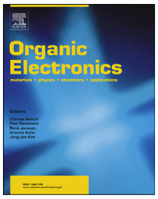
Organic Electronics 37 (2016) 207–212

Contents lists available at ScienceDirect

Organic Electronics

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



Management of charge carriers and excitons for efficient and color-stable white phosphorescent organic light-emitting diodes with simplified structure

Guangguang Han, Bingye Chen, Liangmei Zuo, Kaiwen Xue, Ping Chen*, Yu Duan, Yi Zhao

State Key Laboratory on Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, Changchun, People's Republic of China

ARTICLE INFO

Article history:
Received 6 April 2016
Received in revised form
25 June 2016
Accepted 26 June 2016
Available online 5 July 2016

Keywords:
White organic light-emitting diodes
Color stability
Exciton recombination zone
Co-host
Simplified

ABSTRACT

We have demonstrated color-stable and highly efficient simplified white phosphorescent organic light-emitting diodes. The key feature is the use of a novel approach to confine the distribution of charge carriers and excitons across the whole blue emission layer. The resulting two-color white device has the maximum power efficiency and current efficiency of 45.5 lm/W and 43.5 cd/A with a very low color shift over a wide range of luminance. By systematically investigating the working mechanisms, we found that the ambipolar charge carrier transport ability of co-host layer which ensures the distribution of excitons to form in the whole blue emission layer was the critical factors for constructing color-stable white devices. Our results show that simplified white devices based on two organic materials achieving excellent color stability are possible.

1. Introduction

White organic light-emitting diodes (WOLEDs) have gained much interest due to the potential applications in solid-state lighting sources, full-color flat-panel displays and backlights for liquid-crystal display [1–5]. High efficiency, good color stability, long operation lifetime and high color rendering index (CRI) are rather significant parameters for commercial production. Owing to the nearly 100% internal quantum efficiency of phosphorescent materials [6], various of configurations for phosphorescent WOLEDs have been investigated to obtain higher performances, including a single emission layer (EML) doping with multiple dyes in the corporate host [7,8], multiple emission layers [9–11], a single material possessing broad emission wavelength [12,13], stacked or tandem structure [14,15] and ultrathin layers structure [16–18]. In all of these approaches, WOLEDs based on multiple emission layers have higher efficiency [19]. However, this kind of WOLEDs always show obvious chromaticity shift with the increasing applied voltages, originating from the shift of exciton recombination zone due to the unbalanced charge carriers in the unipolar host. Therefore, it's very meaningful and desirable to develop efficient WOLEDs with good color stability.

Recently, Zhang et al. demonstrated efficient simplified white devices based on two transport materials of 4,4′,4′-tris(Ncarbazolyl)triphenylamine (TCTA) and 2,4,6-tris(3′- (pyridin-3-yl) biphenyl-3-yl)-1,3,5-triazine (TmPPPyTz). The WOLED with two EMLs achieved efficiencies of 38.9 cd/A and 39.8 lm/W [20]. By employing a spaced multilayer structure in a uniformly mixed P and N co-host, Yan et al. demonstrated three-color WOLED with power efficiency of 30.7 lm/W, slower efficiency roll off at high luminance, stable emissive spectra, and high CRI [21].

In this work, we proposed a device concept for simplified WOLEDs consisting of only two organic materials to achieve good color-stability and high efficiency. The core of our architecture is to introduce co-host system into blue EML to manage the distribution of charge and excitons. The resulting white device without interlayer between EMLs has the maximum power efficiency and current efficiency of 45.5 lm/W and 43.5 cd/A. The reason of the superior color-stability of the WOLEDs is assigned to the wide and stable exciton recombination zone and charge carrier balance.

2. Experimental

Fig. 1 shows the detailed energy level diagram and the chemical structures of the organic materials. The fabricated devices were

---

* Corresponding author.
E-mail address: pingchen@jlu.edu.cn (P. Chen).

http://dx.doi.org/10.1016/j.orgel.2016.06.033
1566-1199/

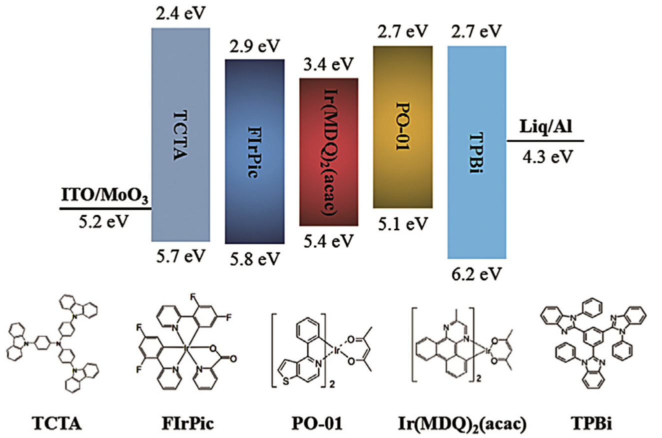


Fig. 1. The detailed energy level diagram and the chemical structures of the organic materials.

grown on glass substrates coated with indium-tin oxide (ITO). Molybdenum(VI) Oxide (MoO_3) was deposited on patterned ITO by thermal evaporation to efficiently facilitate holes injection. TCTA and 1,3,5-tris(2-*N*-pheylbenzimidazolyl)benzene (TPBi) served as hole-transport layer (HTL) and electron-transport layer (ETL), respectively. Iridium(III) bis(4-phenylthieno [3,2-c]pyridinato-N,C2′) acetylacetonate (PO-01) and Bis(3,5-difluoro-2-(2-pyridyl) phenyl-(2-carboxypyridyl)iridium(III) (FIrPic) were selected as orange and blue phosphorescent dyes. Lithium quinolate (Liq)/Al is used as composite cathode. All organic layers were grown by thermal evaporation in a deposition system in a high-vacuum (3×10^{-4} Pa) system without breaking the vacuum. The layer thickness and the deposition rate were controlled with an oscillating quartz thickness monitor. The luminance-current-voltage characteristics and the electroluminescence (EL) spectra were carried out using standard methods [16].

3. Results and discussion

To investigate the influence of the mixed ratios of TCTA to TPBi in blue co-host EML on the distribution of charge carriers and excitons, we firstly fabricated blue/orange two-color WOLEDs with the structures of ITO/MoO_3 (2 nm)/TCTA (50 nm)/co-host: 10% FIrPic (6 nm)/TPBi: 8% PO-01 (5 nm)/TPBi (30 nm)/Liq (1 nm)/Al, where the mixed ratios of TCTA to TPBi in co-host were selected as

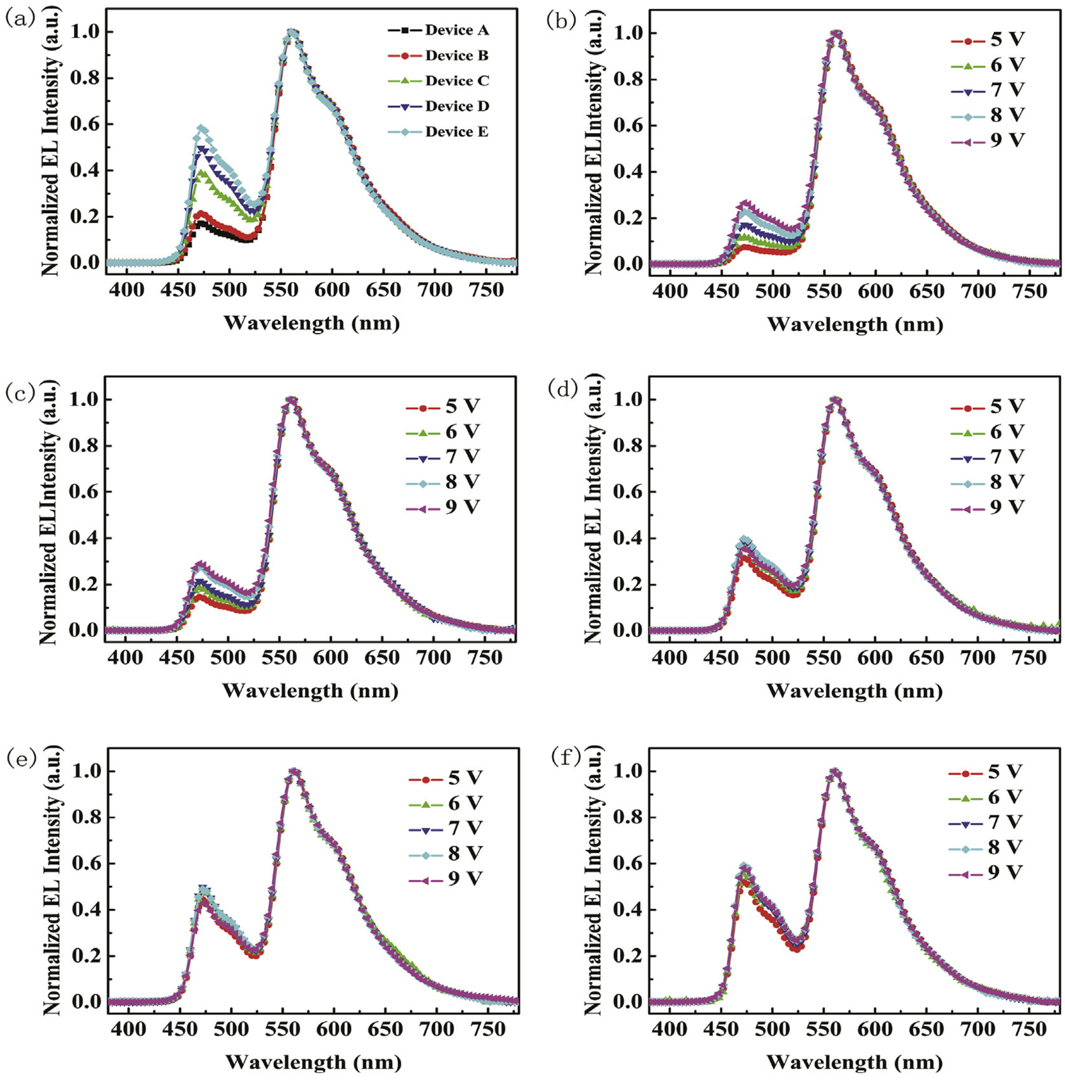


Fig. 2. (a) Normalized EL spectra of the devices A–E at 7 V. (b)–(f) Normalized EL spectra of the devices A–E at the different voltages.