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Optical Properties of the $Sr_2MgSi_2O_7$:Eu^+ Phosphor Coated with SiO_2 Nano-Particles

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We investigated the effects of the SiO_2 surface coating on the optical properties of $Sr_2MgSi_2O_7$:Eu^+ phosphor which is used for a white light source in the blue LED chip. A modified sol-gel method was used for the surface coating of the commercial yellow phosphor with SiO_2. The experimental results suggest that the surface coating of phosphors with SiO_2 nano-particles leads to an increase in the intensity of the 550 nm peak. It is of interest that this increasing tendency depends on the concentrations of the colloidal solution. Thus, the surface coating of phosphors is a way for improving the luminance of the white LED.

Keywords Nano-particles; SiO_2; $Sr_2MgSi_2O_7$:Eu^+ phosphor; surface coating; white light

Introduction

White light-emitting diodes (LEDs) have recently attracted significant attention due to their potential application in many fields such as devices indicators, backlights, automobile headlights and general illumination [1–3]. The combination of red, green, blue phosphor and an ultraviolet or yellow phosphor and blue-emitting chip have been known as a way for obtaining white light [4]. Among them, the combination of blue LED with yellow-emitting phosphor materials is the common way for generating white light [5–7]. The emission color of the $Sr_2MgSi_2O_7$:Eu^+ phosphor mainly covers the yellow region. Combination of a blue LED chip and $Sr_2MgSi_2O_7$:Eu^+ phosphor produces white light. Meanwhile, phosphor's surface coating has been introduced for increasing luminance and preventing the degradation of phosphors [8,9]. Thus, the surface coating is known to be an important technique in improving phosphor characteristics. On the other hand, the modified sol-gel method has been frequently used for the surface treatment because it is a simple process, compared to other chemical methods [10,11]. In order to obtain the LED phosphor with better luminance performances, we prepared the SiO_2 coated $Sr_2MgSi_2O_7$:Eu^+ phosphor by a modified sol-gel method and investigated the optical properties of $Sr_2MgSi_2O_7$:Eu^+ phosphor coated with SiO_2 nano-particles.

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Experimental

The commercial yellow $Sr_2MgSi_2O_7:Eu^+$ (Intermatrix Co.) phosphor was coated with the SiO_2 by a modified sol-gel method [9]. The SiO_2 coating of the phosphor was performed by using the colloidal SiO_2 (LUDOX-AM-30; Sigma-Aldrich Chemical Co.) as a precursor material. To make the concentration of colloidal SiO_2 fixed at a value, we diluted the colloidal SiO_2 with the de-ionized water. The $Sr_2MgSi_2O_7:Eu^+$ phosphor was mixed with the diluted colloidal SiO_2 of about 0.07 wt% and 0.36 wt% concentrations. The mixed solution was stirred with a magnetic bar for 5 hours to be the phosphor suspensions. The phosphor suspensions were washed three times by ethanol. The resulting SiO_2 coated phosphors were filtered and dried at 80°C for 12 hours. The comparison of the properties between the non-coated and the SiO_2 coated yellow phosphor was made by using Scanning Electron Microscopy (SEM), photoluminance (PL), Energy Dispersive X-ray Spectrophotometer (EDS) and X-ray Fluorescence spectroscopy (XRF) of them.

Results and Discussion

Figure 1 represents the SEM images the $Sr_2MgSi_2O_7:Eu^+$ phosphors before and after the SiO_2 coating. The SEM images tell us firmly that the nano-sized SiO_2 particles

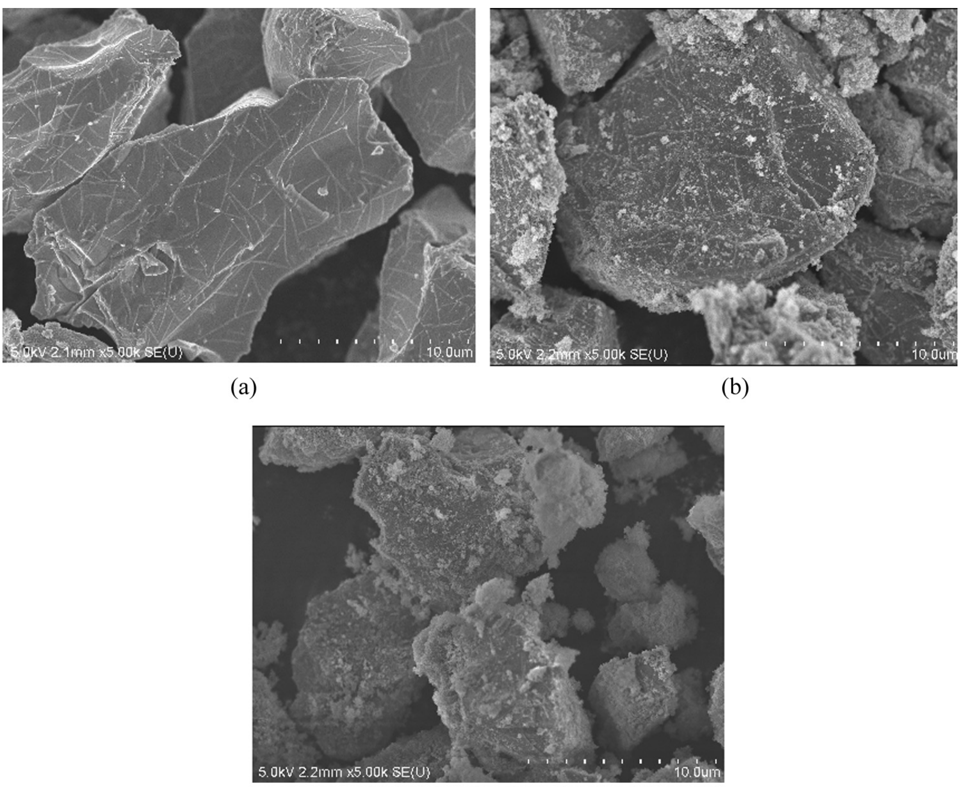
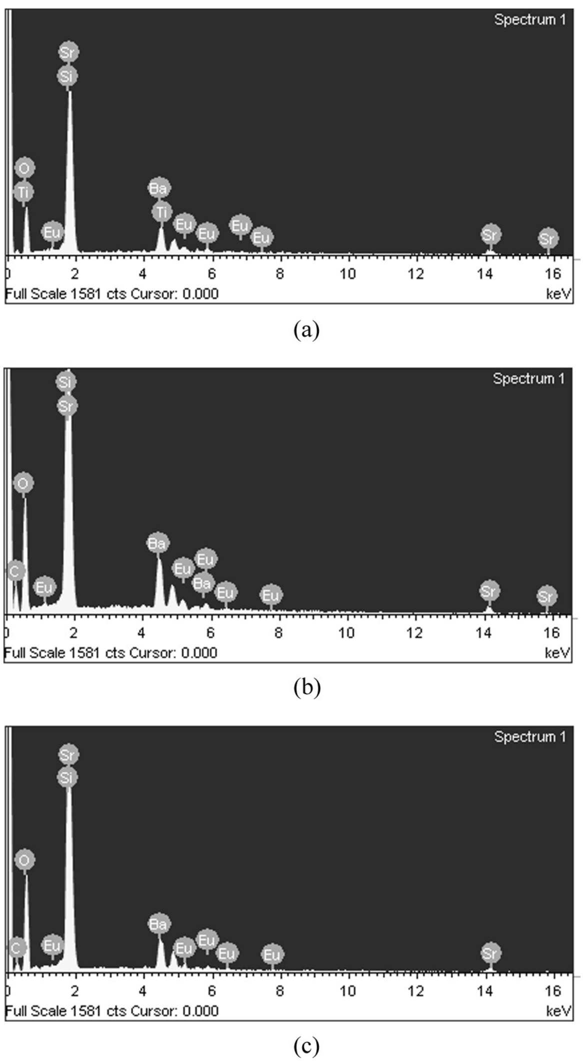


Figure 1. The SEM images of (a) the non-coated $Sr_2MgSi_2O_7:Eu^+$ phosphor, (b) the SiO_2 (0.07 wt%) coated $Sr_2MgSi_2O_7:Eu^+$ phosphor, and (c) the SiO_2 (0.36 wt%) coated phosphor.

are coated well on the surface of $Sr_2MgSi_2O_7{:}Eu^+$ phosphor. We can also easily see that the surface morphology of the $Sr_2MgSi_2O_7{:}Eu^+$ phosphor depends strongly on the concentrations of the colloidal SiO_2 solution. The EDS data of the non-coated and SiO_2 coated phosphors are plotted in Figure 2. As shown in Figure 2(b) and (c), the Si related peak was increased with increasing SiO_2 concentrations and thence we can confirm that the nano-particles as seen in Figure 1(b) and (c) are composed of SiO_2. In order to reconfirm SiO_2 nano-particles on the surface of the coated phosphors, we performed the XRF experiments. Figure 3 shows XRF results of the non-coated and the SiO_2 coated $Sr_2MgSi_2O_7{:}Eu^+$ phosphors. The surface coating of phosphors with SiO_2 nano-particles leads to an increase in the Si peak with increasing SiO_2 concentrations confirming again the SiO_2 coating on the surface



(a) (b) (c)

Figure 2. The EDS data of (a) the non-coated $Sr_2MgSi_2O_7{:}Eu^+$ phosphor, (b) the SiO_2 (0.07 wt%) coated $Sr_2MgSi_2O_7{:}Eu^+$ phosphor, and (c) the SiO_2 (0.36 wt%) coated phosphor.

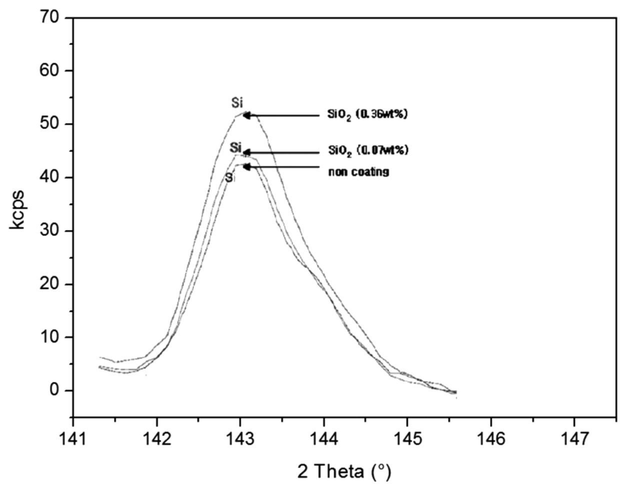


Figure 3. The XRF data of the non-coated and the SiO_2 coated $Sr_2MgSi_2O_7$:Eu^+ phosphors.

of the phosphors. Figure 4 shows the change in PL spectra after SiO_2 coating. The PL spectra measured by using a blue source of wavelength of 450 nm of Xe lamps reveal that the surface coating of phosphors with SiO_2 nano-particles leads to an increase in the intensity of the 550 nm peak, resulting from the 5d–4f transition of Eu^{2+} ions. It is of interest that this increasing tendency depends on the concentrations of the colloidal solution. The increase in the PL intensity is probably originated from reducing surface defect states by the SiO_2 coating [12]. Thus, one can expect that the surface coating of phosphors with oxides gives rise to a promising effect for enhancing the optical properties of phosphors, based on the suppression of the nonradiative recombination via surface defect levels. The surface coating of phosphors with oxides can also affect the degradation of phosphor, which is under investigating.

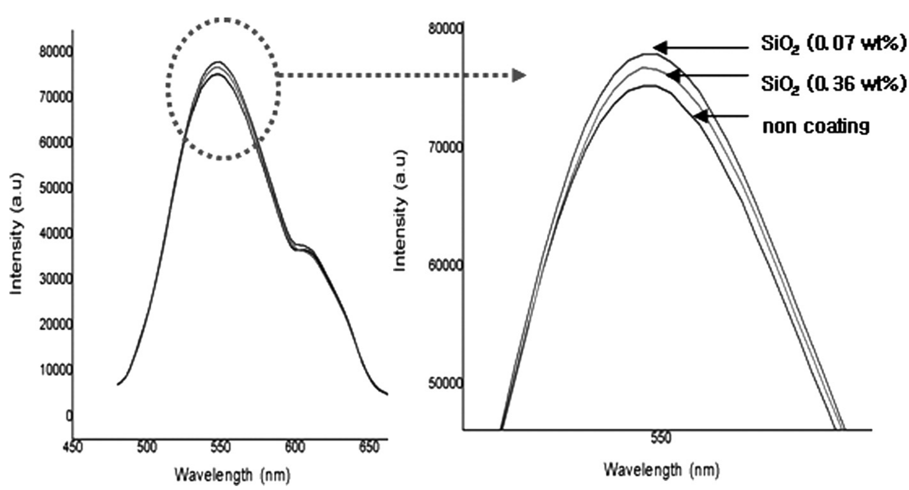


Figure 4. The PL spectra of the non-coated and the SiO_2 coated $Sr_2MgSi_2O_7$:Eu^+ phosphors.

Conclusions

We prepared the $Sr_2MgSi_2O_7:Eu^+$ modified phosphor coated with nano-particles of SiO_2 by a simple sol-gel method and compared optical properties before and after the SiO_2 coating. The SiO_2 coating yields an increase in the PL intensity of the phosphors, a promising effect for LED. This increase can be explained by a suppression of nonradiative recombination by surface defect states. Thus, the SiO_2 surface coating of $Sr_2MgSi_2O_7:Eu^+$ phosphors is a way for improving the luminance of the white LED.

Acknowledgments

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