



ELSEVIER

Contents lists available at SciVerse ScienceDirect

Journal of Luminescence

journal homepage: www.elsevier.com/locate/jlumin

Enhanced efficiency in single-host white organic light-emitting diode by triplet exciton conversion

Qingyang Wu^{a,*}, Shiming Zhang^{a,b,1}, Shouzhen Yue^a, Zhensong Zhang^a, Guohua Xie^c, Yi Zhao^{a,*}, Shiyong Liu^a^a State Key Laboratory on Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, Changchun 130012, People's Republic of China^b Département of Chemical Engineering, École Polytechnique de Montréal, Montréal, Québec, Canada H3C3J7^c Institut für Angewandte Photophysik, Technische Universität Dresden, Dresden 01062, Germany

ARTICLE INFO

Article history:

Received 14 February 2013

Accepted 18 April 2013

Available online 29 April 2013

Keywords:

WOLED

Single host

EQE

Flrpic

PO-01

Co-dope

ABSTRACT

The authors observe that the external quantum efficiency (EQE) of the Iridium (III) bis(4-phenylthieno [3,2-c]pyridinato-N,C²⁻)acetylacetonate (PO-01) based yellow organic light-emitting diode (OLED) is significantly increased by uniformly co-doping Iridium (III)bis[(4,6-difluorophenyl)-pyridinato-N,C²⁻] (Flrpic) and PO-01 into the same wide band-gap host of N,N-dicarbazolyl-3, 5-benzene (mCP). Detailed investigation indicates that the efficiency enhancement is ascribed to effective triplet exciton gathering by Flrpic, followed by energy transfer to PO-01. Compared to the control device, which has maximum EQE of 10.5%, an improved maximum EQE of 13.2% is obtained in the optimization white device based on Flrpic and PO-01 emission according to this principle. This work makes it easier for a single host white OLED to simultaneously harvest high efficiency in both blue and yellow units. Comprehensive experimental results show that this phenomenon can also be found and utilized in other popular hosts to realize more efficient white devices.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Phosphorescent white organic light-emitting diodes (WOLEDs) have drawn particular attention due to their potential applications in solid-state lighting, flat panel display and the unique merits of high external quantum efficiency (EQE) and environmental friendliness, which have a positive effect on the reduction of greenhouse gases [1–4]. Although the state-of-the-art phosphorescent WOLEDs have achieved attractive improvements in efficiencies and lifetimes [5], paving the way for commercial production, further improvement is required to simplify the device structure in order to reduce the production costs and make the technology competitive against other alternative technologies such as inorganic LEDs [6–10]. Among approaches to simplify the device structure, adopting the same host for different emitters to act as a single white emission layer (SWEML) has great potential because it can significantly lower the driving voltage and yield a much higher brightness at low applied voltage due to the reduction of total number of organic layers in the devices, rendering it more easier to be compatible with the conventional driving techniques.

[8,9,11] However, as is known, it is relatively arduous to acquire such a phosphorescent host material, which is suitable for both the blue and yellow/red emitters to simultaneously realize high efficiency. In particular, the blue phosphorescent emitter has a more rigorous demand on the hosts because the latter must simultaneously offer suitable frontier molecular orbital energy levels, wide band-gap (E_g) and high lowest triplet-excited states (T_1) to ensure efficient carrier transport as well as exothermic energy transfer to the emitter molecule [12]. Therefore, the blue-favorite host with a wide E_g is often prior adopted in the SWEML devices [8,13,14], which may cause a considerable efficiency loss in the red/yellow unit inevitably.

N,N-dicarbazolyl-3, 5-benzene (mCP) has been extensively used as a host material for the classical blue phosphorescent material of Iridium (III)bis[(4, 6-difluorophenyl)-pyridinato-N,C²⁻] (Flrpic), [8,13] whereas our studies indicate that it is not a very suitable host for yellow Iridium (III)bis(4-phenylthieno[3,2-c]pyridinato-N,C²⁻)acetylacetonate (PO-01) phosphor. In this work, we report the achievement of high efficiency simplified SWEML WOLEDs based on triplet exciton conversion (TEC) process [9], whereby the efficiency of PO-01-doped mCP yellow device is dramatically enhanced. Detailed study suggests that the enhanced efficiency is ascribed to effective triplet exciton gathering by Flrpic from mCP, followed by energy transfer to PO-01. Significantly, our research results indicate that this phenomenon can also be found

* Corresponding authors. Tel.: +86 431 85168242.

E-mail address: wqy1527@163.com (Q. Wu), yizhao@jlu.edu.cn (Y. Zhao).

¹ These authors contributed equally to this work.² Tel.: +86 431 85168242 8301.

and utilized in other popular hosts, e.g., 4,4',4''-tris(N-carbazolyl) triphenylamine (TCTA) and 4,4'-N,N'-dicarbazole-biphenyl (CBP). According to this principle, a peak forwarding-viewing EQE, power efficiency (PE) and current efficiency (CE) of 13.9%, 38.3 lm/W and 38.4 cd/A, respectively, with a low voltage of 2.5 V for onset and 4 V at 1000 cd/m² is obtained in the optimization SWEML WOLED without any out-coupling enhancements.

2. Experimental, results and discussions

All the devices were fabricated with the conventional process. [15] The current density–voltage–luminance (J – V – L) characteristics, electroluminescence (EL) spectra and Commission Internationale de L'Eclairage (CIE) coordinates were measured with a PR650 Spectrascan spectrometer and a Keithley 2400 programmable voltage–current source. Correlated color temperature (CCT) values were calculated with software SETFOS 3.0 from FLUXIM AG. The absorption spectrum of PO-01 was measured by means of a UV–vis spectrometer (UV 3600, Shimadzu). The devices were measured only in the forward direction without the use of an integrating sphere and additional out-coupling enhancements.

Simplified devices with the following configurations were fabricated: Y1, Indium Tin Oxide (ITO)/MoO₃ (10 nm)/TCTA (60 nm)/mCP: 6% PO-01 (15 nm)/Bphen (50 nm)/LiF (1 nm)/Al (100 nm); Y2, ITO/MoO₃ (10 nm)/TCTA (60 nm)/mCP: 15% Flrpic: 6% PO-01 (15 nm)/Bphen (50 nm)/LiF (1 nm)/Al (100 nm); Y3, ITO/MoO₃ (10 nm)/TCTA (60 nm)/mCP: 0.6% PO-01 (15 nm)/Bphen (50 nm)/LiF (1 nm)/Al (100 nm); and Y4, ITO/MoO₃ (10 nm)/TCTA (60 nm)/mCP: 15% Flrpic: 0.6% PO-01 (15 nm)/Bphen (50 nm)/LiF (1 nm)/Al (100 nm). For all devices, MoO₃ is used as the hole injection layer [16], 4,7-diphenyl-1,10-phenanthroline (Bphen) is the electron transport layer (ETL) and hole blocking layer, LiF is the electron injection layer, and Al is the cathode. Fig. 1 shows the structure and energy level diagram of the devices studied; the energy levels are extracted from literatures [13,17,18].

Fig. 2 shows the J – V – L curves for various devices shown in Fig. 1. It can be seen that the devices exhibit discriminating J – V characteristics. The current density of the Flrpic and PO-01 co-doped devices (Y2, Y4) is significantly higher than that of the solely PO-01 doped control devices (Y1, Y3), whereas a reduction in current density is observed in the device with lower PO-01 doping concentration (Y3). This is because Flrpic in mCP offers good transport channels for both holes and electrons [19], while doping PO-01 into mCP can obviously promote electron transport, which has been proved by the electron-only device as shown in Fig. 3. In addition, as the hole-only device shown in Fig. 3, PO-01 also acts as obvious trapping sites for holes, which indicates that there may exist two different excitation mechanisms for PO-01 in mCP: self-recombination by carrier trapping and energy transfer from mCP to PO-01. [20]

Fig. 4(a) shows the normalized EL spectra and Fig. 4(b) shows the CE, PE and EQE versus luminance plots for devices Y1–Y4. It is

clear that spectra of devices Y1–Y3 are exactly the same as that of PO-01 standard device without any Flrpic emission, whereas only a weak Flrpic emission can be observed in device Y4. Significantly, compared to the control device Y1, which has maximum EQE of 10.2%, the co-doped device Y2 shows a more noticeable value of 12.2%, while device Y4 exhibits a rather high EQE of 11.0% compared to the extreme low value of 2.7% in the solely doped control device Y3. To ascertain the optimal Flrpic dosage, we fabricated devices with different Flrpic doping concentrations: ITO/MoO₃ (10 nm)/TCTA (60 nm)/mCP: $x\%$ Flrpic: 6% PO-01 (15 nm)/Bphen (50 nm)/LiF (1 nm)/Al (100 nm), where x is set to 15, 30, 40, and 50, respectively. The inset of Fig. 4(b) shows the maximum EQE of the devices as a function of Flrpic doping concentration, a high EQE of 14.1% (CE of 46.0 cd/A), which is even superior to that of the conventional CBP based PO-01 emission device (CE of 43.6 cd/A) [21], is observed in the optimization device with 40% Flrpic doping concentration. Self-quenching of Flrpic will be aggravated at higher doping concentration, which should account for the observed EQE degradation [22].

To reveal the hidden reasons for the EQE enhancement in above devices, we examined the detailed energy transfer processes taking place in the EML by comparing the absorption spectra of Flrpic and PO-01, and the photoluminescence (PL) and phosphorescence spectra of mCP and Flrpic (Fig. 5) [23,24]. From Fig. 5, we can clearly see that the metal-to-ligand charge transfer bands from singlet (¹MLCT) and triplet (³MLCT) in PO-01 are clearly resolved at 450 and 508 nm, respectively, whereas the ¹MLCT and ³MLCT transitions are, respectively, observed at 380 and 420 nm for Flrpic. There is a large spectra overlap between the PL/phosphorescence spectra of mCP and the ³MLCT and ¹MLCT of Flrpic, but only a very small overlap can be observed between that of mCP and PO-01. However, significantly, we note that the ¹MLCT and ³MLCT of PO-01 overlaps rather well with the emission spectrum of Flrpic. Based on the above facts, we conclude that the EQE enhancements in the co-doped devices are mainly because the Dexter energy transfer (DET) from T₁ of mCP to Flrpic, followed by energy transfer from T₁ of Flrpic to either the T₁ of PO-01 or to the singlet-excited states of PO-01, which then transits to the T₁ of PO-01 via rapid intersystem crossing, along with a completion of TEC

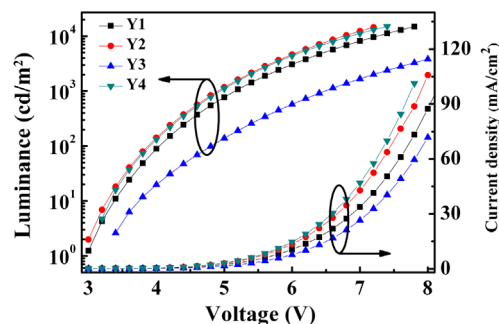


Fig. 2. V – J – L curves for devices Y1–Y4.

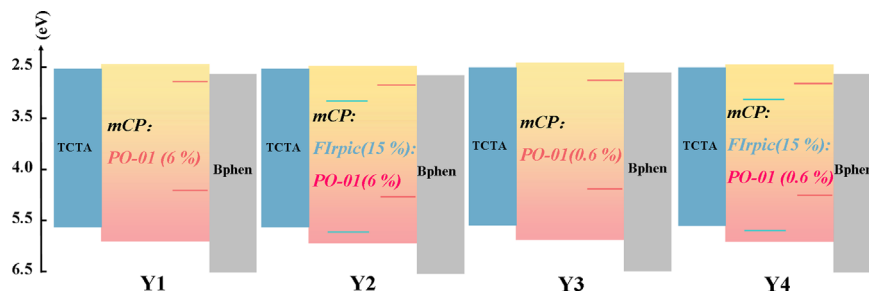


Fig. 1. Device structure and energy bands for devices Y1–Y4.

Download English Version:

<https://daneshyari.com/en/article/5400434>

Download Persian Version:

<https://daneshyari.com/article/5400434>

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