Stable and efficient blue fluorescent organic light-emitting diode by blade coating with or without electron-transport layer

Lan-Sheng Yang a, Hsin-Fei Meng b, *, Yu-Fan Chang b, Cheng-Hsin Lien a, Hsiao-Wen Zan c, Sheng-Fu Horng a, Lian Duan c, Yong Qiu c, C.W. Luo a

a Department of Electrophysics, National Chiao Tung University, Hsinchu, 300, Taiwan
b Institute of Physics, National Chiao Tung University, Hsinchu, 300, Taiwan
c Department of Photonics, Institute of Electro-Optical Engineering, National Chiao Tung University, Hsinchu, 300, Taiwan
d Department of Electrical Engineering, National Tsing Hua University, Hsinchu, 300, Taiwan

1. Introduction

The phosphorescent organic light-emitting diode (OLED) with green and red emission by vacuum evaporation now show both high efficiency and stability. For the blue phosphorescent OLED, so far the lifetime is still a challenge. In order to achieve high stability for blue emission usually the fluorescent approach has to be used. By vacuum evaporation the blue fluorescent OLED is reported to have lifetime as high as 425 h at initial brightness of 5000 cd m⁻² [1]. One of the well-known problem for vacuum evaporation is however the high fabrication cost, and solution process is eventually necessary for OLED fabrication in large areas. As far as there is little report on the stability for the blue fluorescent OLED by all-solution process. In the blue fluorescent OLED with evaporated electron-transport layer, the stability of the device with spin-coated emission layer is much lower than the device with evaporated emission layer [2]. In fact the half operation lifetime of the former is only a few hours at 600 cd m⁻² initial brightness. In vacuum evaporated devices there are two major origins for the degradation during operation. The first origin is the chemical instability of the electron-transport materials. For example the well-known electron-transport/hole-blocking material 2,2'2''-(1,3,5-benzinetriyl)-tris(1-phenyl-1H-benzimidazole) (TPBI) often gives high current efficiency due to the effective hole blocking by its deep highest occupied molecular orbital (HOMO) level at 6.3 eV. The intrinsic instability of TPBI however leads to very short lifetime [3,4]. The second origin of the degradation is the charge carrier accumulation at the interfaces. For example, high hole concentration near the interface between the emission layer and the Alq3 layer may lead to unstable Alq3 molecules with positive charges. Furthermore, any high density of carriers or excitons at the interface...
may lead to unexpected processes like exciton-exciton annihilation or exciton-carrier Auger decay. Those processes may lead to highly excited states and cause bond breaking. By choosing the chemically stable materials and avoiding the carrier accumulation with device design [5,6], the stability of the vacuum-deposited blue fluorescent OLEDs.

Table 1
The HOMO/LUMO energy-level of materials used in this work.

<table>
<thead>
<tr>
<th>Energy-level (eV)</th>
<th>DPyPA</th>
<th>Alq3</th>
<th>SPPO13</th>
<th>Blue D</th>
<th>PT-404</th>
<th>TFB</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOMO</td>
<td>5.9</td>
<td>5.7</td>
<td>6.6</td>
<td>5</td>
<td>5.1</td>
<td>5.3</td>
</tr>
<tr>
<td>LUMO</td>
<td>2.8</td>
<td>3</td>
<td>2.9</td>
<td>2.5</td>
<td>2.1</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Fig. 1. The chemical structures of the organic materials used in the blue fluorescent OLEDs.

Fig. 2. The images and schemes of (a) hot plate and motor (b) blade coater (c) cross section view of blade coater.
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