Application of Sr_3SiO_5:Eu yellow phosphor for white light-emitting diodes

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Abstract

In order to develop new yellow phosphor that emit efficiently under the 450 – 470 nm excitation range, we have synthesized a Eu^{2+}-activated Sr_3SiO_5 yellow phosphor and investigated an attempt to develop white LEDs by combining it with a InGaN blue LED chip (460 nm). Two distinct emission bands from the InGaN-based LED and the Sr_3SiO_5:Eu phosphor are clearly observed at 460 nm and at 570 nm, respectively. These two emission bands combine to give a spectrum that appears white to the naked eye. Our results showed that InGaN (460 nm chip)-based Sr_3SiO_5:Eu exhibits a better luminous efficiency than that of the industrially available product InGaN (460 nm chip)-based YAG:Ce.

1. Introduction

Recently, there have been some detailed studies on the integration of the blue LED and the yellow phosphor, as this creates white light from a combination of a blue LED emission (460 nm) and a broad-band yellow YAG:Ce phosphor. [1,2] However, there are no ideal yellow phosphors that emit efficiently under the 450 - 470 nm excitation range, except the YAG:Ce phosphor and some organic luminescent materials. [3,4] In this view, it is interesting to develop efficient new yellow phosphor that emit efficiently under the 450 - 470 nm excitation range. Here we report an Eu^{2+}-activated Sr_3SiO_5 yellow phosphor and investigate in an attempt to develop white LEDs through the integration of the InGaN blue LED chip (λ_{em} = 460 nm) and the Sr_3SiO_5:Eu phosphor into a single package. In order to develop new yellow phosphor that emit efficiently under the 450 – 470 nm range, we have synthesized a Eu^{2+}-activated Sr_3SiO_5 yellow phosphor and investigated an attempt to develop white LEDs by combining it with a InGaN blue chip (460 nm).

2. Experimental

In this study, the powder samples of Sr_3SiO_5:Eu were prepared by solid-state reaction. To compare the white luminescent LEDs between YAG:Ce and Sr_3SiO_5:Eu phosphors, white luminescence conversion LEDs were fabricated. Based on the standard LED technology, InGaN (460 nm chip)-based YAG:Ce and Sr_3SiO_5:Eu white LEDs were encapsulated in a transparent epoxy resin. The InGaN LED was used because its 460 nm blue emission was used as an optical excitation of the YAG:Ce and Sr_3SiO_5:Eu phosphor. The relative emission spectra of a InGaN-based YAG:Ce and Sr_3SiO_5:Eu LED under a forward bias of 20 mA were measured using a 50 cm single-grating monochrometer.

3. Results and discussion

The photoluminescence (PL) emission intensities of Sr_3SiO_5 samples as a function of Eu^{2+} concentration and excitation wavelength are shown in Fig. 1. It is very significant to point out that the PL emission efficiency of this phosphor when the excitation wavelength is 460 nm. At the 0.07 mol concentration of Eu^{2+}, the emission intensity from λ_{ex} = 460 nm was measured to be 93 % by comparing the emission intensity from λ_{ex} = 365 nm.

The emission spectrum of the white emitting InGaN (460 nm chip)-based Sr_3SiO_5:Eu LED is shown in Fig. 2. As shown in this figure, two distinct emission bands from the InGaN-based LED and the Sr_3SiO_5:Eu phosphor are clearly resolved at 460 nm and at around 570 nm, respectively.

A wide range of whitish colors can be realized by fabricating InGaN-based LED with different amounts of Sr_3SiO_5:Eu concentration. The CIE chromaticity of InGaN-based LED with different amounts of Sr_3SiO_5:Eu concentration are shown in Fig. 3. As the concentration of Sr_3SiO_5:Eu increases, the color shifts from blue to white. In addition, the chromaticity coordinates are close to the straight lines interconnecting the points of the blue pump and white.

Change in temperature of the LED *pn* junction leads to changes in light output, wavelength and spectral width. It is noted, therefore, that the temperature dependence of the phosphor is important. The temperature dependence of the emission intensities of an YAG:Ce and Sr_3SiO_5:Eu phosphor between 25℃ and 250℃ are shown in Fig. 4. With increasing temperatures, the emission intensities of YAG:Ce phosphor is significantly decreased. On the other hand, the emission intensities of Sr_3SiO_5:Eu phosphor does not decreased at all with temperature. It is indicated that the Sr_3SiO_5:Eu phosphor has a more stable structure than the YAG:Ce phosphor when compared to that of the emission intensity with increasing temperature.

4. Conclusion

In the present work, we have synthesized an Eu^{2+}-activated Sr_3SiO_5 yellow phosphor, and investigated its luminescent properties in an attempt to develop white LEDs by integrating the InGaN blue LED chip and the Sr_3SiO_5:Eu phosphor; the combination of a blue LED emitting (460 nm) and a broad-band yellow Sr_3SiO_5:Eu phosphor creates white line. The white InGaN-based Sr_3SiO_5:Eu developed in this work showed a higher luminous efficiency compared with the industrially available InGaN-based YAG:Ce.

5. References

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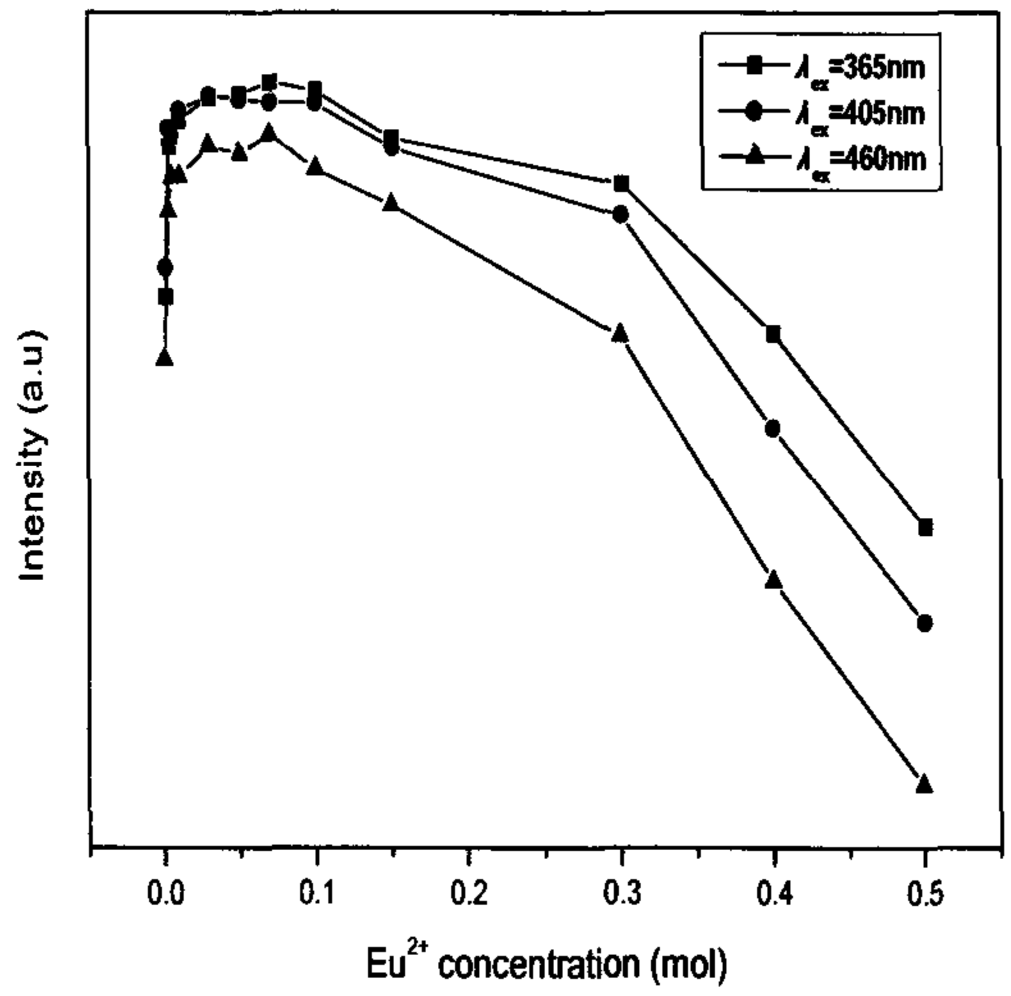

Fig. 1 Emission intensities of Eu^{2+} fluorescence as a function of Eu^{2+} concentration in Sr_3SiO_5:Eu phosphor.

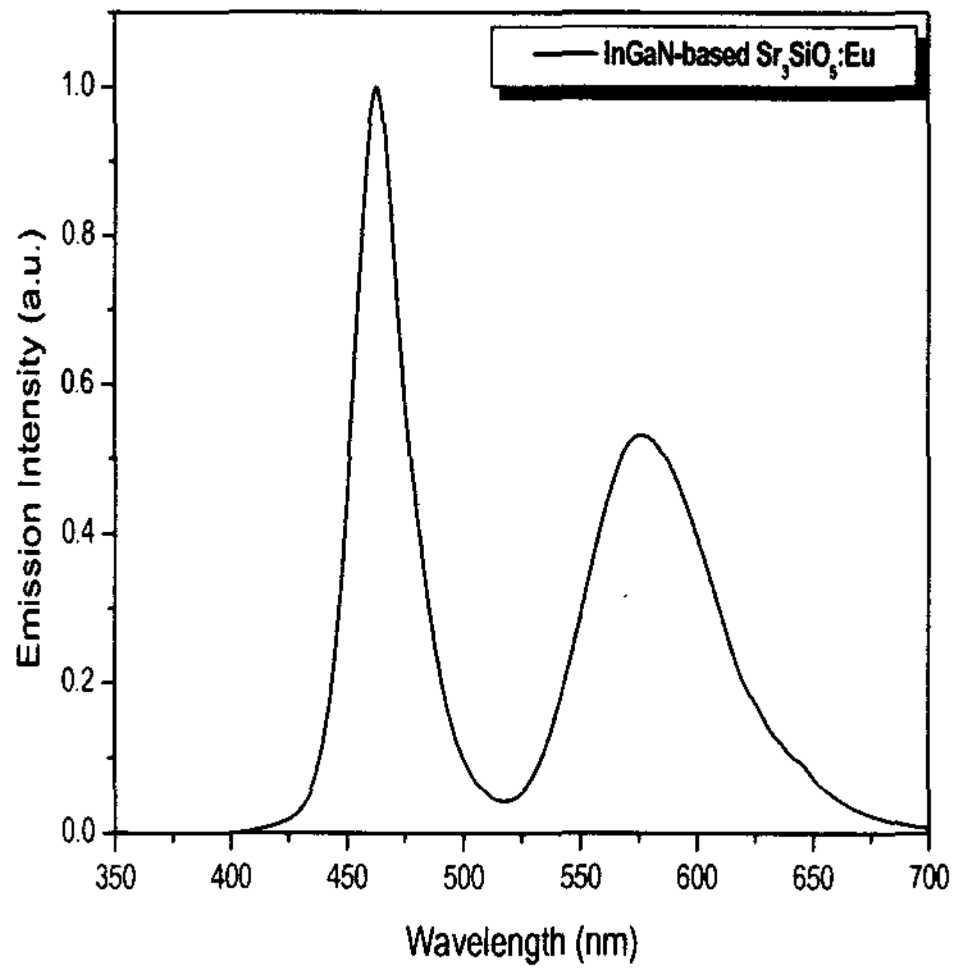

Fig. 2 Emission spectrum of a InGaN-based Sr_3SiO_5:Eu LED under a 20 mA drive current.

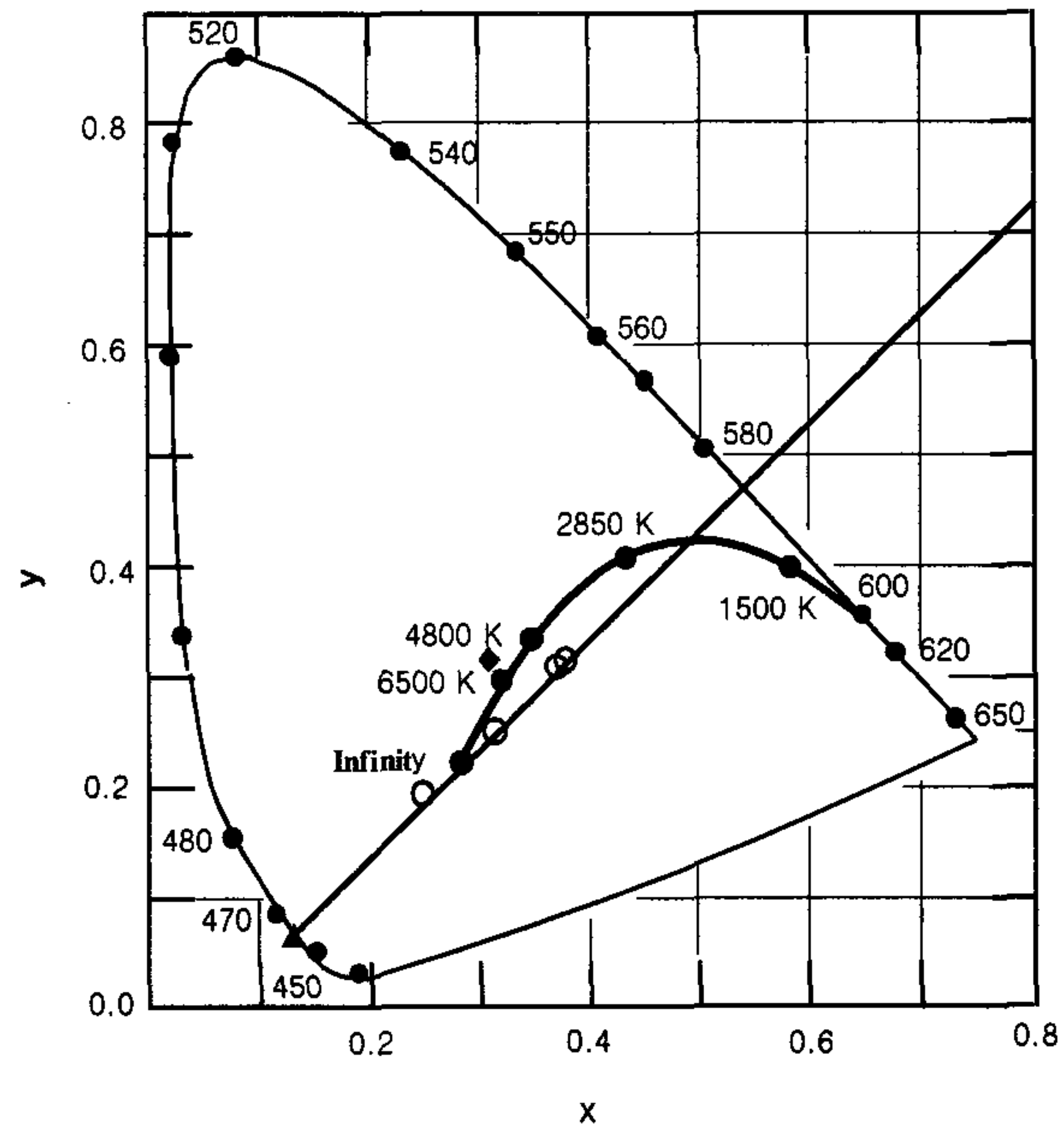

Fig. 3 CIE chromaticity points of InGaN-based Sr_3SiO_5:Eu LED and of corresponding InGaN LED. InGaN-based Sr_3SiO_5:Eu LED (marked by open circle), InGaN LED (closed triangle) and InGaN-based YAG:Ce LED (closed diamond).

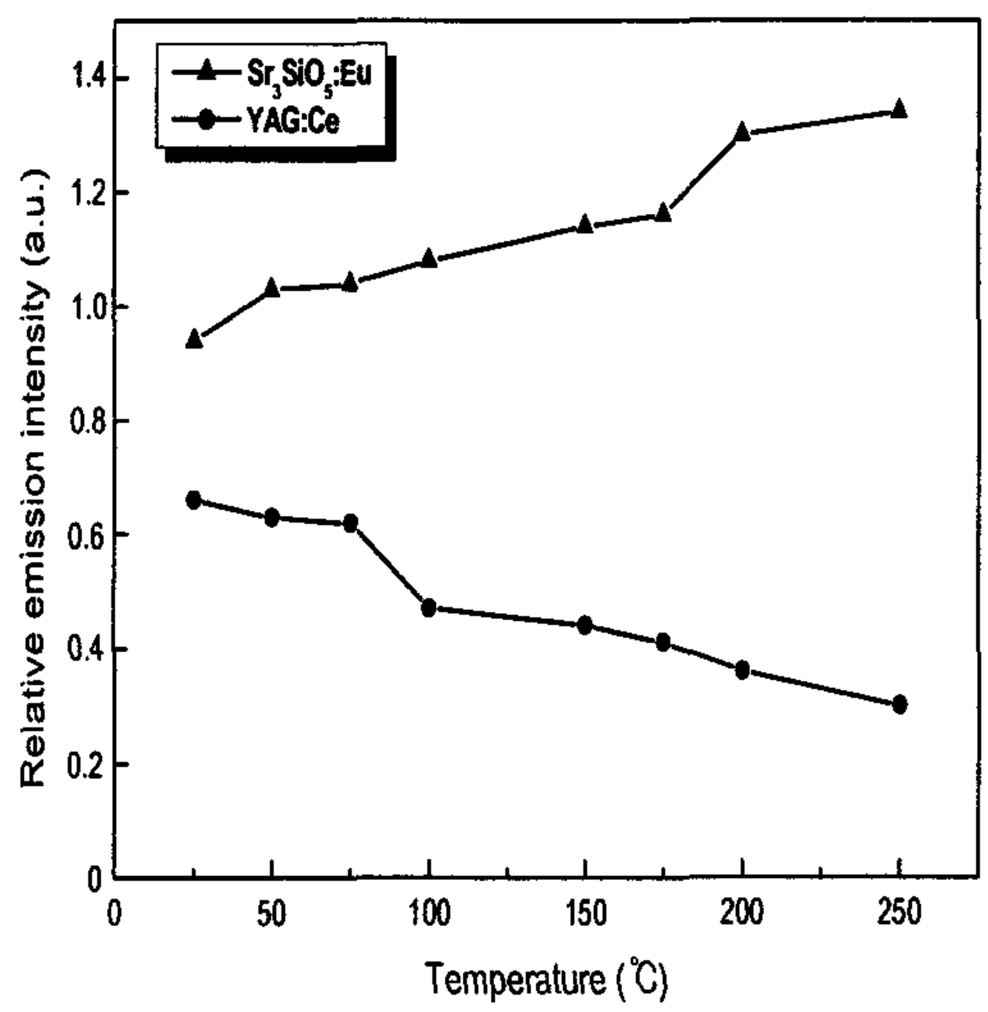

Fig. 4 Temperature dependence of the emission intensities of an YAG:Ce and Sr_3SiO_5:Eu phosphor between 25℃ and 250℃.