

Ba[Mg₂Al₂N₄]Eu²⁺ phosphor for enhancing the optical quality of the 6600K CPW-LEDs

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Abstract

Compared with conventional lamps, LED-based light sources have a superior lifetime, efficiency, and reliability, which promise significant reductions in power consumption and pollution from fossil fuel power plants. The main purpose of this paper is proposed and investigated the effect of the concentration of Ba[Mg₂Al₂N₄]Eu²⁺ conversion phosphor on the CCT deviation (D-CCT) and lumen output (LO) of the 6600 K conformal-packaging white LEDs (CPW-LEDs). For this purpose, we used the Light Tools and Mat Lab software to investigate this problem. From the research results, we can state that the concentration of the red phosphor crucially influenced on the optical quality of the 6600 K CPW-LEDs. The D-CCT can be decreased from 4700K to 2500K, and the LO can be increased from 600 lm. to 1200 lm. This research can provide the new recommendation for LEDs industry at this time.

Keywords: CPW-LEDs, D-CCT, LO, optical quality, red-emitting phosphor

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1. Introduction

Conventional incandescent or fluorescent lamps have huge disadvantages due to the significant energy losses based on high temperatures performance and massive Stokes shifts. In comparison with the conventional lighting methods, light-emitting diodes (LEDs) based on spontaneous light emission in semiconductors with some excellent advantage such as superior lifetime, efficiency, and reliability can be considered as the next lighting generation [1-10]. In LEDs industry, we can generate the white light in three ways. Firstly, the white light is generated by mixing blue, green, and red colors LEDs. In a second way, the white light can be generated by using blue, green, and red phosphors in the phosphor layer LEDs. The last way, the white light can be generated by combining ultraviolet (UV) LEDs with blue, green, and red phosphors. In this research, we consider the second case with the following characteristics: (i) high conversion efficiency; (ii) high stability against chemical, oxygen, carbon dioxide, and moisture; (iii) low thermal quenching; (iv) small and uniform particle size (5–20 nm); and (v) appropriate emission colors [11-20].

The purpose of this research is investigated the effect of the concentration of Ba[Mg₂Al₂N₄]Eu²⁺ conversion phosphor on the CCT deviation (D-CCT) and lumen output (LO) of the 6600 K conformal-packaging white LEDs (CPW-LEDs). For this purpose, we used the Light Tools and Mat Lab software to investigate this problem. From the research results, we can state that the concentration of the red phosphor crucially influenced on the optical quality of the 6600 K CPW-LEDs. The D-CCT can be decreased from 4700K to 2500K, and the LO can be increased from 600 lm. to 1200 lm. This research can provide the novel recommendation for LEDs industry at this time. The rest of our paper can be presented in the following sections. The second section provides the physical model, scattering processes in the phosphor layer. The third section gives results and some discussions. The last section concludes this manuscript. The main contributions of our paper can be drawn as the followings:

- Light Tools conduct the physical model of the 6600K CPW-LEDs.

- The scattering processes in the phosphor compounding of CPW-LEDs is investigated by Mat Lab.
- The effect of the red phosphor concentration on the D-CCT and LO is investigated and convinced.

2. Research Method

2.1. The CPW-LEDs Physical Model

In this section, we use the Light Tools to conduct the 6600K CPW-LEDs. The main parameters of the LEDs are listed as the following:

- The depth, the inner and outer radius of the reflector to 2.07 mm, 8 mm and 9.85 mm, respectively.
- Nine LED chips are covered with a fixed thickness of 0.08 mm and 2.07 mm. Each blue chip has a dimension of 1.14 mm by 0.15mm, the radiant flux of 1.16 W, and the peak wavelength of 453 nm, shown in Figure 1 (a-b) [13-15].

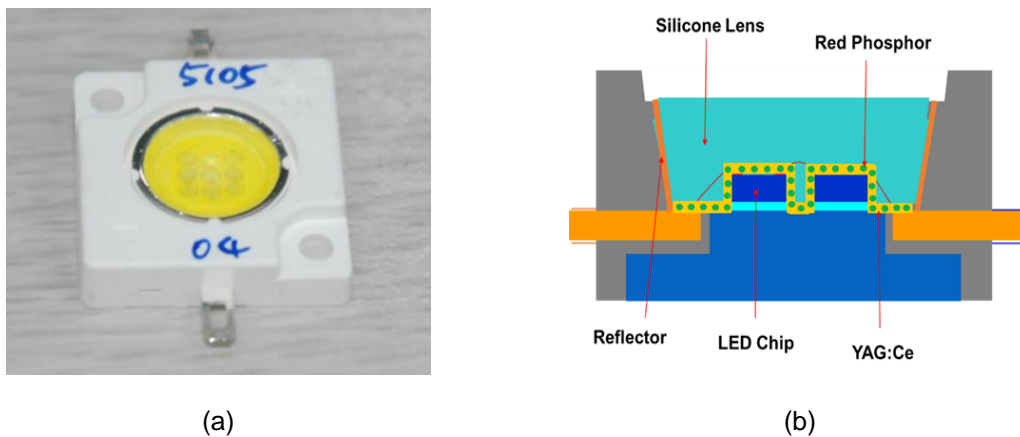


Figure 1. (a) The real WLEDs, (b) The physical model of the 6600K CPW-LEDs

2.2. The Scattering Processes in the Phosphor Compounding

In this section, we use the Mie-scattering theory to investigate the scattering processes in the phosphor compounding of the CPW-LEDs as in [21-26]. The scattering coefficient $\mu_{sca}(\lambda)$ (mm⁻¹), the absorption coefficient $\mu_{abs}(\lambda)$ (mm⁻¹), anisotropy factor $g(\lambda)$ (mm⁻¹), and reduced scattering coefficient $\delta_{sca}(\lambda)$ (mm⁻¹) can be computed by the below expressions (1), (2), (3), and (4):

$$\mu_{sca}(\lambda) = \int N(r)C_{sca}(\lambda, r)dr \quad (1)$$

$$\mu_{abs}(\lambda) = \int N(r)C_{abs}(\lambda, r)dr \quad (2)$$

$$g(\lambda) = 2\pi \int_{-1}^1 p(\theta, \lambda, r)f(r) \cos \theta d \cos \theta dr \quad (3)$$

$$\delta_{sca} = \mu_{sca}(1 - g) \quad (4)$$

3. Results and Discussion

In this section, we investigate the scattering processes in the phosphor compounding of the 6600K CPW-LEDs by Mat Lab software. The scattering coefficient (SC) versus the concentration of the red phosphor is plotted in Figure 2. In Figure 2, the SC of all increase

significantly while the concentration of the red phosphor varies from 0% to 26%. This effect is caused by enhancing the white light quality in the CPW-LEDs by controlling the red phosphor concentration. Furthermore, the reduced scattering coefficient (RSC) with wavelengths 453 nm, 555 nm, and 680 nm have illustrated in Figure 3 with the increasing the concentration of the red phosphor from 0% to 26%. We can see that the RSC are the same as the red, yellow, and blue lights due to the scattering stability of red phosphor in the phosphor layer of the CPW-LEDs. Finally, the anisotropy coefficient (AC) versus the red phosphor concentration is plotted in Figure 4. From the research results, we can state that the AC of the red and blue light is the same and are crucially lower than the AC of the yellow light.

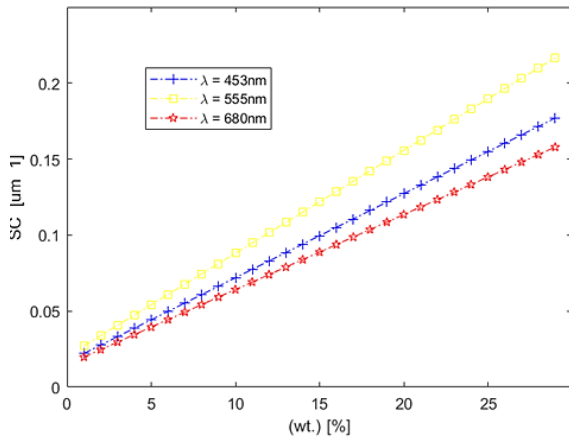


Figure 2. Scattering coefficient (SC)

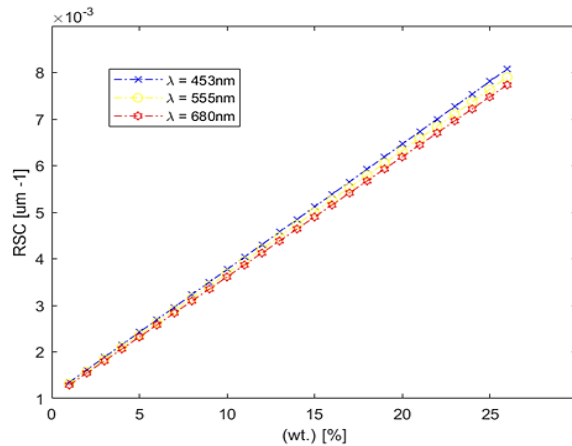


Figure 3. Reduced scattering coefficient (RSC)

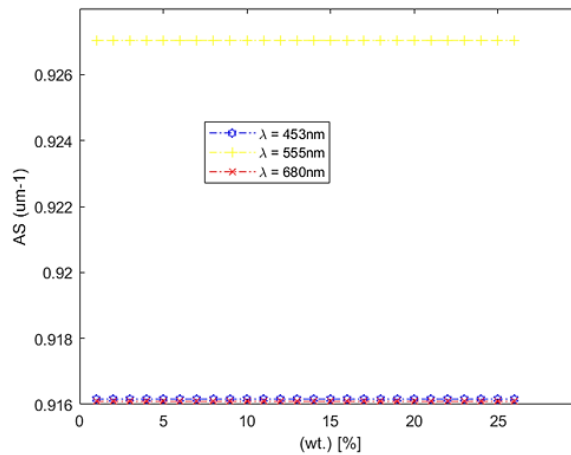


Figure 4. Anisotropy coefficient (AC)

Furthermore, the D-CCT versus concentration of the red phosphor of the 6600k CPW-LEDs is illustrated in Figure 5. In this Fig., the concentration of the red phosphor varies from 0% to 26% in the phosphor layer. As shown in Figure 6, the D-CCT has a massive decrease from 4700K to 2500K when the concentration of the red phosphor varies from 0% to 26%. This effect is caused by the more scattering process on the phosphor compounding of the 6600K CPW-LEDs. Moreover, the effect of the concentration of the red phosphor on the LO of the 6600K CPW-LEDs is plotted in Figure 6. From this Figure, we can see that the LO increases from 600 lm to 1300 lm with the increasing concentration from 0% to 26%. This effect can be caused by the more scattering and reduced scattering of the red phosphor particle in the phosphor layer.

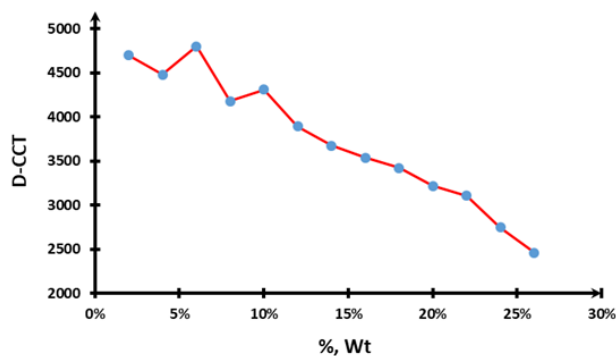


Figure 5. The D-CCT

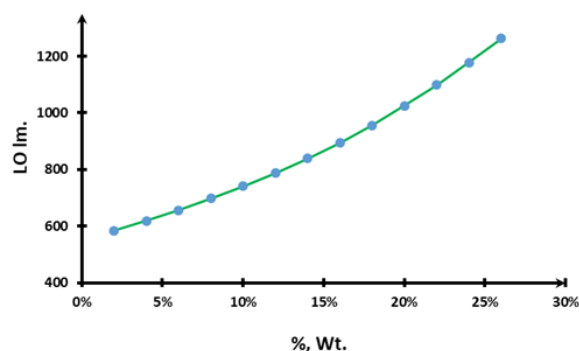


Figure 6. Lumen output (LO)

4. Conclusion

In this paper, we proposed and investigated the effect of the concentration of $\text{Ba}[\text{Mg}_2\text{Al}_2\text{N}_4]\text{Eu}^{2+}$ conversion phosphor on the CCT deviation (D-CCT) and lumen output (LO) of the 6600 K conformal-packaging white LEDs (CPW-LEDs). For this purpose, we used the Light Tools and Mat Lab software to investigate this problem. From the research results, we can state that the concentration of the red phosphor has a significant effect on the optical quality of the 6600 K CPW-LEDs. The D-CCT can be decreased from 4700K to 2500K, and the LO can be increased from 600 lm. to 1200 lm. This research can provide the novel recommendation for LEDs industry at this time.

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