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High brightness red light from fluorescence polymer/InGaN hybrid light-emitting diodes

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Abstract

This study demonstrated an efficient red-light emission based on fluorescence polymer/InGaN hybrid light-emitting diodes (FABD LEDs). For the FABD LEDs, the output power, external quantum efficiency, and CIE (x, y) coordinates at 100mA are 46.6 mW, 16.0%, and (0.646, 0.334), respectively. In comparison with the output power for FABD LEDs and AlGaInP LEDs, that enhanced the light output power by an approximate 26.6%.

1. Introduction

Solid-state light-emitting diodes (LEDs) have a number of niche markets along its development, for example the automotive market, backlighting of display screens, display projectors, street signals, and most recently the important market of cell phones. AlGaInP is the material of choice for the long wavelength part of the visible spectrum, namely for red, orange, yellow, and yellow–green wavelengths. Although the epitaxial technology of AlGaInP materials was quite mature due to the intense investigation of previous studies, and as a consequence, around 100% of internal quantum efficiency was achieved. At present, the efficiency of AlGaInP-based red LEDs is still lower than GaN-based blue LEDs in general illumination applications. Additionally, nitride and borate-based red-emitting phosphors have very high cost than other phosphors [1]. Recently, fluorescence polymer phosphor application in LEDs is more dazzle than the inorganic materials due to their high luminescence quantum yield and low cost [2,3]. This study has demonstrated the hybridization of fluorescence polymer on the InGaN blue LEDs to achieve high brightness red light emission. The electrical and optical characteristics of the hybrid devices are also investigated and presented.

2. Experimental

In this study, UV cured polymer was used for encapsulation. Diallyldiphenylsilane (DDS, Fig.1(a)), methacryl polyhedral oligomeric silsesquioxanes (methacryl POSS) with 8 acrylate functional groups (Fig.1(b)), and 2-hydroxy-2-methyl-1-phenylpropane-1-one (1173) were used as monomer, crosslinker, and photoinitiator, respectively. A fluorescence copolymer (FABD) with the anthracene, dioctylfluorene, benzothiadiazole, and bis-thienyl-benzothiadiazole segments as repeating units (Fig. 1(c)) was synthesized by the Suzuki coupling polymerization method [4].

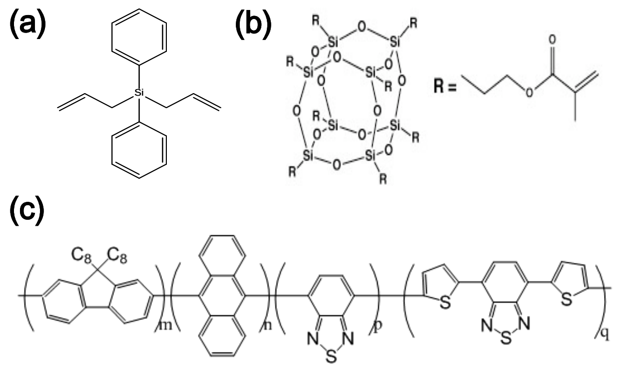

Fig. 1 Chemical structures of UV curable compositions (a) DDS monomer, (b) methacryl POSS crosslinker, and (c) fluorescent polymer, FABD (m:n:p:q = 1:0.2:0.7:0.1).

The UV curable compositions (DDS, methacryl POSS, and 1173) were mixed, casted on the InGaN-based LED chip, and UV cured to make the primary encapsulation layer. Then, the high quantum yield fluorescence polymers, FABD, were blended with the UV curable compositions. The mixture was casted on the primary encapsulation layer and UV cured for fabrication of the FABD LEDs. The absorption peaks of the FABD polymer are 455 nm and the emission peaks are 640 nm. The blue light from the InGaN LED can be effectively down converted by FABD polymers to the red light. Figs. 2(a) and 2(b) showed the schematic cross-section image and top-view image of the hybrid

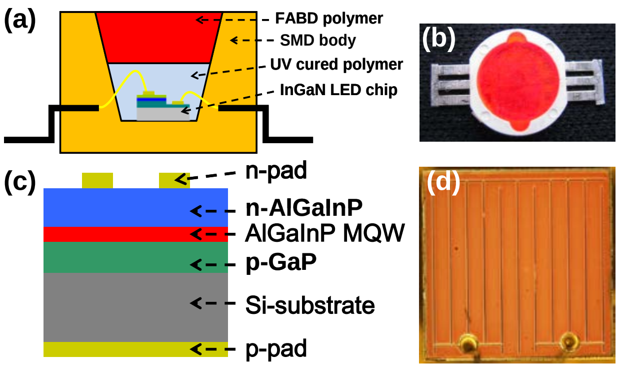

Fig. 2 (a) and (b) Schematic image of the FABD LED structures. (c) and (d) Schematic image of the AlGaInP LED structures.

organic/semiconductor-based LED structures (FABD LEDs). Additionally, the vertical structures of AlGaInP red LEDs used in this study to compare with FABD LEDs. AlGaInP LEDs are the structures and fabrication processes, as the same Ref. 5. The AlGaInP LED chips are packaged into TO can without epoxy resin for the subsequent measurement. Figs. 2(c) and 2(d) shows the schematic image of the AlGaInP-based LEDs.

3. Results and Discussion

The electrical and optical properties of all LEDs were measured by 20 in. integrating sphere, including output power, external quantum efficiency (EQE), and CIE color coordinate (x, y). Figs. 3(a) and 3(b) shows the measurement results of room temperature output power (*L-I-V* curve) and EQE of FABD LEDs and AlInGaP LEDs as a function of the forward-bias current, respectively. The turn-on voltage of the FABD LED and AlGaInP LED were about 2.5 V and 1.6 V, respectively. The light output power-current (*L-I*) curves of both devices show the linear features under our measurement condition of the driving current up to 100 mA. The light output powers at 100 mA of the FABD LEDs and AlGaInP LEDs were 46.6 and 36.8 mW, respectively. It is clearly observed that the light output powers of the FABD LEDs are larger than those of the AlGaInP LEDs. In comparison with the output power for FABD LEDs and AlGaInP LEDs, that enhanced the light output power by an approximate 26.6%. The measured EQEs of FABD LEDs and AlGaInP LEDs at a driving current of 100 mA were 16.0% and 12.7%, respectively.

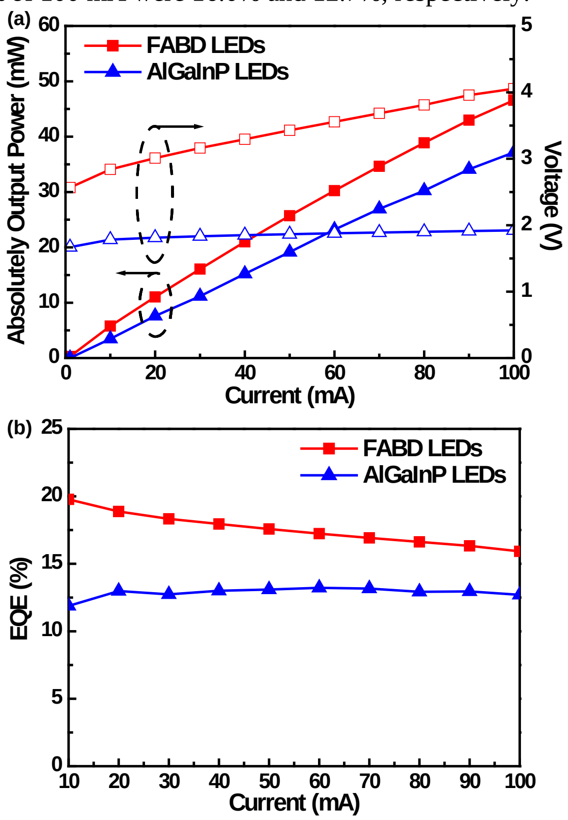

Fig. 3 (a). *L-I-V* characteristics of FABD LEDs and AlGaInP LEDs. (b) The EQE for FABD LEDs and AlGaInP LEDs.

The color stability of FABD LEDs is important for their practical applications. Fig. 4 represents color characteristics of all LED emissions on the CIE chromaticity diagram, under the driving current 100 mA. The CIE (x, y) coordinates define a number of standard illuminants that are used as colorimetric references. The CIE (x, y = 0.646, 0.334) coordinates of the FABD LEDs, and CIE (x, y = 0.671, 0.320) coordinates of the AlGaInP LEDs are located in the red region of the CIE chromaticity diagram, respectively.

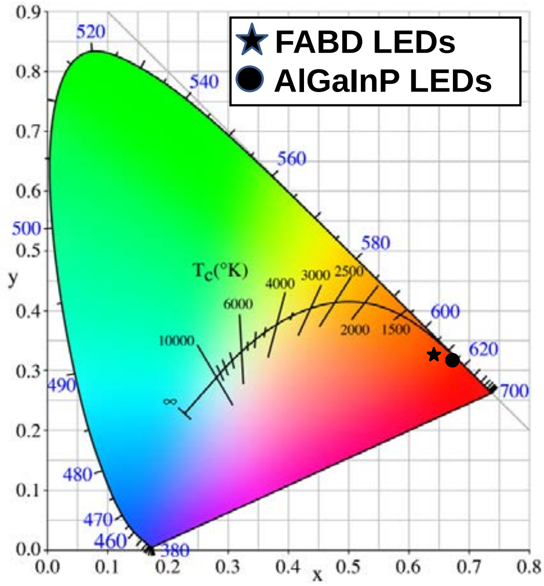

Fig. 4 CIE color chromaticity coordinates (x, y) for the FABD LEDs and AlGaInP LEDs, at a driving current 100 mA.

4. Conclusion

This study demonstrated the high brightness red light emission from the hybrid fluorescence FABD polymer/InGaN LEDs. The light output power of the FABD LED at 100 mA can be achieved to 46.6 mW, which corresponds to the EQE of 16.0%. The CIE (x, y) coordinates of the red light are (0.646, 0.334). The output power of FABD LEDs exhibited the enhancement 26.6% that compared with the AlGaInP LEDs. The application of this technique can sufficiently lower the cost of bright red LEDs and increase the optical quality of lighting.

Acknowledgements

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