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$Ca[Mg_3SiN_4]Ce^{3+}$ phosphor: effect of particle concentration on lighting properties of the 7000K IPW-LEDs

Q.S. Vu[1], Tang Tin Dao[2], Minh Tran[3]
[1,2] Faculty of Electronics and Automation, Hong Bang International University, Ho Chi Minh City, Vietnam
[3] Optoelectronics Research Group, Faculty of Electrical and Electronics Engineering, Ton Duc Thang University, Ho Chi Minh City, Vietnam

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ABSTRACT

Nowadays, the white-light-emitting diodes (LEDs) have a vast application on the real-life based on its superior advantages for application in both industrial and civil area. In this paper, we co-doping the $Ca[Mg_3SiN_4]Ce^{3+}$ Phosphor on the phosphor compound of the 7000K In-cup Packaging White LEDs (IPW-LEDs) for improving the lighting properties. By varying the concentration of $Ca[Mg_3SiN_4]Ce^{3+}$ Phosphor from 0% to 1.8%, the effect of the $Ca[Mg_3SiN_4]Ce^{3+}$ on the D-CCT, CRI, CQS, and LO of the 7000K IPW-LEDs are investigated. Using the Light Tool and software, the research results show that the concentration of the IPW-LEDs has a massive influence on the lighting properties of the 7000K IPW-LEDs. All the results are convinced by Light Tool simulation.

Corresponding Author:

Minh Tran,
Optoelectronics Research Group,
Faculty of Electrical and Electronics Engineering,
Ton Duc Thang University, Ho Chi Minh City, Vietnam.
Email: tranhoangquangminh@tdtu.edu.vn

1. INTRODUCTION

Nowadays, the white-light-emitting diodes (LEDs) have a vast application on the real-life based on its superior advantages for application in both industrial and civil area. There are three ways to generate the white light by LEDs for the human eye vision in commonly way as 1) first way is color-mixing from the LEDs to conduct the white light 2) The second is using the phosphor to convert the blue light to the white light in the device called phosphor-converted LEDs, 3) and the third way is the combination of options 1 and 2 to generate the white light [1-6]. In the conventional pc-LEDs, the blue light from the chip die is absorbed by the yellow phosphor to generate the red and yellow lights. The absorption of the red, blue, yellow lights in the phosphor compounding of the LEDs is called self-absorption. The scattering, trapping, and absorption of light are the reason to decrease the efficiency of LED devices caused by energy loss. However, the light scattering and trapping by phosphor particles also increase the probability of light being absorbed by the cup, packaging materials, mainly by LEDs die to improve the optical properties of the LEDs. Here, the lighting performance of the LEDs is influenced by the concentration of phosphor, the thickness of the phosphor-composite layer, the size of phosphor particles, and the curvature of the encapsulating surface [6-15]. From that point of view, improving the lighting properties of the White LEDs (WLEDs) by researching the material in the phosphor layer is need more and more developed and it is the goal of this paper.

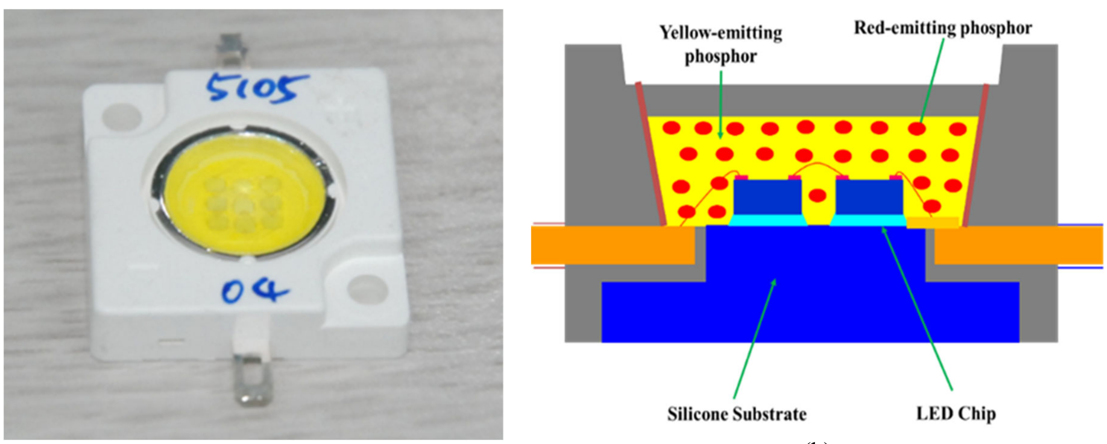
In this paper, we co-doping the $Ca[Mg_3SiN_4]Ce^{3+}$ on the phosphor compound of the 7000K In-cup Packaging White LEDs (IPW-LEDs) for improving the lighting properties. By varying the concentration of

$Ca[Mg_3SiN_4]Ce^{3+}$ from 0% to 1.8%, the effect of the $Ca[Mg_3SiN_4]Ce^{3+}$ Phosphor on the D-CCT, CRI, CQS, and LO of the 7000K IPW-LEDs is investigated. Using the Light Tool and software, the research results show that the concentration of the IPW-LEDs has a massive influence on the lighting properties of the 7000K IPW-LEDs. All the results are convinced by Light Tool simulation. There are some main contributions of this research:

a. The IPW-LEDs model is simulated by Light Tools software in the second section with the real LEDs parameters.
b. We use the Mat Lab software to investigate the scattering processes in the phosphor layer IPW-LEDs in the third section.
c. The effect of the $Ca[Mg_3SiN_4]Ce^{3+}$ Phosphor concentration on the lighting properties in terms of CRI, CQS, D-CCT, and LO is convinced by the LightTool simulation in the third section.

2. RESEARCH METHOD

In this section, the 5600K RP-WLEDs are employed. Figure 1(a) presents a real WLEDs package. Based on this package, the remote phosphor compound is built using Light Tools software, as shown in Figure 1(b). In this model, IPW-LEDs have been c configured as in previous studies. The primary parameters of the 7000K IPW-LEDs can be conducted as in [13].



(a) (b)

Figure 1. (a) The real white LEDs package, (b) The IPW-LEDs

3. RESULTS AND DISCUSSION

The optical properties of Ca[Mg3SiN4]Ce3+ particles are configured by using the Mat Lab software based on Mie-theory as in [13, 16-25]. The scattering coefficient $\mu_{scattering}(\lambda)$, anisotropy factor $g(\lambda)$, and reduced scattering coefficient $\delta_{sca}(\lambda)$ can be formulated as

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

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

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

In these equations, the primary coefficients are chosen as in [13, 18-22].

By using the Mat Lab software, the influence of the Ca[Mg3SiN4]Ce3+ particles concentration on the scattering, reduced scattering and anisotropy coefficients are plotted in Figures 2, 3 and 4, respectively. In this simulation analysis, we vary the concentration of the Ca[Mg3SiN4]Ce3+ particles from 1% to 5%. As shown in Figure 2, we can state that the scattering coefficients of the wavelength 453, 555, and 680 nm have considerable increase while the concentration of the Ca[Mg3SiN4]Ce3+ particles rise from 1% to 5 %. The scattering coefficient of the wavelength 680 nm is the lowest one and of the 452 nm is the highest one. It can be observed that the scattering of the yellow light in the phosphor layer is higher than of the other one. This can be lead to the higher lighting performance of the IPW-LEDs. Furthermore, the anisotropy coefficient versus the Ca[Mg3SiN4]Ce3+ particle concentration is illustrated in Figure 3 with rising of the Ca[Mg3SiN4]Ce3+ particles concentration from 1% to 5%. From Figure 3, we can see that the anisotropy coefficient of the453and 680 nm is the same with each other, but the anisotropy of the 555 nm is higher than others. It can happen because of the anisotropy process in the phosphor layer of the yellow light is better than other ones as the above case of the scattering coefficient. Finally, the reduced scattering process in the phosphor layer of the IPW-LEDs in the connection with the Ca[Mg3SiN4]Ce3+ particle concentration is showed in Figure 4. As illustrated in Figure 4, the scattering coefficient of all red, blue and yellow lights are the same. From the research results, it can be stated that the influence of the Ca[Mg3SiN4]Ce3+ particles concentration on the scattering processes in the IPW-LEDs phosphor layer is considerable [23-25].

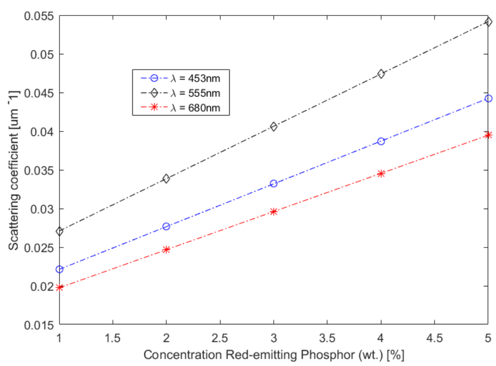


Figure 2. Scattering coefficients

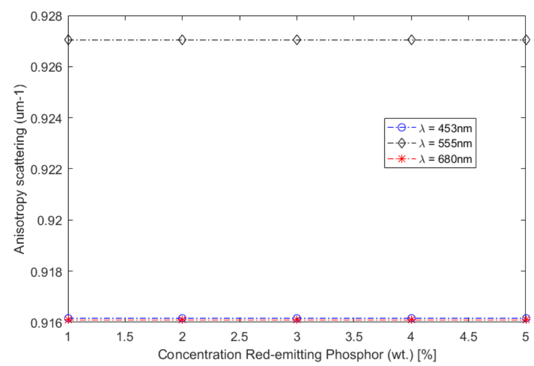


Figure 3. Anisotropy scattering

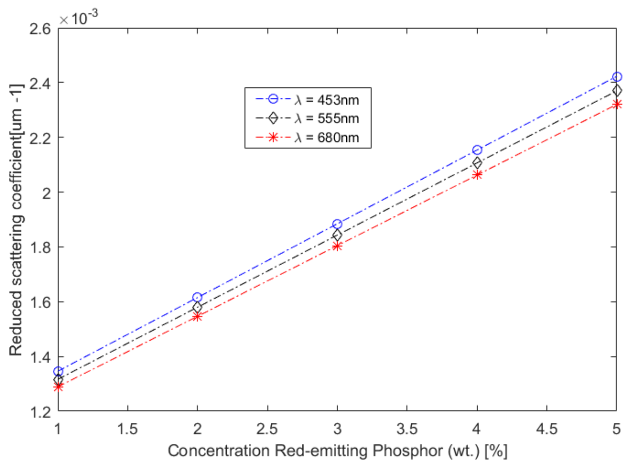


Figure 4. Reduced scattering coefficients

The influence of the Ca[Mg3SiN4]Ce3+ particle concentration on the CRI is shown in Figure 5 with rising of the concentration from 0% to1.8%. As shown in Figure 5, the CRI falls from 68 to 61 with raising the concentration of the Ca[Mg3SiN4]Ce3+. Furthermore, the CQS versus the Ca[Mg3SiN4]Ce3+ concentration is drawn in Figure 6. As in Figure 5, we set the values of the Ca[Mg3SiN4]Ce3+ concentration from 0% to 1.8%. The CQS decreases from 66 to 62 with the rising of the Ca[Mg3SiN4]Ce3+ concentration. The results from Figure 5 and 6 can be observed that the doping of the Ca[Mg3SiN4]Ce3+ on the phosphor layer has a huge impact on the CRI and CQS of the IPW-LEDs by influence on the scattering processes on the phosphor layer.

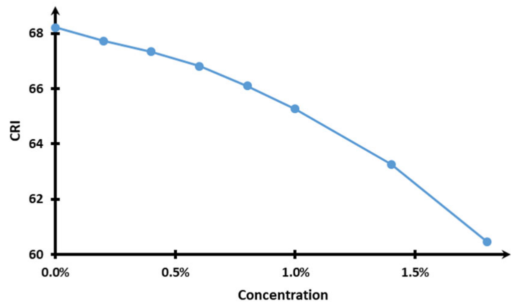


Figure 5. CRI

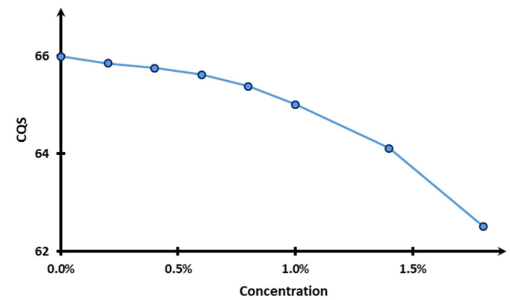


Figure 6. CQS

Finally, the LO and D-CCT versus the Ca[Mg3SiN4]Ce3+ concentration are illustrated in Figure 7 and 8, respectively. As shown in Figure 7, the LO has a huge increase from 800 lm to 1400 lm with the rising of the Ca[Mg3SiN4]Ce3+ concentration from 0% to 1.8%. Furthermore, the D-CCT decreases from 4000K to 1500K while we vary the Ca[Mg3SiN4]Ce3+ concentration from 0% to 1.8% as in Figure 8. It can be stated that the higher the Ca[Mg3SiN4]Ce3+concentration, the better LO and D-CCT of the IPW-LEDs. These results agree well with the scattering processes analysis in the above section.

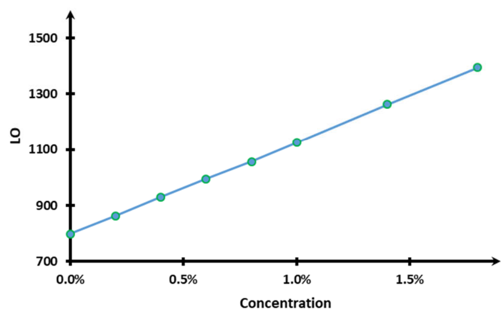


Figure 7. Luminous flux

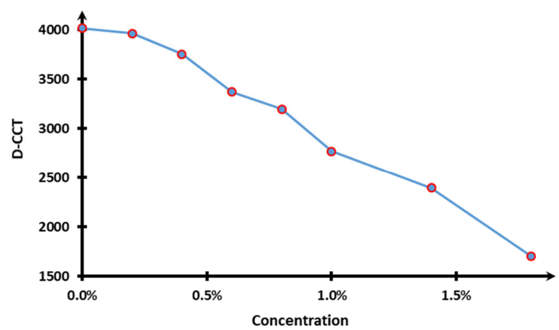


Figure 8. D-CCT

4. CONCLUSION

In this paper, we co-doping the $Ca[Mg_3SiN_4]Ce^{3+}$ on the phosphor compound of the 7000K IPW-LEDs for improving the lighting properties. By varying the concentration of $Ca[Mg_3SiN_4]Ce^{3+}$ Phosphor from 0% to 1.8%, the effect of the $Ca[Mg_3SiN_4]Ce^{3+}$ on the D-CCT, CRI, CQS, and LO of the 7000K IPW-LEDs are investigated. Using the Light Tool and software, the research results show that the concentration of the IPW-LEDs has a massive influence on the lighting properties of the 7000K IPW-LEDs. All the results are convinced by Light Tool simulation and provide a novel recommendation for LEDs manufacturing.

ACKNOWLEDGMENTS

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