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Doped Blue Emitters of 9,10-*di*(2-naphthyl)anthracene in Organic Electroluminescent Devices

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Abstract

Blue EL emission of 9,10-*di*(2-naphthyl)anthracene (ADN) based emitter in OLED is highly dependent upon its thickness and attenuated by the microcavity effect of the emitter. By carefully tuning the thickness of ADN and optimizing the doping concentration of TBP, one of the highest efficiencies reported for the anthracene based blue emitter at 6.6 cd/A with a CIE of x = 0.13; y = 0.21 is achieved.

Keywords: opto-electronic devices, electroluminescence, thin-film structures

1. Introduction

Tetra(*t*-butyl)perylene (TBP) doped in 9,10-*di*(2-naphthyl)anthracene (ADN) has been reported to produce efficient blue emission in OLED with a luminance efficiency of ~3.4 cd/A and a CIE coordinates of x = 0.15; y = 0.23. This doped device is also one of the few blue OLEDs that have been demonstrated to be stable [1] with a half life of 4,000 h starting from an initial luminance of 636 cd/m^2. Further studies of this blue ADN emitter revealed however, that its EL performance was not always reproducible nor was the nature of this device robust. Both luminance and color were found to be dependent upon the thickness of each of the organic layers of the device with the emitting layer appeared to be the most sensitive. Slight variation of the thickness of emitter could result in the grow-in of two extraneous shoulders in the green region around 500 nm and 540 nm in addition to the main EL emission at λ_{max} ~ 460 nm which corresponds to the solid PL of ADN. Evidence will be presented in this paper which supports that the variation in EL performances and emission spectrum are mainly due to an optical effect rather than what was commonly believed to be the formation of exciplex [2] or the shift of recombination zone within the emitter [3].

2. Experimental

The device architecture was [ITO (1700Å)/CuPc (150Å)/NPB (400Å) /ADN + TBP (x Å) /Alq_3 (200Å)/LiF (10Å)/Al (2000Å)] and the structure of this blue host and dopant studied in this report is shown in Fig. 1 where CuPc was the hole injection layer, NPB the hole transport material, ADN was the blue host, TBP was the blue dopant and Alq_3 was the electron transport backing layer. Prior to organic deposition, the ITO coated glass plate was thoroughly cleaned by scrubbing, sonication, vapor degreasing, and oxygen plasma treatment. Devices were fabricated under the vacuum of 10^{-6} Torr in a thin-fim evaporation coater following a published protocol [4].

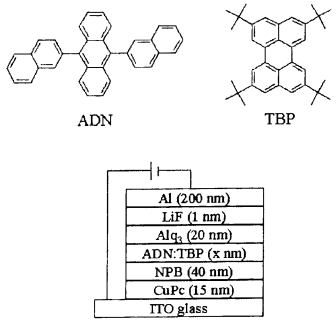

Fig. 1 Device structure and blue host and dopant materials.

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Table 1. EL performance comparison of doped and undoped TBP/ADN blue emitters.

Thickness CuPc/NPB/ADN/Alq_3 (nm)	Concentration TBP (%)	EL peak (nm)	Luminance at 20mA/cm^2 (cd/m^2)	Lum. Yield (cd/A)	CIE coordinates (x,y)	Voltage (V)	Efficiency (lm/W)
25/50/30/40	2	465	636	3.4	0.15,0.23	9.7	1.10
15/40/30/20	0	456	763	3.8	0.16,0.17	8.6	1.39
15/40/130/20	0	456	550	2.8	0.15,0.09	18.2	0.48
15/40/30/20	1	464	1311	6.6	0.13,0.21	8.9	2.33

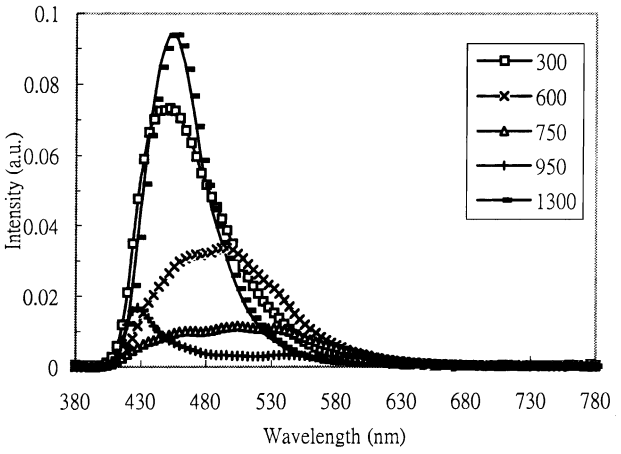

Fig. 2. EL spectra of ADN vs. film thickness

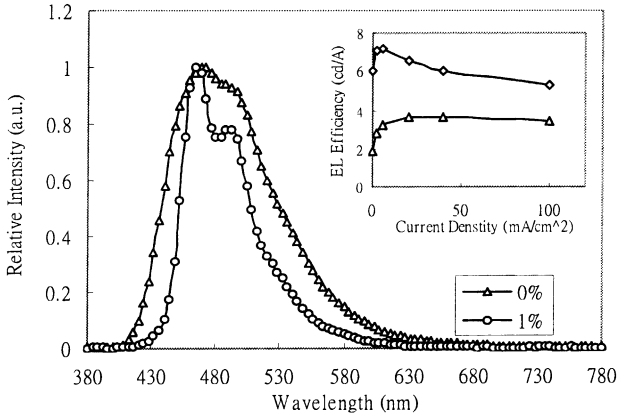

Fig. 3. EL spectra of doped and undoped TBP/ADN blue devices

3. Results and Discussion

Fig. 2 shows the unnormalized EL spectra of the undoped devices where the thickness of the blue ADN emitter layer was systematically increased from 300Å to 1300Å. The blue emission at around 460 nm is noted to broaden and its intensity dropped sharply as the thickness of the emitter layer increased to 600Å and 750Å, respectively. Further increase in thickness was observed to recover the blue emission beginning at ~950Å and maximized at 1300Å when the full EL spectrum of ADN was restored with a narrower FWHM. This periodicity of changing emissive pattern which can no longer be explained by the shift of the exciton recombination zone is best rationalized by the weak microcavity effects of the ADN emitter in OLED [5].

To eliminate the possibility of exciplex formation in interpreting the EL spectral behavior with respect to thickness variations, we replaced the NPB (Ip –5.2eV) with TPD (Ip -5.5eV) in our device structure and fabricated a series of devices by varying the ADN emitter thickness accordingly. It was reasoned that if the broad emission at around 540 nm were indeed produced by the exciplex formation at the ADN/NPB interface, the replacement of TPD with a higher Ip should alleviate it. The fact that similar periodicity of emissive pattern remained for TPD device suggests the exciplex emission does not appear to play a role in the ADN based blue device.

These findings allow us to optimize the blue device structure by doping with TBP at various concentrations in ADN emitter with different thickness. Their EL device performances in terms of luminance efficiency and CIE coordinates are tabulated and benchmarked against Kodak's recent result [1] in Table 1. Increasing the thickness of ADN to 1300Å resulted in producing a much saturated blue emission at CIE x = 0.15; y = 0.09 albeit at a lower luminance efficiency (2.8 cd/A) and a higher drive voltage (18.2V) which could be due to the unbalanced carriers for recombination in the thicker ADN layer. The optimized doping concentration of TBP in the device with 300Å of ADN was determined to be around 1% which produced a blue emission peaking at 464 nm with a CIE x = 0.13; y = 0.21. At the drive current density of 20 mA/cm^2 and 8.9V, this blue device achieved a luminance of 1311 cd/m^2 which corresponds to a luminance efficiency of 6.6 cd/A and a power efficiency of 2.33 lm/W that are among the best ever reported for electrofluorescent OLEDs. Fig. 3 shows the comparison of this doped EL spectrum with that of the undoped device with the insert depicts the relationship between the luminance efficiencies (cd/A) and drive currents of both devices. The near "flat" efficiency response with respect to drive current is particularly desirable for passive matrix OLED flat panel display applications.

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