$Sr[Mg_3SiN_4]Eu^{2+}$ phosphor: solution for enhancing the optical properties of the 5600K remote-packaging WLEDs

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ABSTRACT

In the last decade, light-emitting diodes (LEDs), which based on spontaneous light emission in semiconductors can be considered as the main light sources for civil and industrial purposes. In this paper, we presented and investigated the effect of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the optical properties of the 5600K remote-packaging WLEDs (RP-WLEDs). We use the Mat Lab and the LightTool software to investigate the effect of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the CRI, CQS, D-CCT and LO of the 5600K RP-WLEDs. From the result, we can state that the concentration of the $Sr[Mg_3SiN_4]Eu^{2+}$ influenced on the CRI, CQS, D-CCT and LO of the RP-WLEDs. The red $Sr[Mg_3SiN_4]Eu^{2+}$ phosphor can be considered as the novel recommendation for LEDs industry.

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1. INTRODUCTION

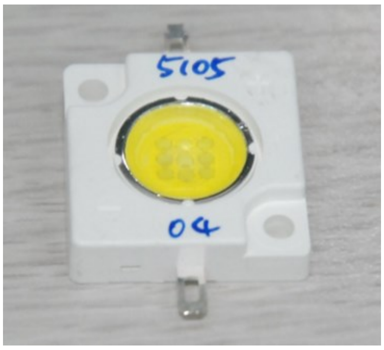
In the last decade, light-emitting diodes (LEDs can be considered as the main light sources for civil and industrial purposes. In comparison with conventional lamps, LEDs with the excellent advantages such as superior lifetime, efficiency, and reliability can be considered as the promising solution for significant reductions in power consumption and pollution from fossil fuel power plants [1-8]. In order to improve the performance of LEDs, a lot of issues such as chip processing, light extraction efficiency, heat sink structures, resin materials, reliability, life test, etc. is necessary to investigate. Phosphor coating is the most critical fluid flow problem in LED packaging since the coating process determines the phosphor thickness, location, distribution, and morphology in LED packaging [9-15].

In this paper, we presented and investigated the effect of the $Sr[Mg_3SiN_4]Eu^{2+}$ phosphor on the optical properties of the 5600K remote-packaging WLEDs (RP-WLEDs). We use the Mat Lab and the light tool software to investigate the effect of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the CRI, CQS, D-CCT, and LO of the 5600K RP-WLEDs. From the result, we can state that the concentration of the $Sr[Mg_3SiN_4]Eu^{2+}$ influenced on the CRI, CQS, D-CCT and LO of the RP-WLEDs. The rest of this paper can be drawn as the following section. In the second section, the physical model and the mathematical scattering model is presented. Next, the results and some discussions are provided in third section. Finally, some conclusions are convinced in the last section.

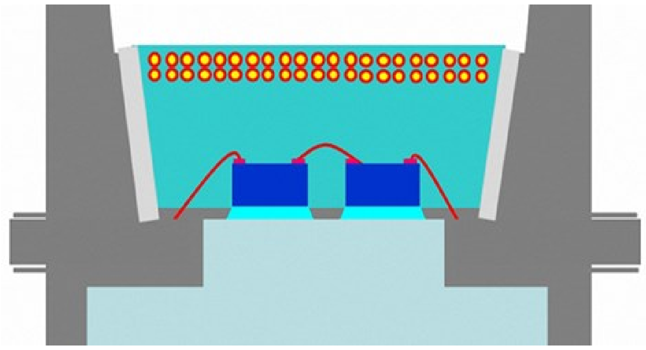
2. RESEARCH METHOD

Explaining research chronological, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition [1-3]. The description of the course of research should be supported references, so the explanation can be accepted scientifically [2, 4]. We conducted the physical model of the 5600K RP-WLEDs using Light Tool software with the primary parameters as:

- We set the depth as 2.07 mm, the inner and outer radius of the reflector as 8 mm and 9.85 mm, respectively.
- 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 (Figure 1) [15-20].



(a)



(b)

Figure 1. (a) The RP- WLEDs; (b) The physical model

The scattering processes in the phosphor layer can be analyzed by using the Mie-scattering theory, as shown in [20-27]. The scattering coefficient $\mu_{sca}(\lambda)$.

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

Anisotropy factor $g(\lambda)$

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

Reduced scattering coefficient $\delta_{sca}(\lambda)$

$$\delta_{sca} = \mu_{sca}(1 - g) \quad (3)$$

qhere *N(r)* and *f(r)* can be defined as

$$f(r) = f_{dif}(r) + f_{phos}(r) \quad (4)$$

$$N(r) = N_{dif}(r) + N_{phos}(r) = K_N.[f_{dif}(r) + f_{phos}(r)] \quad (5)$$

where *c* is the phosphor concentration can be calculated by

$$c = K_N \int M(r)dr \quad (6)$$

The mass distribution *M(r)* (milligrams) can be defined as the below equation

$$M(r) = \frac{4}{3}\pi r^3[\rho_{dif} f_{dif}(r) + \rho_{phos} f_{phos}(r)] \quad (7)$$

In Mie theory, C_{sca} can be calculated as

$$C_{sca} = \frac{2\pi}{k^2}\sum_0^\infty (2n-1)(|a_n|^2 + |b_n|^2) \quad (8)$$

where a_n and b_n can be calculated by the below equations

$$a_n(x,m) = \frac{\psi'_n(mx)\psi_n(x) - m\,\psi_n(mx)\psi'_n(x)}{\psi'_n(mx)\xi_n(x) - m\,\psi_n(mx)\xi_n{}'(x)} \quad (9)$$

$$a_n(x,m) = \frac{m\psi'_n(mx)\psi_n(x) - \psi_n(mx)\psi'_n(x)}{m\psi'_n(mx)\xi_n(x) - \psi_n(mx)\xi_n{}'(x)} \quad (10)$$

Here, the phase function $p(\theta, \lambda, r)$ can be defined as the following

$$p(\theta, \lambda, r) = \frac{4\pi\beta(\theta,\lambda,r)}{k^2 C_{sca}(\lambda,r)} \quad (11)$$

where $\beta(\theta, \lambda, r)$ is the dimensionless scattering function, which can be calculated as the followings

$$\beta(\theta, \lambda, r) = \frac{1}{2}[|S_1(\theta)|^2 + |S_2(\theta)|^2] \quad (12)$$

$$S_1 = \sum_{n=1}^\infty \frac{2n+1}{n(n+1)}\begin{bmatrix} a_n(x,m)\pi_n(\cos\theta) \\ +b_n(x,m)\tau_n(\cos\theta) \end{bmatrix} \quad (13)$$

$$S_2 = \sum_{n=1}^\infty \frac{2n+1}{n(n+1)}\begin{bmatrix} a_n(x,m)\tau_n(\cos\theta) \\ +b_n(x,m)\pi_n(\cos\theta) \end{bmatrix} \quad (14)$$

In (13) and (14), $\pi_n(\cos\theta)$ and $\tau_n(\cos\theta)$ are the angular dependent functions.

3. RESULTS AND ANALYSIS

In this section, we use the Mat Lab and Light Tool software to investigate the influence of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the optical properties in terms of D-CCT, CRI, CQS, and LO. As shown in Figure 2, the D-CCT has a considerable increase with the rising of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration. The D-CCT increases from 1000 K to 5000K when we vary the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration from 0% to 16%. From the results, we can state that the more $Sr[Mg_3SiN_4]Eu^{2+}$ added to the phosphor compounding, the more D-CCT can be obtained. The excellent value of the D-CCT can be obtained with the lowest concentration of the $Sr[Mg_3SiN_4]Eu^{2+}$. It can be observed that the $Sr[Mg_3SiN_4]Eu^{2+}$ takes part in the scattering processes in the phosphor layer.

Furthermore, the influence of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the CQS and CRI of the 5600K RP-WLEDs is drawn in Figures 3 and 4, respectively. From Figure 3, we can see that the CQS increases while the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration rises from 0% to 12% and has a massive decrease with the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration from12% to 16 %. The optimal value of the CQS is76, with 12% red phosphor concentration. In the same way, the CRI rises when the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration increases from 0% to 10% and then decreases significantly while the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration varies from 10% to 16%. The CRI has the maximum value as 87 with 10% $Sr[Mg_3SiN_4]Eu^{2+}$ concentration, as illustrated in Figure 4.

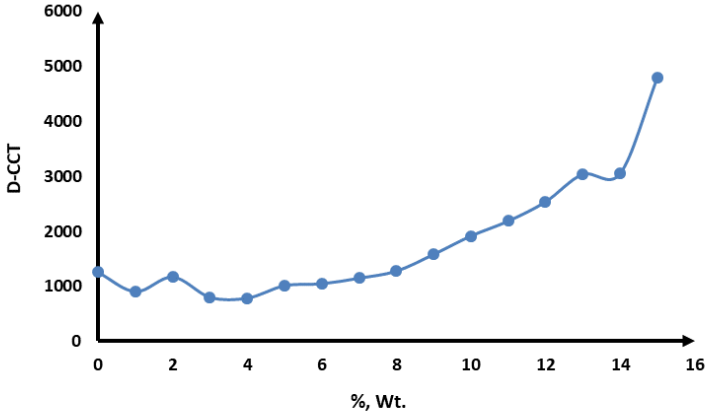


Figure 2. D-CCT

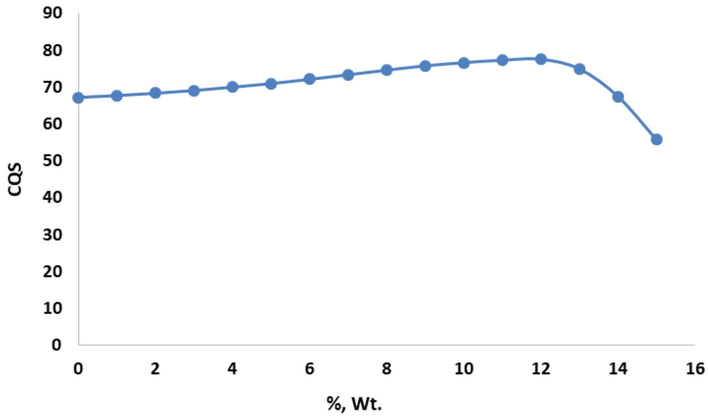


Figure 3. CQS

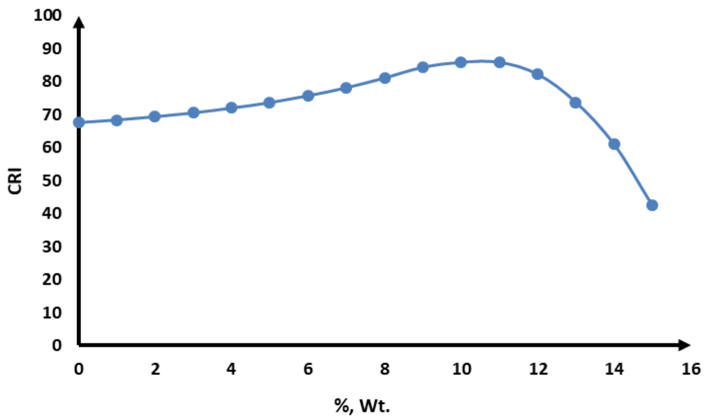


Figure 4. CRI

From these results, we can state that the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration has a significant impact on the CQS and CRI of the 5600K RP-WLEDs. Finally, the impact of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the LO of the 5600K RP-WLEDs is presented in Figure 5. Here, we varied the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration from 0% to 16% and investigated the influence of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the LO. As shown in Figure 5, the Lo has a massive fall with the rising of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration to convince the influence of the $Sr[Mg_3SiN_4]Eu^{2+}$ concentration on the LO of the 5600K RP-WLEDs.

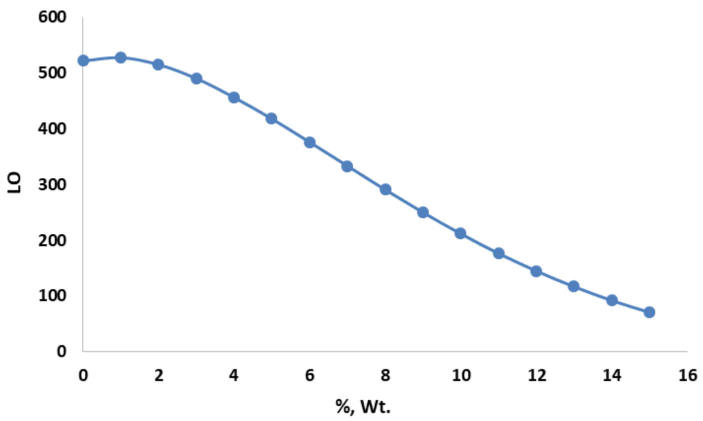


Figure 5. LO

4. CONCLUSION

In this paper, we presented and investigated the effect of the red $Sr[Mg_3SiN_4]Eu^{2+}$ phosphor concentration on the optical properties of the 5600K RP-WLEDs. We use the Mat Lab and the Light Tool Software to investigate the effect of the red phosphor concentration on the CRI, CQS, D-CCT, and LO of the 5600K RP-WLEDs. From the result, we can state that the concentration of the red phosphor influenced on the CRI, CQS, D-CCT and LO of the RP-WLEDs. This research can be proposed the novel recommendation for LEDs manufacturing in the near future.

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