Synthesis and Luminescent Property Investigation of the $Lu_3Al_5O_{12}$:Ce for the White LEDs

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Abstract

In this report, cerium doped lutetium aluminate ($Lu_3Al_5O_{12}$:Ce) phosphor has been synthesized by the solid state method under reduction atmosphere with mixture gas. The prepared phosphor shows a main luminescent peak at 555nm. Consequently, this phosphor is possible to be applicable to white LED lamp by InGaN chips.

1. Introduction

The $Lu_3Al_5O_{12}$ (LuAG) doped with Ce was very attractive for lighting and display applications. And this material is known to be a promising host structure for scintillating materials. The currently commercial white LEDs are obtained mainly by combining a 465 nm blue-emitting InGaN LED with a yellow-emitting yttrium aluminum garnet ($Y_3Al_5O_{12}$) doped Ce^{3+} phosphor. The LuAG was shown the yellow emission. Using the various dopping materials, the LuAG was alternated optical properties.

The light emitting diodes (LEDs) is widely investigated for alternation of the incandescent electric lamps and fluorescent lamps. There are widely used in electronic elements requiring a high light rate and with a high level of electric power, as LEDs have nearby 100% luminescence efficiency, a high electron movement rate, and function at high temperatures. In order to apply LEDs for a light source of the incandescent electric lamps and fluorescent lamps, it is basically to fabricate a LED lamp which emits white light. General methods are employed to generate white LED light by using integration of phosphors. One method is the integration of yellow phosphor or green and orange or red phosphors on a blue LED chip. The other method is the accumulation of two (blue and yellow) or three (red, green and blue) phosphors on an ultraviolet (UV) chip. In order to use phosphors for white LEDs, part of the commonly ultraviolet or blue light from GaN (>370nm) or InGaN(<470nm) chips must be absorbed and converted.

Our goal was verified possibility of application for light emitting diode. The prepared phosphor was shown good photoluminescence property with 450nm. Consequently, this phosphor is possible to be applicable to white LED lamp by blue-InGaN chips.[1-2]

2. Experimental

The yellow phosphor $Lu_3Al_5O_{12}$:Ce was synthesized from solid powders (≥ 99.9 %) of Lu_2O_3, Y_2O_3, Al_2O_3, and CeO_2 using a solid-state reaction method. Initially, appropriate proportions of the raw materials were mixed in acetone and dried in an air oven at 100℃. The mixed powder was heated to different temperatures for 3h under under an reduction condition with 5% H_2/ 95% N_2. In order to determine the crystal property of the prepared phosphor, a Rigaku (D/MAX-2200V) X-ray diffraction (XRD) system with Cu *Kα* radiation (Ni filter) was utilized. The luminescence characteristics of the synthesized samples at room temperature were obtained by a spectrometer equipped with Xe-lamp, PMT, and monochrometers. The size and morphology of the prepared phosphors were observed by scanning

electron microscopy (JSM-6360, JEOL Corporation Japan). The platinum was coated onto the sample surface by electric power before SEM observation. The White LEDs were fabricated from the InGaN-based blue LED chip and prepared phosphor (optimized $Lu_3Al_5O_{12}$:Ce) in a single package using a transparent epoxy resin. The photoluminescence characteristics of the white LEDs were verified using a PR-650 spectrascan spectracolorimeter with a 50 cm single-grating monochrometer under a forward bias of 20 mA current.

3. Results and discussion

Fig. 1 shows typical PL excitation and emission spectra of optimized $Lu_3Al_5O_{12}$:Ce phosphor. The emission spectra were measured under 450 nm because part of the commonly blue light from InGaN(<470nm) chips must be absorbed and converted. In case of the excitation spectrum, that has high excitation band at 349 and 468 nm which was emitted by ultraviolet excitation sources. In case of the emission band, main peak appears at 555 nm wavelength.[3]

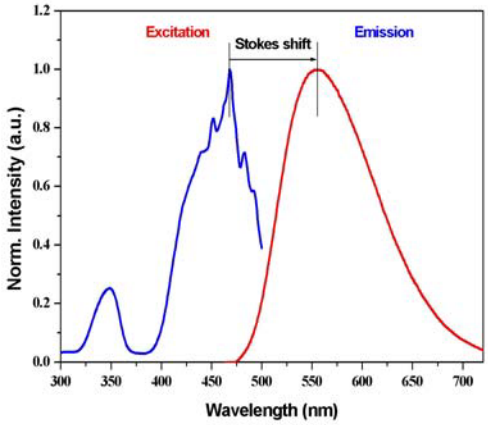

Fig. 1. Typical emission and excitation spectra of optimized $Lu_3Al_5O_{12}$:Ce phosphor.

The size and morphology of $Lu_3Al_5O_{12}$:Ce yellow phosphor was shown Fig. 2. The sample particles showed good quality of crystallinity that were shape with the size about 5 ~ 10 μm.

A white LED was prepared through the intergration of a InGaN blue LED chip and synthesized phosphor ($Lu_3Al_5O_{12}$:Ce yellow phosphor) into a single package.

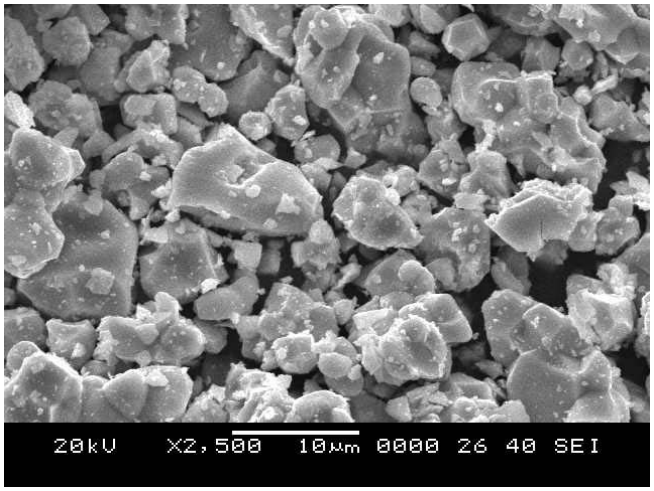

Fig. 2. SEM image of $Lu_3Al_5O_{12}$:Ce samples

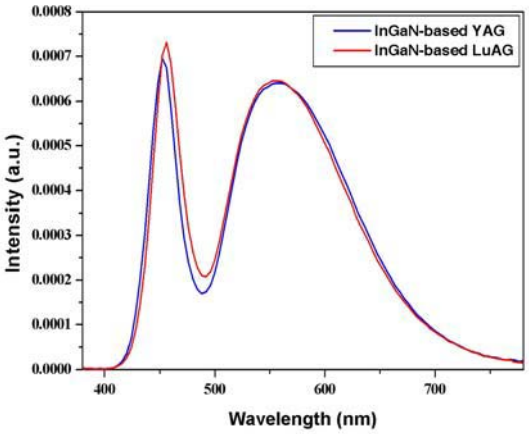

Fig. 3. The emission spectra of the white-emitting InGaN-based YAG:Ce LED and InGaN-based synthesized phosphor ($Lu_3Al_5O_{12}$: Ce) LED under a 20 mA drive current.

The emission spectra of the InGaN (460 nm chip)-based YAG:Ce LED and the InGaN (460 nm chip)-based synthesized phosphor ($Lu_3Al_5O_{12}$:Ce yellow phosphor) are shown in Fig 3. In the case of the InGaN-based YAG:Ce LED, two distinct emission bands from the InGaN-based LED and the YAG:Ce phosphor were clearly resolved at 452 and 560 nm. Similarly, the InGaN-based synthesized phosphor ($Lu_3Al_5O_{12}$:Ce yellow phosphor) LEDs showed two bands at 456 and 560 nm. The 456 nm emission band was due to a radiative recombination from an InGaN active layer. This 456 nm emission was used as an exitation source of the phosphors. The yellow emission band at 560 nm was due to the $Lu_3Al_5O_{12}$:Ce

yellow phosphor. These two emission bands combine to give a spectrum that appears white light to the naked eyes.[4] The fabricated white LED in this study shows a CIE chromaticity (CIE x = 0.34, CIE y = 0.37) and a color temperature of 5200 K. This advantage was less than that of industrially available InGaN-based YAG:Ce (color temperature = 6500 K) LEDs; however, through this investigation a new possibility for replacement devices for general illuminations was studied.

4. Summary

$Lu_3Al_5O_{12}$:Ce phosphor was prepared by solid state method through using an reduction atmosphere. When we obtained the best synthesis condition at 0.1 mole of Ce concentration, at 1700℃ for 3 hours. The prepared phosphor shows a main luminescent peak at 555nm. And we could confirm the possibility to be applied to yellow phosphor for white LEDs.

5. References

1. S. H. Lee, S. Y. Seo, *J. Electro. Soc.,* **149**, J85(2002).
2. A. Wang, Q. Su, *Appl. Phys. Lett.,* **89**, 71921 (2006).
3. X. J. Liu, H. L. Li, R. J. Xie, Y. Zeng, L. P. Huang., *J. Lumine.,* 124, **75** (2007)
4. J. K. Park, K. J. Choi, J. H. Yeon, S. J. Lee and C. H. Kim, *Appl. Phys. Lett.,* **88**, 43511 (2006)