Development of high performance near-ultraviolet OLEDs based on the Double Wide Band Gap Emissive Layers

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Abstract

Organic light-emitting diodes (OLEDs) based on the double wide band gap emissive layers in the range of 380 nm to 440 nm are reported. An efficient electroluminescence with a maximum at 400nm was observed at room temperature under a forward bias about 10V. With the wide band gap organic materials for near-ultraviolet emission, the low operating voltage (5V) and high current efficiency (3 cd/A) have been obtained at 2mA/cm^2

1. Introduction

The rapid advancement of organic light-emitting diodes (OLEDs) in recent years has extended the emission wavelengths over the whole visible range and has enabled realization of full-color OLED displays.[1]-[3] For full-color displays, several approaches have been proposed and demonstrated. One of the approaches makes use of a deep blue OLED and converting the blue light to either red or green light with phosphors or "color conversion". Ultraviolet/violet OLEDs are also highly desirable as, eg., excitation sources for other red-to-blue fluorescent films and fluorescent sensors. [4]-[6] In addition, compact and efficient UV emitters would find many uses in high storage devices, fluorescent sensors, and bio applications.

In this study, we describe a near ultraviolet OLED based on double wide band gap emitters.

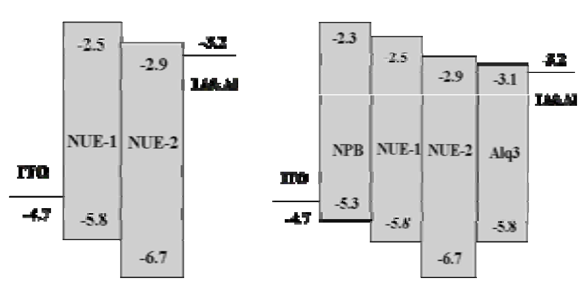
2. Results

2-1. Physical properties and Device configurations

The wide band gap organic materials (NUE-1, NUE-2) are used to emitting layer for near-ultraviolet emission. During the course of our investigation, we found that The NUE-1 and NUE-2 are suitable for an efficient near-ultraviolet emitting materials. The physical properties and OLED configurations of NUE-1 and NUE-2 are described in Table 1 and Figure 1. Absorption, photoluminescence (PL), and electroluminescence (EL) spectra were measured by Hewlett Packard 8453 and Oriel Specetrograph MS125. The energy levels of materials (HOMO, highest occupied molecular orbital and LUMO, lowest unoccupied molecular orbital) were estimated by cyclic voltammetry (CV).

Table 1. Physical properties of organic materials

Materials	T_g/T_m (℃)	HOMO/ LUMO (eV)	UV λ_{max}	PL λ_{max}
NUE-1	152/321	5.8/2.5	335	400
NUE-2	159/331	6.7/2.9	312	382



(a) (b)

FIG. 1. OLED device configurations of (a) S1 and (b) S2

2-2. Device Structures

We use indium-tin-oxide (ITO) substrates and that patterned by photolithographic methods. The structures of the OLED studied in this experiment are as follows:

S1: ITO / NUE-1 (20nm) / NU2-EML (20nm) /LiF (1nm) /Al (120nm)

S2: ITO / NPB (20nm) / NUE-1 (20nm) / NUE-2 (20nm) / Alq_3 (40 nm) / LiF (1nm) /Al (120nm)

S2 have the additional organic layers such as a hole transport layer (NPB) and an electron transport layer (Alq_3) to improving performance. All layers are deposited by thermal evaporator in vacuum chamber with base pressure of $< 10^{-7}$ torr.

2-3. Results and Discussion

The photoluminescence spectra of NUE-1, NUE-2, and NPB are summarized in FIG. 2. PL peaks are observed for NUE-1 at 400 nm and NUE-2 at 382 nm. Therefore, it is possible to identify ultraviolet emitters as being for EL emission at 382 nm ~ 400 nm.

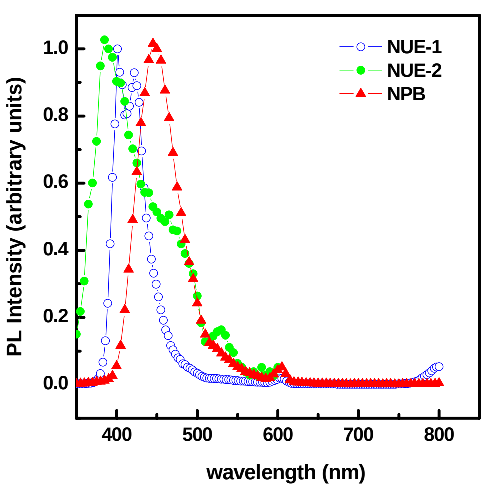


FIG. 2. PL spectra of NUE-1, NUE-2, and NPB

Typical EL spectra with bias at 10V of S1 and S2 OLEDs are shown in FIG. 3. For a S1, a maximum peak can be observed at a near-ultraviolet wavelength around 400 nm. However, EL spectra of S2 with NPB and Alq_3 can be observed at a blue wavelength of 440 nm. Because of PL emission of NPB and Alq_3, EL spectra of S2 shift to blue emission.

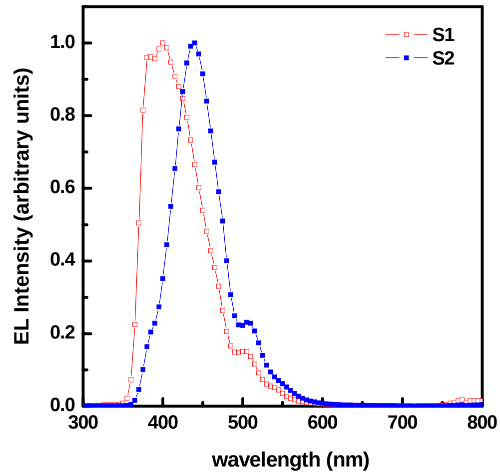


FIG. 3. Normalized EL spectra of type "S1" and type "S2" OLEDs

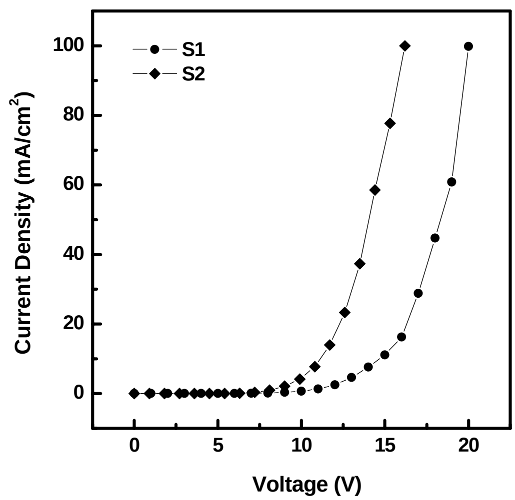


FIG. 4. Current density versus voltage (J-V) characteristics of devised OLEDs

The typical current density-voltage (J-V) characteristics of devised OLEDs are plotted in Fig 4. The J-V characteristics of S2 showed much lower turn-on voltage (at 1 nit) than S1. As can be seen, The S1 had a turn-on voltage of ~5V and S2 had a 7.5V. This result indicated that S2 is more efficient as introduced HTL and ETL. OLEDs containing large energy band gap emitters would usually lead to a greater difficulty in carrier injection and, consequently, a higher device voltage [6].

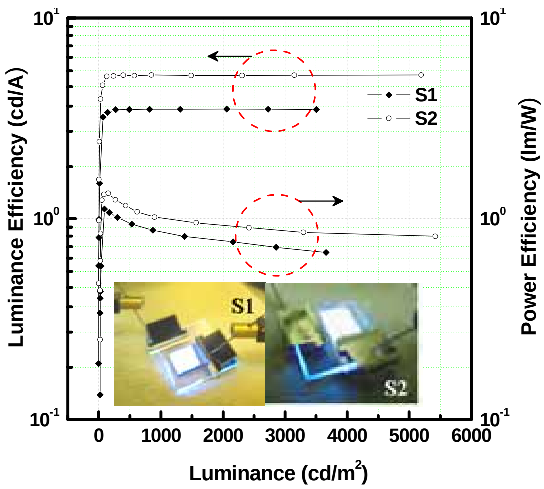


FIG. 5. The plot of luminance yield and Power efficiency vs. current density for S1 and S2

The luminance yield of device S2 is higher than S1 without HTL and ETL through all current density regions by 5 cd/A as shown in FIG. 5.

In this letter, device S2 is higher efficient than S1 because of introducing a HTL and an ETL. However, S1 is more related UV emission area than S2.

3. Conclusion

Efficient near-ultraviolet OLEDs based on the wide band gap emitters have been fabricated and characterized without doping process. The wide band gap small molecular emitters to have PL wavelength of 380 nm ~ 400 nm are possible to identify near-ultraviolet emission. However, to improving the performances, HTL and ETL to have visual rang PL emission peak are not usable because of existing color shift by emission overlap and OLEDs for UV emission need more introducing the carrier blocking layer. The near-ultraviolet OLEDs are utilized in biological/fluorescent sensors, full-color displays by generating blue-to-red emission, or high density information storage devices.

4. Acknowledgements

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5. References

[1] Tang, C.W., VanSlyke, S. A. *Appl. Phys. Lett.*, **51**, 913 (1987)

[2] J. R. Sheats et al., *Science* **273**, 884 (1996)

[3] P. E. Burrows et al., *Appl. Phys. Lett.* **76**, 2493 (2000)

[4] Y. Kostov et al., *Biotechnol. Bioeng.* **70**, 473 (2000)

[5] J. Sipior et al., *Rev. Sci. Instrum.* **68**, 2666 (1997)

[6] Teng-Chin Chao et al., *Adv. Mater.* **17**, 996 (2005)