Extended Abstracts of the 2008 International Conference on Solid State Devices and Materials, Tsukuba, 2008, pp. 990-991

E-10-3

White Light Generation from DBPPV Polymer-CdSe/ZnS Quantum Dot–InGaN/GaN Quantum Well Dual Hybrid Light-Emitting Diodes

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1. Introduction

With the global warming effects becoming serious, people understand that the widespread use of solid-state lighting (SSL) can effectively save more than 50% of the electricity consumption and reduce the carbon emission by 3×10^6 tons annually. Within the next five years, it is expected the LED-based white light sources will completely replace conventional incandescent and fluorescent lamps [1]. In fact, the techniques of fabrication of WLEDs have come a long way and many high quality materials such as organic dyes [2], quantum dots (QDs) [3-5] and polymer [6] are continually discovered as phosphors for color-conversion. Among these materials, the QDs are the most promising candidates due to their relatively narrow emission band and small overlap between the photoluminescence (PL) and absorption spectra. Besides, the emission wavelength of the QDs could be determined by adjusting the diameter of the QDs. The hybrid QD-WLEDs with high color rendering index (CRI) and high luminous efficacy have been reported [3-5]. In the report, we chose conjugated polymer, 2,3-dibutoxy-1,4-poly (phenylene vinylene) (DBPPV), and CdSe/ZnS QDs to fabricate the dually-hybridized WLEDs. With different amount of DBPPV/QDs blends, blue, green, cold and warm white lights can be obtained. More precisely, pure white light with the commission internationale de l'eclairage (CIE) coordinates of (0.33, 0.34), luminous flux of 0.55 lm, luminous efficiency of 8.7 lm/W, CRI of 75.1 and correlated color temperatures (CCT) of 5600 K is achieved. However, the CIE coordinates of WLED can be slightly shifted with current increasing. Simultaneously, it can be also easily observed that the CCT and CRI were decreased by 5% and 17 %, respectively.

2. Experimental

The synthesized CdSe/ZnS core/shell QDs are capped with trioctylphosphine oxide (TOPO) and well-dispersed in toluene with the concentration of 5 mg/ml. The transmission electron microscopy (TEM) image, PL and absorption spectra of QDs are shown in Fig. 1. From the figure, we can observe the QDs have the average diameter of 5.4 nm and PL peak at 625 nm with the full width at half maximum (FWHM) of 40 nm. Subsequently, the DBPPV powder is scattered in toluene with the concentration of 0.6 wt % and stirred for 24 hours. The device configuration of the WLEDs is shown in Fig. 2. The DBPPV and QD solutions are then blended in a volume ratio of 1:2 and the formed DBPPV/QD composite are further blended with the resin to adjust emission wavelength and Commission Internationale de l'Eclairage (CIE) chromaticity coordinates of the devices. The blend ratio of composite to resin is 1:2.5 to obtain the pure white light. The InGaN/GaN blue LEDs has a turn-on voltage of 2.8 V and electroluminescence (EL) peak of 454 nm.

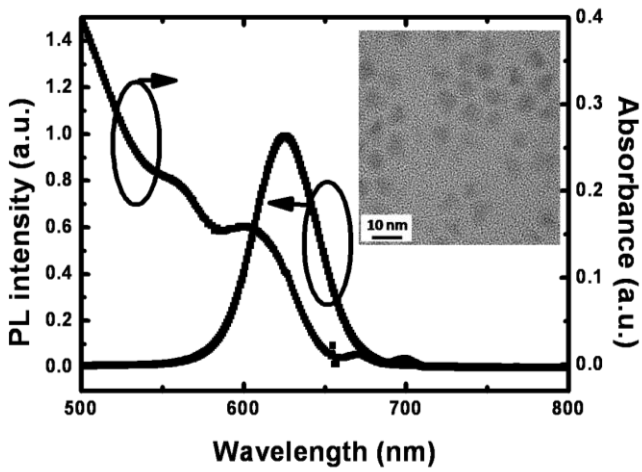

Fig. 1 (a) The TEM image, (b) PL and absorption spectra of CdSe/ZnS quantum dots.

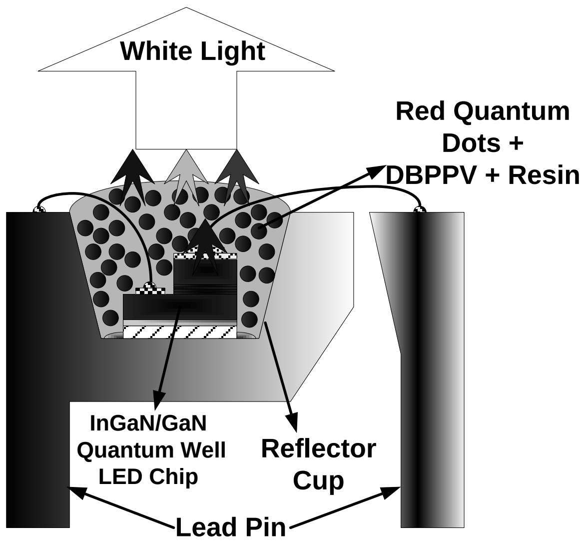

Fig. 2 The schematic diagram of device configuration of the hybrid WLED.

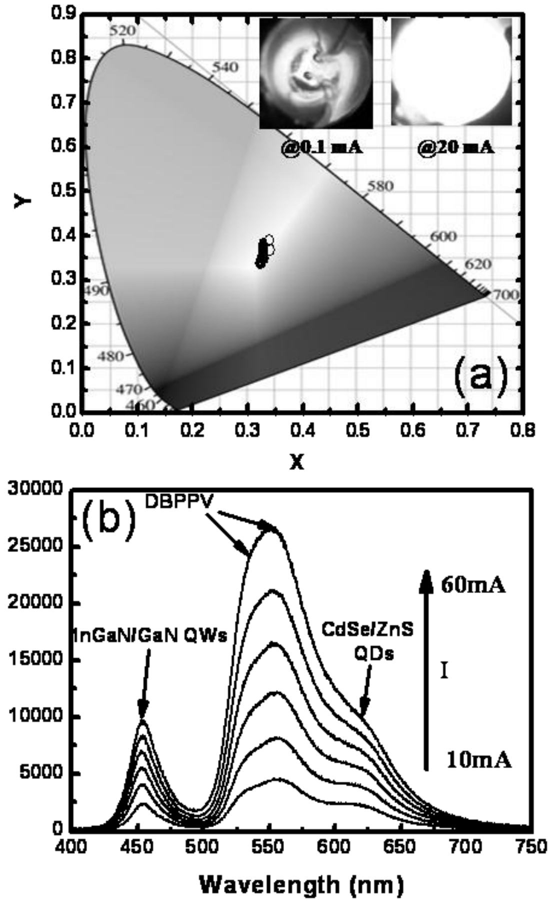

Fig. 3 The variations of (a) CIE coordinates, (b) EL spectrum of the WLED with current increasing from 10 mA to 60 mA. The insets in (a) are the micrographs of the WLED biased at 0.1 mA and 20 mA.

3 Results and Discussion

The variations of CIE coordinates and EL spectrum of the hybrid WLED with current increasing are shown in Fig. 3(a) and 3(b). With current increasing, the CIE coordinates of device are slightly shifted due to the greater increase of green light from DBPPV. From the EL spectra, the emission intensity of the blue light InGaN chip, CdSe/ZnS QDs, and DBPPV can be clearly observed at 454 nm (λ_{InGaN}), 625 nm (λ_{QD}), 535 nm ($\lambda_{DBPPV\text{-}a}$) and 551 nm ($\lambda_{DBPPV\text{-}b}$), respectively. Moreover, the micrographs of the WLED biased at 0.1mA to 20mA are shown in the insets of Fig. 3(a). As shown, the pure white light can be clearly observed. The WLED biased at 20 mA has luminous flux of 0.55 lm, luminous efficiency of 8.7 lm/W, CRI of 75.1 and correlated color temperatures (CCT) of 5600 K.

The CCT and CRI of the WLED are concurrently measured as the current is increased from 2 mA to 60 mA. The CCT and CRI as a function of injection current are shown in Fig. 4. It is observed that the CCT and CRI are initially increased with current increasing because the EL intensity of blue light from InGaN Chip is increased by a wide margin as current is increased. As the current is greater than 10 mA and increased continuously, the CCT is decreased by 5 % and was stabilized at 5656 K above 30 mA accompanying with the 17% decrease of CRI. Finally, it can be easily observed that the WLED biased at 10 mA has maximum CCT of 5884 K and CRI of 76.

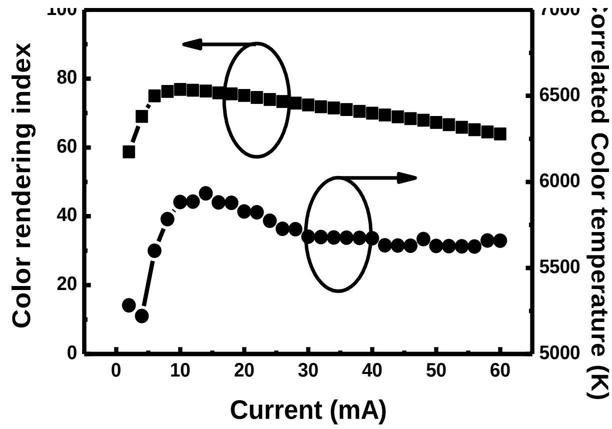

Fig. 4 The CRI and CCT of fabricated WLED as a function of injection current.

4. Conclusion

We have demonstrated the hybrid WLEDs dually hybridized with DBPPV polymer and CdSe/ZnS QDs. The white light is generated by mixing the blue light from InGaN/GaN quantum wells (λ_{InGaN} = 454 nm), the yellowish-green light from DBPPV (λ_{DBPPV} = 535 nm and 551 nm), and the red light from QDs (λ_{QD} = 625nm). With certain amount of DBPPV/QD composite, stable and pure white light with CIE coordinates of (0.33, 0.34), luminous flux of 0.55 lm, efficiency of 8.7 lm/W, CRI of 75.1, and CCT of 5600 K is achieved. Moreover, with current increasing, the CIE coordinates of WLED are slightly shifted and CCT and CRI are decreased by 5% and 17 %, respectively.

Acknowledgements

The authors would like to thank Office of R&D, National Cheng Kung University. This work was supported by the Landmark Project of National Cheng Kung University, Taiwan.

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