



# Constructing a novel single-layer white organic light-emitting device through a new sky-blue fluorescent bipolar host

Jun Ye<sup>a,b</sup>, Kai Wang<sup>c</sup>, Zhan Chen<sup>c</sup>, Fei-Fei An<sup>c</sup>, Yi Yuan<sup>a</sup>, Chi Zhang<sup>b</sup>, Xiao-Hong Zhang<sup>c,\*</sup>, Chun-Sing Lee<sup>a,\*</sup>

<sup>a</sup> Center of Super-Diamond and Advanced Films (COSDAF) and Department of Physics and Materials Sciences, City University of Hong Kong, Hong Kong Special Administrative Region

<sup>b</sup> China–Australia Joint Research Center for Functional Molecular Materials, School of Chemical and Material Engineering, Jiangnan University, Wuxi 214122, PR China

<sup>c</sup> Nano-organic Photoelectronic Laboratory and Key Laboratory of Photochemical Conversion and Optoelectronic Materials, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100190, PR China

## ARTICLE INFO

### Article history:

Received 10 September 2014  
Received in revised form 30 September 2014

Accepted 4 October 2014  
Available online 16 October 2014

### Keywords:

White organic light emitting device  
Single layer  
Bipolar host  
Blue fluorescence  
Fluorescence and phosphorescence hybrid

## ABSTRACT

A novel device concept was realized for simple single-layer small-molecule white organic light emitting devices. The single organic active layer here is simply comprised of a newly synthesized sky-blue fluorescent bipolar host (TPASO) and a common orange phosphorescent dopant. Suppressed singlet Förster energy transfer induced by a low-concentration doping and spontaneous high- to low-lying triplet energy transfer, respectively, lead to sky-blue fluorescence from TPASO and orange phosphorescence from the dopant. The resulting two-organic-component device exhibits a low turn-on voltage of 2.4 V, maximum current/power efficiencies up to  $11.27 \pm 0.02 \text{ cd A}^{-1}$  and  $14.15 \pm 0.03 \text{ lm W}^{-1}$ , and a warm-white CIE coordinate of (0.42, 0.45) at  $1000 \text{ cd m}^{-2}$ .

© 2014 Elsevier B.V. All rights reserved.

## 1. Introduction

White organic light-emitting devices (WOLEDs) are of intensive interest nowadays because they show the great potential in solid-state lighting applications. The progressive inventions of novel device concepts and organic semiconducting materials have resulted in significant progress in this field [1–4]. To gain high efficiencies, the most popular device strategy is using a multilayer structure in which different functional layers, e.g. for charge carrier injection, transport, blocking and exciton confining, are employed in order to achieve carrier recombination balance [5–12]. These multilayer configurations may become more

complicated in a white device, once it arranges independent emissive layers to individually emit at one of the primary RGB colors. With the aim to save the manufacturing cost which is highly dependent on the consumed materials and processing time, special attentions then have been put on single-layer (SL) devices in which all the carrier injection, transport, recombination processes occur within one single organic layer. Currently, SL polymer-WOLEDs have already experienced considerable progress [13–20]. Zou et al. [18] realized a high power efficiency (PE) of  $20.7 \text{ lm W}^{-1}$  at  $1000 \text{ cd m}^{-2}$  by co-doping blue and yellow phosphorescent complexes into a blend of poly(*N*-vinylcarbazole) (PVK) host and 1,3-bis[(4-*tert*-butylphenyl)-1,3,4-oxadiazolyl] phenylene (OXD-7) electron-transport material. By contrast, the reports on the fabrication of SL small-molecule (SM) WOLEDs are still rare [21–27]. Approaches of blending blue/red fluorescent dopants [21],

\* Corresponding authors.

E-mail addresses: [xhzhang@mail.ipc.ac.cn](mailto:xhzhang@mail.ipc.ac.cn) (X.-H. Zhang), [apcslee@cityu.edu.hk](mailto:apcslee@cityu.edu.hk) (C.-S. Lee).

combining exciplex [22] or dimer emissions [23] have used to be demonstrated, however, with low efficiencies. Only very recently, remarkable improvement for SL SM-WOLEDs has been obtained in several fully-phosphorescence devices [24–27]. These devices share a common concept of using non-radiative hosts with high triplet energy levels ( $E_T$ ) to sensitize two or more phosphors from blue to red. For examples, Qiu's group [24] realized a maximum power efficiency (PE) of  $7.2 \text{ lm W}^{-1}$  in a RGB phosphorescent device, using a dual-host system of 9,9-bis[4-(3,6-di-*tert*-butylcarbazol-9-yl)phenyl]fluorene (TBCPF) and 3-Bis[(4-*tert*-butylphenyl)-1,3,4-oxadiazolyl]phenylene(OXD-7); Chen et al. [25] examined a series of oxadiazole-based materials mixed in a host of 3,5-di(carbazol-9-yl)tetraphenylsilane (SimCP2) to boost electron injection from the cathode and achieved a maximum PE of  $8.86 \text{ lm W}^{-1}$  in a blue/orange phosphorescent SM-WOLED; Xie's group [26] also fabricated a blue/orange two-phosphor device basing on a bipolar host, 2,7-bis(diphenylphosphoryl)-9-[4-(*N,N*-diphenyl-amino) phenyl]-9-phenylfluorene (POAPF), showing a maximum PE of  $21.9 \text{ lm W}^{-1}$ . Therefore, using a blend of n- and p-type hosts or a bipolar host seems to be an efficient method to enhance the performance of SL SM-WOLEDs. However, in these fully-phosphorescence devices, high  $E_T$ s ( $>2.65 \text{ eV}$ ) are indispensable for the hosts to confine the blue triplet excitons, and thus would inevitably enlarge their energy gaps ( $E_g$ ), leading to high carrier injection energy barriers at the organic/electrode interfaces. On the other hand, the use of a non-radiative bipolar host or blended hosts still increases the complexity of device fabrication.

In this paper, we present an alternative concept for designing efficient SL SM-WOLEDs, where the single active organic layer is simply comprised of a newly synthesized sky-blue fluorescent bipolar host and a common orange phosphorescent dopant. This fluorescence and phosphorescence (F/P) hybrid concept has the following advantages as compared to the aforementioned fully-phosphorescence concept: (i) narrower  $E_g$  in a blue fluorescent host with respect to that of a non-radiative host for sensitizing blue phosphors, thus endowing more efficient carrier injection from the electrodes; (ii) simpler fabrication process with the single organic layer readily formed by co-deposition of only two organic materials; (iii) easier way to obtain white light by solely controlling the Förster energy transfer from the fluorescent host to the orange phosphor. A new compound, 4-(dibenzothiophene-*S,S*-dioxide-2-yl)triphenylamine (TPASO), was characterized to have well-matched frontier molecular orbital levels, highest occupied molecular orbital (HOMO) level of 5.25 eV and lowest unoccupied

molecular orbital (LUMO) level of 2.69 eV, with the work functions of the  $\text{MoO}_3$ -modified ITO anode and the LiF/Al composite cathode. It also possesses a unit fluorescent quantum yield ( $\Phi_f$ ) in toluene, a sky-blue EL light with a peak wavelength at 493 nm, as well as a  $E_T$  above 2.24 eV which is sufficiently high to sensitize those orange triplet excitons ( $E_T \sim 2.1 \text{ eV}$ ). The SL F/P-hybrid SM-WOLED doping TPASO with 0.2 wt% tris(2-phenylquinoline)iridium(III) Ir(2-phq)<sub>3</sub> exhibits a warm-white emission with a Commission Internationale de L'Eclairage (CIE) coordinate recorded at (0.42, 0.45) at  $1000 \text{ cd m}^{-2}$ , and a low turn-on voltage of 2.4 eV which is significantly reduced as compared to those ( $>3.5 \text{ V}$ ) reported for SL fully-phosphorescence SM-WOLEDs [24–27]. In addition, impressive maximum current/power efficiencies (CE/PE) of  $11.27 \pm 0.02 \text{ cd A}^{-1}$  and  $14.15 \pm 0.03 \text{ lm W}^{-1}$  were also observed, suggesting that efficient WOLEDs with such an extremely simplified configuration could be realized.

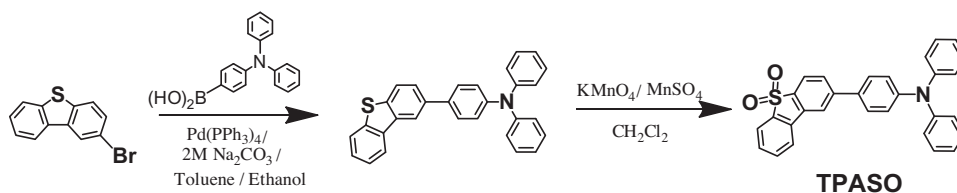
## 2. Experimental

### 2.1. General information

$^1\text{H}$  spectra was measured with a Varian Gemin-400 spectrometer. Mass spectra were recorded on a Finnigan 4021C GC-MS spectrometer. Elemental analysis was performed on a Vario EL III microanalyzer. The film samples (30 nm-thick) were prepared by vacuum deposition on quartz plate. The absorption and emission spectra were recorded on a Hitachi U-3010 UV-vis spectrophotometer and a Hitachi F-4500 fluorescence spectrophotometer, respectively. The film photoluminescence yield was measured by an integrating sphere method. Cyclic voltammetry was performed with a CHI600A analyzer with scan rate of  $100 \text{ mV s}^{-1}$  at room temperature. The electrolytic cell was a conventional three-electrode setup consisting of a glassy carbon working electrode, a Pt wire auxiliary electrode, and an aqueous saturated calomel electrode (SCE) as the reference. Tetra-*n*-butylammoniumhexafluorophosphate (TBAPF<sub>6</sub>, 0.10 M) was used as the supporting electrolyte and DMF or  $\text{CH}_2\text{Cl}_2$  as the solvent, respectively. The ferrocene/ferrocenium couple was used as the internal standard.

### 2.2. Synthesis

All solvents and materials were used as received from commercial suppliers without further purification. The synthetic route is shown in Scheme 1.



Scheme 1. Synthetic route of TPASO.

Download English Version:

<https://daneshyari.com/en/article/10565813>

Download Persian Version:

<https://daneshyari.com/article/10565813>

[Daneshyari.com](https://daneshyari.com)