Organic Electronics 23 (2015) 138–143

Contents lists available at ScienceDirect

Organic Electronics

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

High efficiency fluorescent white organic light-emitting diodes having a yellow fluorescent emitter sensitized by a blue thermally activated delayed fluorescent emitter

Wook Song [a], In Ho Lee [b], Seok-Ho Hwang [b], Jun Yeob Lee [a,*]

[a] School of Chemical Engineering, Sungkyunkwan University, 2066, Seobu-ro, Jangan-gu, Suwon, Gyeonggi 440-746, Republic of Korea
[b] Department of Polymer Science and Engineering, Dankook University, 152, Jukjeon-ro, Suji-gu, Yongin, Gyeonggi 448-701, Republic of Korea

ARTICLE INFO

Article history:
Received 22 March 2015
Received in revised form 11 April 2015
Accepted 17 April 2015
Available online 18 April 2015

Keywords:
Quantum efficiency
White device
Fluorescent device
Delayed fluorescence
Blue device

ABSTRACT

Fluorescent white organic light-emitting diodes having a blue thermally activated delayed fluorescent emitter and a yellow fluorescent emitter was developed by co-doping the blue and yellow emitters in a single emitting layer. The blue delayed fluorescent device showed high quantum efficiency of 22.6% at a very high doping concentration of 50% and the white devices exhibited a high quantum efficiency of 15.5% even though a fluorescent yellow emitter was doped in the blue thermally activated delayed fluorescent emitting layer. Minimized charge trapping and Dexter energy transfer by low yellow doping concentration of 0.05% as well as efficient Förster energy transfer could develop the high efficiency fluorescent white organic light-emitting diodes.

1. Introduction

White organic light-emitting diodes (OLEDs) have been applied as light-emitting devices for large size television because they can generate red, green and blue colors using color filter and for lighting devices because of broad white emission of the white OLEDs. Several commercial products have already been on the market and the application of the white OLEDs is being expanded.

In general, the white OLEDs contain red/green/blue or yellow/blue emitting materials and there have been several ways to realize the white OLEDs by combining different emitting materials [1–4]. At first, white OLEDs were constructed using only fluorescent materials and the quantum efficiency of the all fluorescent white OLEDs was low due to intrinsic low quantum efficiency of the fluorescent emitters [1]. The low quantum efficiency of the all fluorescent white OLEDs could be overcome by developing all phosphorescent white OLEDs because the quantum efficiency of triplet emitters is theoretically four times higher than that of fluorescent emitters [5–11]. The other way of improving the quantum efficiency of all fluorescent white OLEDs was to hybridize a blue fluorescent emitter with red/green or yellow triplet emitters. The use of the blue fluorescent emitter with a higher triplet energy than green triplet emitter utilized the singlet exciton for blue emission and triplet excitons for red/green or yellow emission [3–4,12–14].

Recently, as an alternative of the all phosphorescent and hybrid white OLEDs, white OLEDs possessing a thermally activated delayed fluorescent (TADF) emitter was developed [15–17] because TADF emitters can harvest both singlet and triplet excitons [18–24]. All TADF white OLEDs and hybrid white OLEDs hybridizing the TADF emitters with triplet emitters were reported and demonstrated high quantum efficiency. However, the high quantum efficiency in the white OLEDs was achieved only when triplet excitons of the emitters are harvested without quenching. The high efficiency could not be obtained in the white OLEDs if red/green or yellow fluorescent emitters are included in the emitting layer because they quench the triplet excitons of the blue emitters. However, it would be useful to develop high efficiency white OLEDs by incorporating common red/green or yellow fluorescent emitters in the emitting layer because of low cost production and excellent stability of the fluorescent emitters.

In this work, a novel high efficiency white OLED device architecture with a fluorescent yellow emitter doped in the blue TADF emitting layer was developed by incorporating very low doping concentration of the yellow fluorescent emitter. It was demonstrated that the new white OLEDs with a blue TADF emitting layer doped with a yellow fluorescent emitter could achieve 15.5% external quantum efficiency by minimizing charge trapping by the

* Corresponding author.
E-mail address: leej17@skku.edu (J.Y. Lee).

http://dx.doi.org/10.1016/j.orgel.2015.04.016
1566-1199/

yellow fluorescent emitter and Dexter energy transfer from the blue TADF emitter to the yellow fluorescent emitter. This work is the first demonstration of novel white OLEDs with a combined emitting layer of blue TADF emitter and yellow fluorescent emitter.

2. Experimental

Blue TADF OLEDs with the bis[4-(9,9-dimethyl-9,10-dihydroacridine)phenyl]sulfone (DMAC-DPS) emitter had a device structure of ITO (120 nm)/PEDOT:PSS (60 nm)/TAPC (10 nm)/TCTA (10 nm)/mCP (10 nm)/DPEPO:DMAC-DPS (25 nm)/TSPO1 (5 nm)/TPBI (30 nm)/LiF (1 nm)/Al (200 nm), where ITO is indium tin oxide, PEDOT:PSS is poly(3,4-ethylenedioxythiophene):poly (styrenesulfonate), TAPC is 4,4′-cyclohexylidenebis[N,N-bis (4-methylphenyl)aniline], TCTA is tis(4-carbazol-9-ylphenyl)amine, mCP is 1,3-bis(N-carbazolyl)benzene, DPEPO is bis[2-(diphenylphosphino)phenyl]ether oxide, TSPO1 is diphenylphosphine oxide-4-(triphenylsilyl)phenyl and TPBI is 1,3,5-tris(N-phenylbenzimidazole-2-yl)benzene. DMAC-DPS was doped at concentrations of 20%, 30% and 50%. White OLED structure was ITO (120 nm)/PEDOT:PSS (60 nm)/TAPC (10 nm)/TCTA (10 nm)/mCP (10 nm)/DPEPO:DMAC-DPS:TBRb (25 nm)/TSPO1 (5 nm)/TPBI (30 nm)/LiF (1 nm)/Al (200 nm), where TBRb was 2,8-ditert-butyl-5,11-bis(4-tert-butylphenyl)-6,12-diphenyltetracene. DMAC-DPS concentration was fixed at 50% and TBRb doping concentrations were 0.03% and 0.05%. Device characterization was conducted according to the method reported in the literature [20].

3. Results and discussion

In order to obtain high quantum efficiency in the singlet emitting layer white OLEDs made up of blue and yellow emitters, high efficiency blue emitting layer is necessary because the dominant light-emission mechanism is energy transfer from a blue emitter to a yellow emitter. Therefore, high quantum efficiency blue TADF emitter, bis[4-(9,9-dimethyl-9,10-dihydroacridine)phenyl]-sulfone (DMAC-DPS), was chosen as the blue emitting material of the white OLEDs [20]. It was reported that the DMAC-DPS blue emitter could provide high quantum efficiency close to 20% in the blue TADF devices and it is suitable as the blue emitter of the white OLEDs doped with a yellow emitting 2,8-ditert-butyl-5,11-bis(4-tert-butylphenyl)-6,12-diphenyltetracene (TBRb) fluorescent emitter.

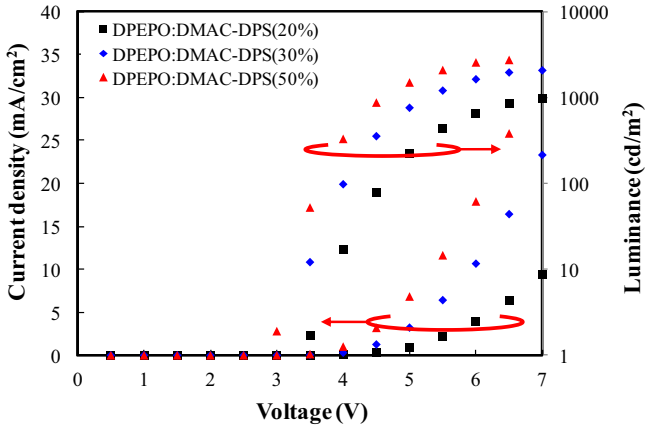

Fig. 2. Current density–voltage–luminance curves of DPEPO:DMAC-DPS devices according to doping concentrations of DMAC-DPS.

Before fabricating the white OLEDs, the device performances of the DMAC-DPS based blue TADF OLEDs were optimized to maximize the device performances of the white OLEDs. Chemical structures of organic materials used in this work are shown in Fig. 1. Doping concentration of DMAC-DPS was changed from 20% to 50% to optimize the quantum efficiency of the DMAC-DPS devices. Current density and luminance of the DMAC-DPS devices were plotted against driving voltage in Fig. 2. The increase of the

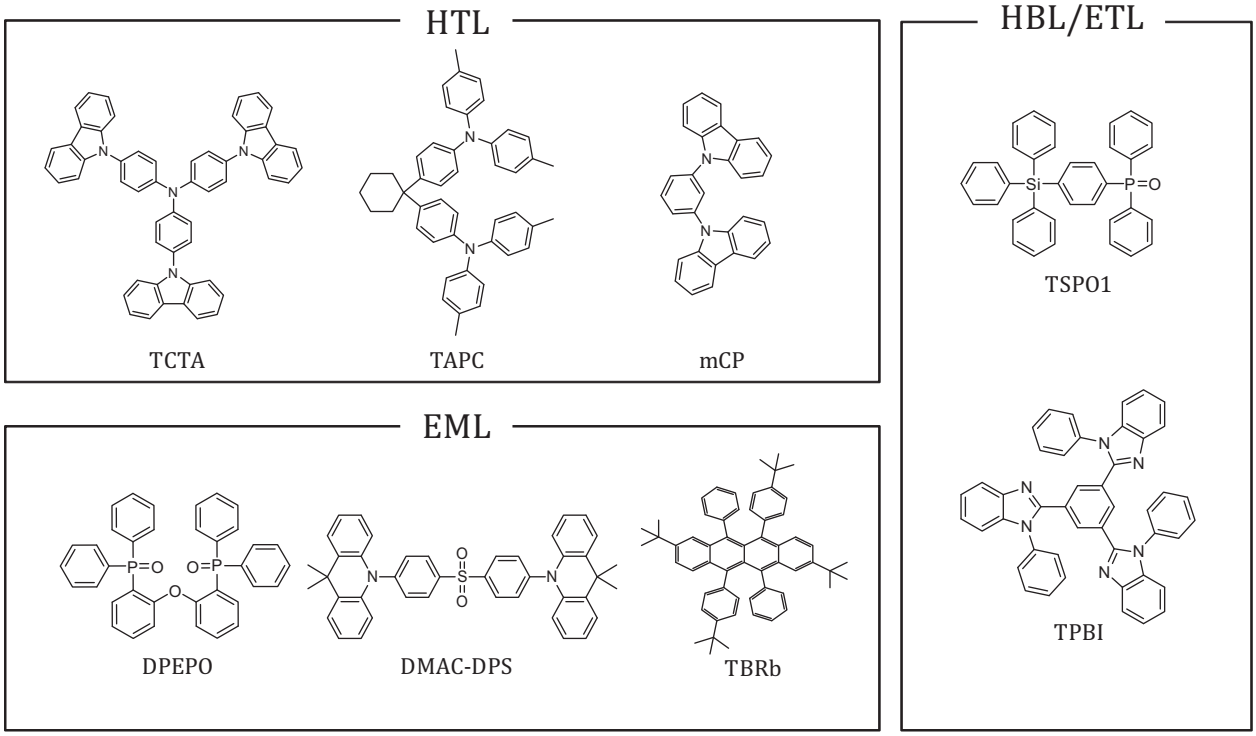

Fig. 1. Chemical structures of organic materials used to fabricate blue and white devices.