting layers sequence order and exciplex effect. According to HOMO-LUMO energy levels of hole transport, emitting and electron transport layers effect of quantum well structure and exciplex on electrical and optical properties such as current densities and luminous efficiencies was examined how to improve blue OLED’s device performances eventually.

Keyword: OLED, Blue OLED, Exciplex, Quantum Well Structure, Power Consumption, Luminous Efficiency

1. INTRODUCTION
In recent years, there has been considerable interest in developing blue organic light-emitting devices (OLEDs) with high efficiency, deep-blue color.[1] but performance of blue OLEDs still needs to be improved for commercialization.[2] Various methods have been developed to optimize blue OLED's performance. Among these methods were replacing emitters from fluorescent to phosphorescent materials[3] and balancing carrier ratio in EML.[4] Another method is designing better surface texture for improving external quantum efficiency.[5]

In this work we fabricated blue OLEDs using two fluorescent materials of ADN and Balq as double EML were fabricated under different order of layers to obtain optimized electrical and optical performances. Luminous efficiency and I-V-L characteristics were observed considering effects of exciplex formation and quantum-well structure in EML.

2. EXPERIMENTAL AND RESULTS
Table 1 shows the device structures of fabricated blue OLEDs as devices A, B, C and D with different order of layers. As shown in Figure 1, current densities of device A, B, C and D were 56.83 mA/cm², 14.92 mA/cm², 20.11 mA/cm², and 22.73 mA/cm² at 6V respectively. Device A has highest current density because ADN is a p-type organic semiconductor with high hole-mobility and relatively lower electron mobility whereas device D has lowest current densities although current densities of device C and D were close each other. This result explains that current flow was affected more by hole-mobility than electron mobility near anode region.

Interface of Balq HOMO and NPB HOMO energy levels prevented hole transfer to the ADN emitting layer not depending on Balq thickness in device C (150Å) or device D (75Å). These inverse energy level structures decreased current flow in devices consequently.

Fig. 1. J-V characteristics of devices A, B, C, and D.

Luminescence characteristics and luminous efficiencies of device A, B, C, and D were 1384 cd/m², 538.6 cd/m², 735.5 cd/m² and 879.8 cd/m² at 6V respectively and 2.6 cd/A, 3.61 cd/A, 3.67 cd/A and 3.91 cd/A at 20 mA/cm², respectively in Figure 2. Although luminescence properties of device A was highest, device D has highest luminous efficiencies which is almost two times higher comparing to that of device A. These results can be implied by current density properties in inverse energy level and quantum well and exciplex structures in Figure 3.

Table 1. Device structures of fabricated blue OLEDs.

<table>
<thead>
<tr>
<th>Device</th>
<th>ITO(1800Å) / NPB(700Å) / ADN(300Å) / Bphen(300Å) / Liq(20Å) / Al(1200Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device A</td>
<td>ITO(1800Å) / NPB(700Å) / Balq(300Å) / Bphen(300Å) / Liq(20Å) / Al(1200Å)</td>
</tr>
<tr>
<td>Device B</td>
<td>ITO(1800Å) / NPB(700Å) / Balq(150Å) / ADN(150Å) / Bphen(300Å) / Liq(20Å) / Al(1200Å)</td>
</tr>
<tr>
<td>Device C</td>
<td>ITO(1800Å) / NPB(700Å) / Balq(150Å) / ADN(75Å) / Bphen(300Å) / Liq(20Å) / Al(1200Å)</td>
</tr>
<tr>
<td>Device D</td>
<td>ITO(1800Å) / NPB(700Å) / Balq(75Å) / ADN(75Å) / Bphen(300Å) / Liq(20Å) / Al(1200Å)</td>
</tr>
</tbody>
</table>

¹ Ju-An Yoon: jjuan25@naver.com
² Woo Young Kim: wykim@hoseo.edu
Device D has two quantum well structures in HOMO levels and LUMO levels between ADN and Balq interface. As mentioned in above, inverse energy level structures suppress hole transporting from HTL to EML as well as trapping holes in HOMO quantum well between ADN and Balq. 0.7 eV gap of HOMO energy levels between NPB and Balq decreased hole injection effect and 0.3 eV quantum well of HOMO levels between ADN and Balq trapped hole transfer whereas 0.4 eV and 0.3 eV gap of LUMO energy levels between Bphen, ADN, and Balq lead to trap electrons injected from cathode. As increased bias voltages, injected electrons from cathode were recombined with trapped holes due to 0.9 eV gap of HOMO energy levels between NPB and Balq is major factor to influence on balance of holes and electrons recombination. In addition, quantum well structures in the device D enhance exciplex effect between trapped holes and electrons in interface of ADN and Balq.

Figure 4 shows electroluminescence characteristics at 6 V of devices A, B, C, and D. Major emission peaks of devices A, B, C, and D were appeared at 460 nm, 488 nm, 484 nm, and 484 nm, respectively. In device C and D, emission peak at 484 nm was generated by exciplex between ADN and Balq layers because this wavelength can be estimated to 2.7 eV based on photoenergy equation of E=hν=hc/λ. However, ADN emitting layer of device A having 3.0 eV of HOMO-LUMO energy gap showed main emission peak at 460 nm which formed by electroluminescence. Therefore exciplex peaks of device C and D was expected to appear between 480 and 488 nm which has smaller energy gap of HOMO-LUMO of AND and Balq. Quantum well structure and exciplex presence in devices C and D have relatively broad peaks of electroluminescence spectra. These results indicate that OLED devices using quantum well and exciplex structures can improve their luminous efficiency and color coordinates through optimized design of device structure considering HOMO-LUMO energy levels of layer materials.

3. SUMMARY

We fabricated blue OLEDs using quantum well and exciplex effect between ADN and Balq, and characterized their optical and electrical properties. Blue OLED devices A-D demonstrated effects of quantum well and exciplex formed in interface of emitting layers. Luminous efficiency, I-V-L characteristics and electroluminescence was determined by HOMO and LUMO energy levels and sequence order of ADN and Balq EML. Devices of C and D with quantum well structure and exciplex effect showed more stable and improved luminous efficiency under different current density for reliable blue OLED.

4. ACKNOWLEDGEMENT

Following are results of a study on the “Leaders Industry-University Cooperation” Project, supported by the Ministry of Education, Science & Technology (MEST).

5. REFERENCES

191105 (2005).