Highly Efficient Deep Blue Fluorescence Emitter Based on Highly Conjugated Boron Structure

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Abstract

We synthesized and evaluated new deep blue fluorescence emitter, KH-FBD1. This emitter exhibits pure deep blue PL spectrum peak at 452 nm with 20 nm full width half maximum. Fabricated device shows high efficiency of 7.4% with deep blue color coordinate of (0.14, 0.07). In addition, this device indicates long operational lifetime (LT_{95}) of 100 hours at initial luminance 1,000 cd/m^2. It also shows high efficiency of 12.7% in high T_1 device with maintaining the deep blue color characteristic.

1. Introduction

Recently, many studies on thermally activated delayed fluorescence (TADF) organic light emitting diode (OLED) have been conducted in many laboratories because fluorescence emitter has limitation of 25% internal quantum efficiency (IQE). For the last several years, many researchers reported highly efficient TADF emitters. Generally, to achieve small ΔE_{ST}, most of TADF emitters are utilizing donor-acceptor structure with highly twisted angle, which results in strong intramolecular charge transfer (ICT) characteristic. Consequently, TADF materials normally indicate large full width at half maximum (FWHM) and poor color purity derived from strong ICT characteristic. To overcome these limitation, Takuji Hatakeyama group reported blue TADF emitter 5,9-diphenyl-5,9-dihydro-5,9-diaza-13b-boranaphtho[3,2,1-de]anthracene (DABNA) indicating small ΔE_{ST} without donor-acceptor structure and high efficiency [1]. This multi-resonance concept structure achieved small FWHM and ΔE_{ST} without spatial separation of highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) by positioning electron donating nitrogen atom and electron withdrawing boron atom appropriately. Recently, several materials utilizing the DABNA core have been reported because of its advantage of color purity [2-4]. However, there are few reports of stable deep blue materials based on DABNA core.

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2. Result and Discussion

In this study, we report new deep blue fluorescence emitter, KH-FBD1. This material is designed by utilizing highly conjugated rigid DABNA core for high color purity and high efficiency. We applied additional diphenylamine group for extending conjugation and tert-butyl groups for preventing self-quenching. Therefore, we expected that this new emitter would indicate high PLQY and deep blue emission with narrow FWHM. As expected, PL spectrum

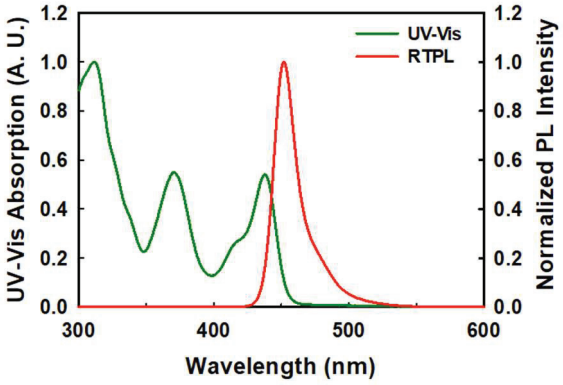

Figure 1. UV-vis spectra and PL spectra in toluene

showed deep blue emission peak at 452 nm with 20 nm of FWHM as shown in Figure 1. In addition, it showed high PLQY value of ~90%, so we expected that highly efficient deep blue device could be fabricated.

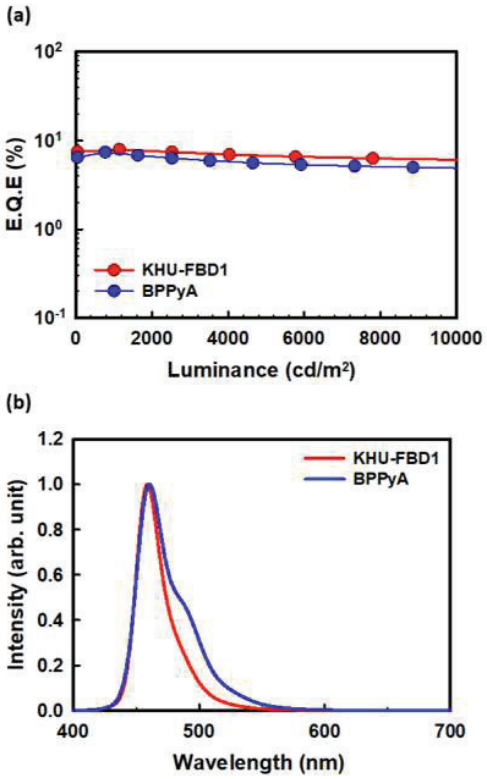

Figure 2. Fluorescence device performances of KHU-FBD1 device

(a) EQE versus Luminance (b) EL spectra

To evaluate our new dopant, fluorescent device was fabricated in the following order of ITO / 1,4,5,8,9,11-hexaazatriphenylenehexacarbonitrile (HATCN) (7 nm) / N,N'-Di(1-naphthyl)-N,N'-diphenyl-(1,1'-biphenyl)-4,4'-diamine (NPB) (60 nm) / KHU-FBH : 5% KHU-FBD1 (25 nm) / KHU-ETL (20 nm) / LiF (1.5 nm) / Al (100 nm). The device showed high maximum external quantum efficiency (EQE) of 7.4% even though it was a fluorescent device and it maintained high EQE of 7.2% at 1,000 cd/m^2, indicating low roll-off characteristic as shown in Figure 2 (a). It showed deep blue EL peak at 459 nm and very narrow FWHM of 24 nm as shown in Figure 2 (b). Therefore, we achieved deeper blue color coordinate of (0.14, 0.07) than the National Television System Committee (NTSC) blue color. In addition, device operational lifetime was evaluated at initial luminance of 1,000 cd/m^2. Here KHU-FBD1 indicated very deep blue color, so it requires quite high current density of 25 mA/cm^2 to emit light at a luminance of 1,000 cd/m^2. Nevertheless, as shown in Figure 3, it showed very long operational lifetime (LT_{95}) of 100 hours, which is demonstrating high stability of KHU-FBD1.

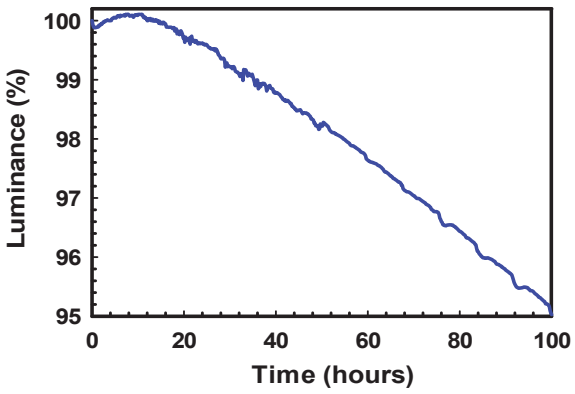

Figure 3. Fluorescence device lifetime of KHU-FBD1 device at initial luminance of 1000cd/m^2

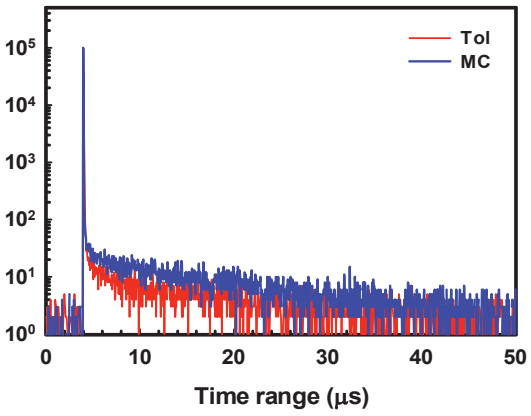

Figure 4. Exciton decay lifetime graph of KHU-FBD1

On the other hand, KHU-FBD1 contains DABNA core possessing TADF characteristic, so we measured low temperature PL and time resolved PL spectrum to confirm the TADF characteristic. As a result, KHU-FBD1 has small ΔE_{ST} of 0.163 eV due to the multi-resonance effect. It also indicated weak TADF characteristic with long delayed exciton lifetime of 5.3 μs in toluene as shown in Figure 4. From this result, similar efficiency with DABNA and severe roll-off characteristics were expected in high T_1 device. To find out if KHU-FBD1 has possibility of TADF characteristic, device was fabricated in the following order of ITO / HATCN (7 nm) / NPB (50 nm) / 9,9-dimethyl-10-(9-phenyl-9H-carbazol-3-yl)-9,10-dihydroacridine (PCZAC) (10 nm) / 3',5-di(9H-carbazol-9-yl)-[1,1'-biphenyl]-3-carbonitrile (mCBP-CN): 5% KHU-FBD1 (25 nm) / 2,4-bis(dibenzo [b,d]furan-2-yl)-6-phenyl-1,3,5-triazine (DDBFT) (5 nm) / KHU-ETL (15 nm) / LiF (1.5 nm) / Al (100 nm). PCZAC and DDBFT was used as triplet exciton blocking layer and mCBP-CN was used as high T_1 host. As expected, fabricated device showed high maximum EQE of 12.7% and reduced to 7.2% at 1,000 cd/m^2 as shown in Figure 5 (a). This severe roll-off characteristic was derived from long delayed exciton lifetime. Instead, it exhibited almost same deep blue emission with fluorescent device as shown in Figure 5 (b). Therefore, our new material could be also utilized as a highly efficient deep blue TADF dopant. We believe that our design concept could be utilized for future material design. The detailed information will be discussed at the presentation.

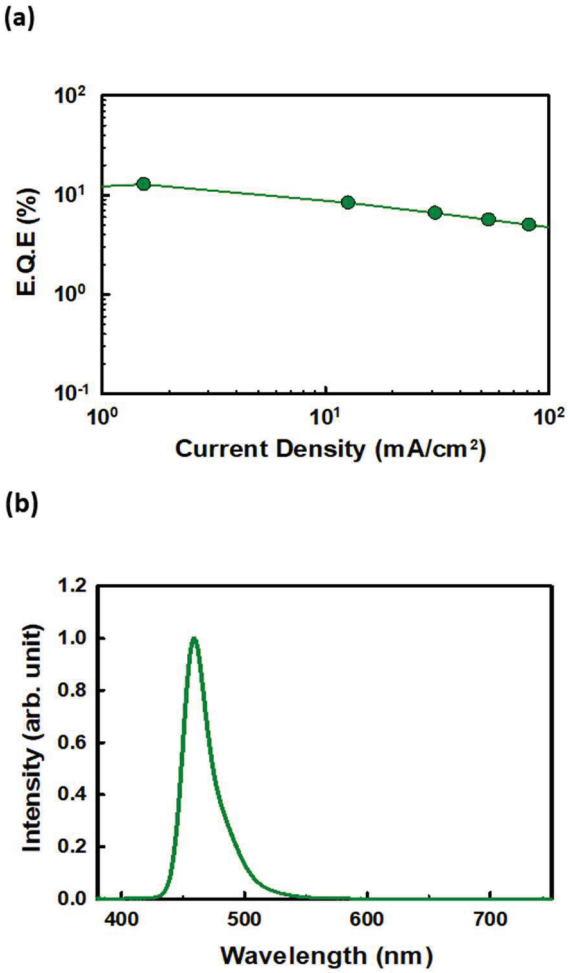

Figure 5. TADF device performance of KHU-FBD1 device (a) EQE (b) EL spectra

3. Conclusion

We applied highly conjugated boron based core structure as a fluorescence emitter and the device showed high maximum EQE of 7.4%. In addition, high EQE of 12.7% with maintaining the same color characteristic was achieved in TADF device.

4. References

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