



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^d, Lian Duan^e, Yong Qiu^e, 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

^e Department of Chemistry, Tsinghua University, Beijing, 100084, PR China

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ABSTRACT

Multi-layer small-molecule blue fluorescent organic light-emitting diode (OLED) is fabricated by blade coating. The emission layer is based on a mixed host of 1-(7-(9,9'-bianthracen-10-yl)-9,9-dioctyl-9H-fluoren-2-yl)pyrene (PT-404) and electron-transport material 2,7-Bis(diphenylphosphoryl)-9,9'-spirobifluorene (SPPO13), and the blue guest emitter is 4-4'-(1E,1'E)-2,2'-(naphthalene-2,6-diyl)bis(ethane-2,1-diyl)bis(N,N-bis(4-hexyl-Phenyl) aniline) (Blue D). A hole-transport layer of Poly-(9,9-dioctylfluorenyl-2,7-diyl)-co-(4,4-(N-(4-sec-butylphenyl)) diphenylamine) (TFB) is added on top of PEDOT: PSS anode. The electrons are blocked away from TFB by a layer of pure host emission layer of PT-404 between TFB and the mixed-host emission layer. For the device with the electron transport layer of Tris(8-hydroxyquinolinato) aluminum (Alq₃) blade-coated over the emission layer the efficiency and lifetime at initial brightness of 500 cd m⁻² are 7.5 cd A⁻¹ and 150 h for Alq₃/CsF/Al cathode. When the Alq₃/CsF/Al is replaced by simply CsF/Al over the mixed-host emission layer the efficiency and lifetime are 6.4 cd A⁻¹ and 300 h (2 times longer than that of the Alq₃/CsF/Al cathode). The lifetime depends on the electron-hole balance tuned by the mixed-host blending ratio as well as the electron injection from the cathode. This work shows good stability is possible for all-solution-processed blue OLED.

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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]. 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. So far 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-1-H-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]. Tris(8-hydroxyquinolinato)aluminum (Alq₃) is one of the few electron-transport materials with widely accepted high stability for blue fluorescent OLED. 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

* Corresponding author.

E-mail address: meng@mail.nctu.edu.tw (H.-F. Meng).

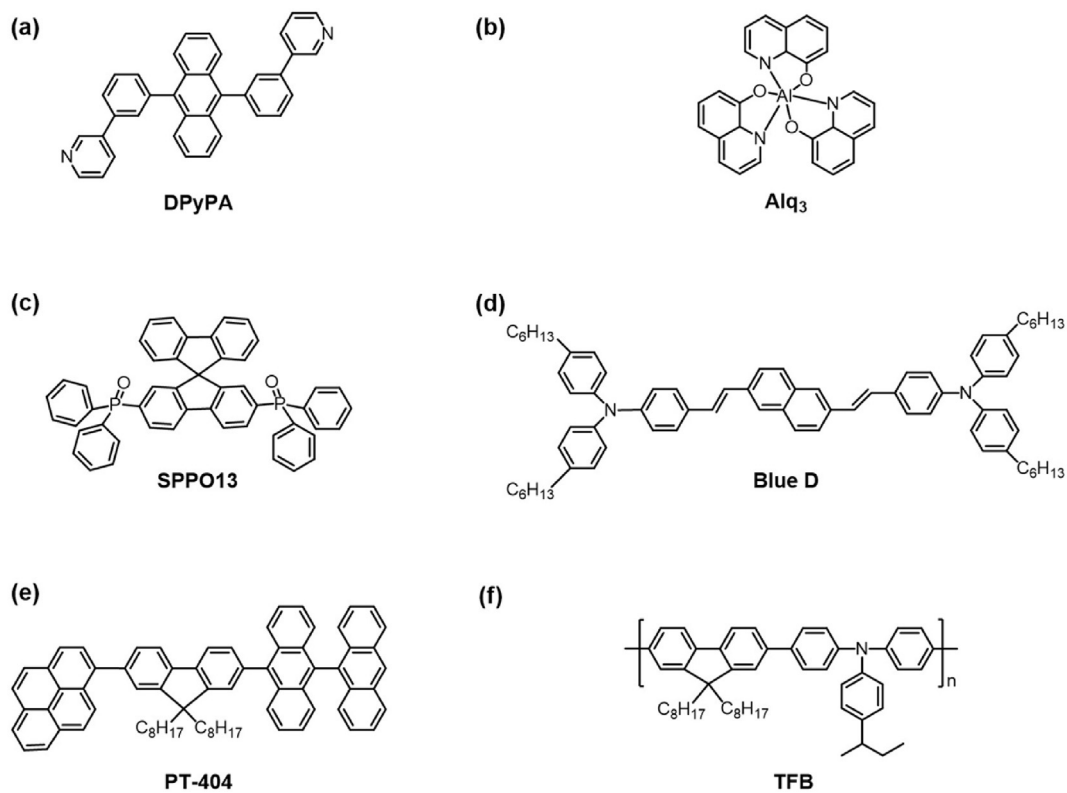


Fig. 1. The chemical structures of the organic materials used in the blue fluorescent OLEDs.

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

Energy-level (ev)	DPyPA	Alq ₃	SPP013	Blue D	PT-404	TFB
HOMO	5.9	5.7	6.6	5	5.1	5.3
LUMO	2.8	3	2.9	2.5	2.1	2.3

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



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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