New Red Phosphor with the Improved Color Purity for PDP Applications

Sun-il Mho
Department of Molecular Science and Technology, Ajou University, Suwon 442-749, Korea

E-mail: mho@madang.ajou.ac.kr, Phone: +82-31-219-2599, Fax: +82-31-219-1615

▪Abstract

As a new host material for a red phosphor for PDP applications, has studied $(Y,Gd)Al_3(BO_3)_4$ which gives non-centrosymmetric sites for Eu^{3+} activators. Vacuum ultraviolet (VUV) excitation spectrum of new red phosphor $(Y,Gd)Al_3(BO_3)_4:Eu^{3+}$ has two broad bands. One band with the absorption edge at ca. 168 nm is the band-gap absorption of aluminoborate and the other broad band centered 240 nm is the charge transfer transition between Eu^{3+} and the neighboring oxygen anions. The PL spectrum shows the strongest emission at 617 nm due to the electric dipole $^5D_0 \rightarrow ^7F_2$ transition of Eu^{3+}, whose luminescent chromaticity is (0.67, 0.33).

1. Introduction

Plasma display panels (PDP) are regarded as the most promising candidate for large sized flat panel displays (FPD) [1-4]. Phosphors for PDP are required to have high conversion efficiency by the VUV radiation of 147 nm or 172 nm from the Xe gas plasma [3]. At present, the most widely used red-emitting phosphor for PDP is $(Y,Gd)BO_3:Eu^{3+}$, which strongly absorbs the VUV radiation. The Eu^{3+} site has an inversion symmetry in $(Y,Gd)BO_3$, as in Ba_2GdNbO_5, $NaLuO_2$, and $InBO_3$ [5,6]. Therefore, in emission spectra of $YBO_3:Eu^{3+}$ or $(Y,Gd)BO_3:Eu^{3+}$, the magnetic dipole $^5D_0 \rightarrow ^7F_1$ transition is stronger than the electric dipole $^5D_0 \rightarrow ^7F_2$ transition, since Eu^{3+} ions are at centrosymmetric sites [7,8].

The objective of this research is to find red phosphors with excellent color purity by selecting a host lattice which will supply the non-centrosymmetric site for Eu^{3+} activator. $(Y,Gd)Al_3(BO_3)_4$ is known to have rhombohedral symmetry with the space group R32, where rare earth ions are in the center of distorted trigonal prism [9].

The rare earth ions are in non-centrosymmetric sites in the lattices. The major emission peak for Eu^{3+} activator in non-centrosymmetric site is the electric dipole $^5D_0 \rightarrow ^7F_2$ transition. Hence, Eu^{3+} ion is doped into $(Y,Gd)Al_3(BO_3)_4$ lattices pursuing a red phosphor with excellent colorimetric characteristics for PDP applications.

2. Experimental

Powder samples of $YAl_3(BO_3)_4:Eu^{3+}$, $Y_{0.65}Gd_{0.35}Al_3(BO_3)_4:Eu^{3+}$, and $Y_{0.65}Gd_{0.35}BO_3:Eu^{3+}$ were prepared by the conventional solid state reaction method, by heating carbonates and oxides of its component metal at 1150℃ for 8 hrs.

The VUV and UV excitation spectra in the wavelength range of 120 to 300 nm were measured at room temperature by a home-built VUV spectrometer, which is composed of a 30 W deuterium lamp (Acton Research Corp., ARC DS775-100), a vacuum monochromator (1200 line/nm; f. l. = 200 mm, D^{-1} = 4 nm/mm; ARC VM502), a vacuum sample compartment, and a photomultiplier tube (PMT, ARC DA-780). A high vacuum of 1×10^{-5} Torr was maintained for the excitation monochromator and the sample compartment by a molecular pump (Alcatel, ACT200T). The VUV and UV excitation spectrum was corrected by sodium salicylate, whose quantum efficiency is almost constant in the region [8]. The PL spectra were measured by a spectrofluorometer (Kontron SFM25), which is composed of a 150 W Xe high-pressure arc lamp, two monochromators (1200 line/nm; f. l. = 100 mm, D^{-1} = 8 nm/mm), and a photomultiplier tube (PMT Hamamatsu R928).

3. Results and discussion

The VUV excitation spectrum of $(Y,Gd)Al_3(BO_3)_4:Eu^{3+}$ shows two bands as shown in Fig. 1. The one band in the VUV with the

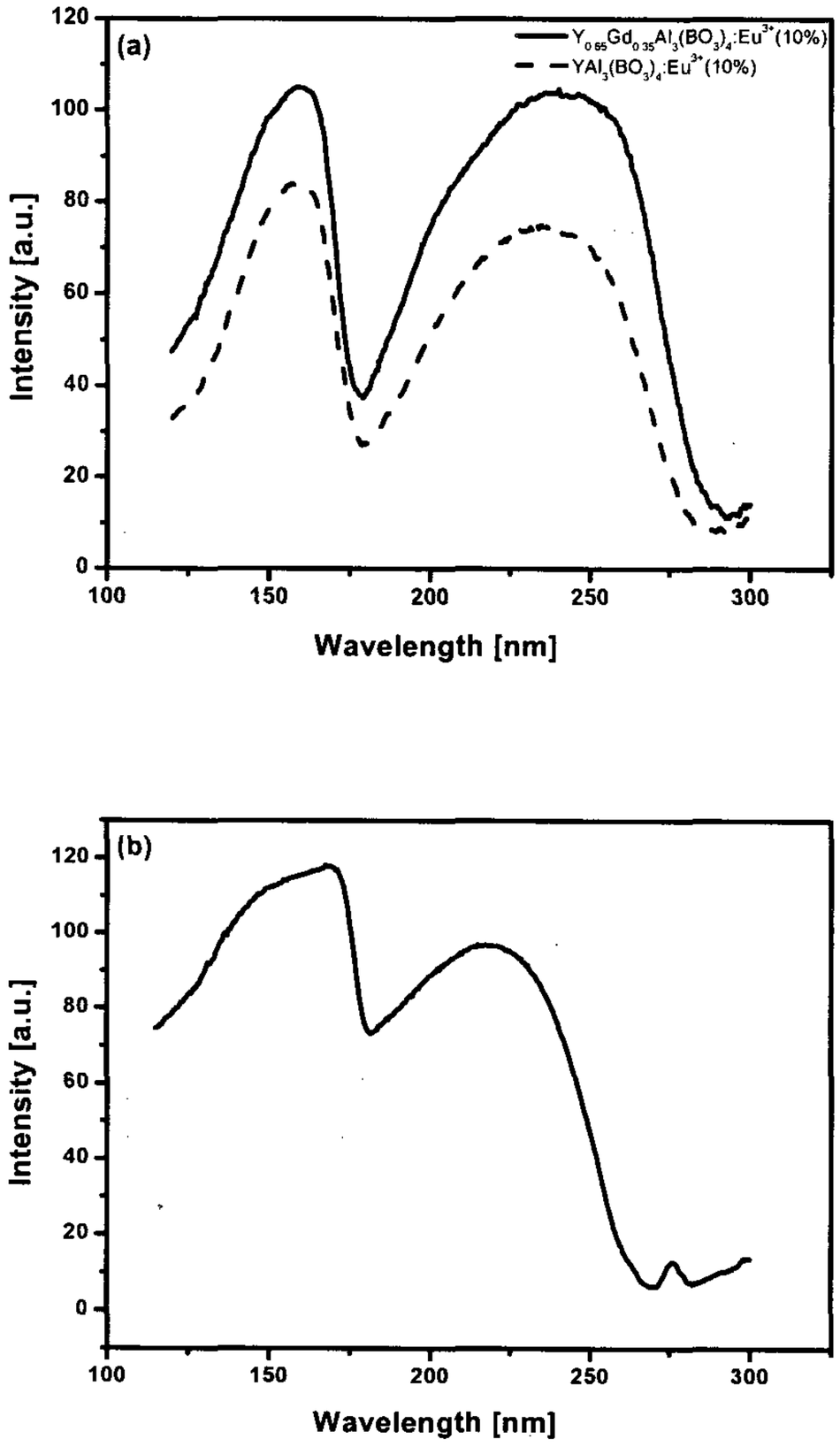

Fig. 1. The vacuum UV excitation spectra of (a) $YAl_3(BO_3)_4:Eu^{3+}$ (--) and $Y_{0.65}Gd_{0.35}Al_3(BO_3)_4:Eu^{3+}$ (–) phosphor, and (b) $Y_{0.65}Gd_{0.35}BO_3:Eu^{3+}$.

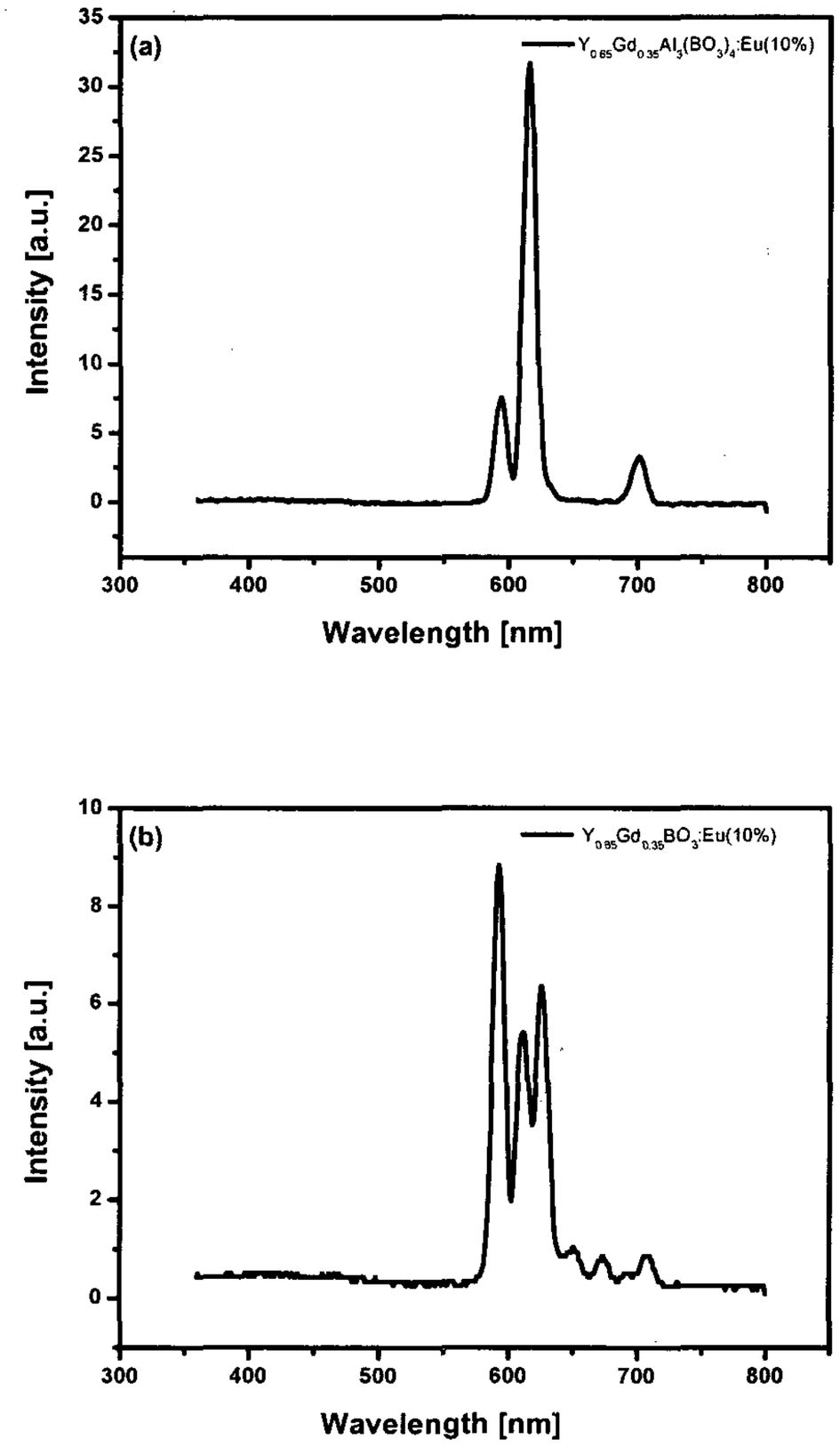

Fig. 2. Photoluminescence spectra of (a) $Y_{0.65}Gd_{0.35}Al_3(BO_3)_4:Eu^{3+}$ obtained with the excitation wavelength of 265 nm and (b) $Y_{0.65}Gd_{0.35}BO_3:Eu^{3+}$ obtained with the excitation wavelength of 242 nm.

absorption edge at ca. 168 nm is the band-gap absorption of the host lattice (aluminoborate) and the other band at 240 nm is the charge-transfer absorption. The position of the VUV band-gap absorption for $(Y,Gd)Al_3(BO_3)_4$ is very similar to that for $(Y,Gd)BO_3$ (Fig. 1(b)), which results in strong absorption of the Xe gas plasma. On the other hand, the charge-transfer band between Eu^{3+} ion and O^{2-} ions for $(Y,Gd)Al_3(BO_3)_4:Eu^{3+}$ is red shifted ca. 20 nm than that for $(Y,Gd)BO_3:Eu^{3+}$. In the charge-transfer states (CTS), electrons in the neighboring oxygen anions are transferred to a 4f orbital of Eu^{3+} ion. This process is an allowed transition and results in a strong optical absorption. The energies for CTS are more dependent on their environments, i.e. the host lattices, than those for 4f electron levels [10,11].

There are three emission peaks at 595 nm, 617 nm, and 702 nm as shown in Fig. 2. Among which the emission peak at 617 nm is the strongest for $(Y,Gd)Al_3(BO_3)_4:Eu^{3+}$. The weak emission peak at 595 nm corresponds to the transition from $^5D_0$ level to $^7F_1$ level of Eu^{3+} ion. The emission peak at 617 nm is originated from the electric dipole transition of $^5D_0 \rightarrow {}^7F_2$, induced by the lack of inversion symmetry at the Eu^{3+} site. As a new host lattice for Eu^{3+} activator for PDP applications, yttrium aluminoborate $YAl_3(BO_3)_4$ adopts the normal trigonal huntite type structure with Y-centered

distorted trigonal prisms as shown in Fig. 3, and BO_3 triangles; AlO_6 octahedra share edges to form helices extending along [001]. The PL spectrum of $(Y,Gd)Al_3(BO_3)_4:Eu^{3+}$ is dominated by the peak at 617 nm due to the forced electric dipole $^5D_0 \rightarrow {}^7F_2$ transition of Eu^{3+} ion as shown in Fig. 2(a). It exhibits an excellent purity of red color with CIE chromaticity coordinates of (0.67, 0.33), whereas Y atoms in YBO_3 are surrounded by eight oxygen atoms in an arrangment which can be described as a trigonal bicapped antiprism, having the inversion center [7].

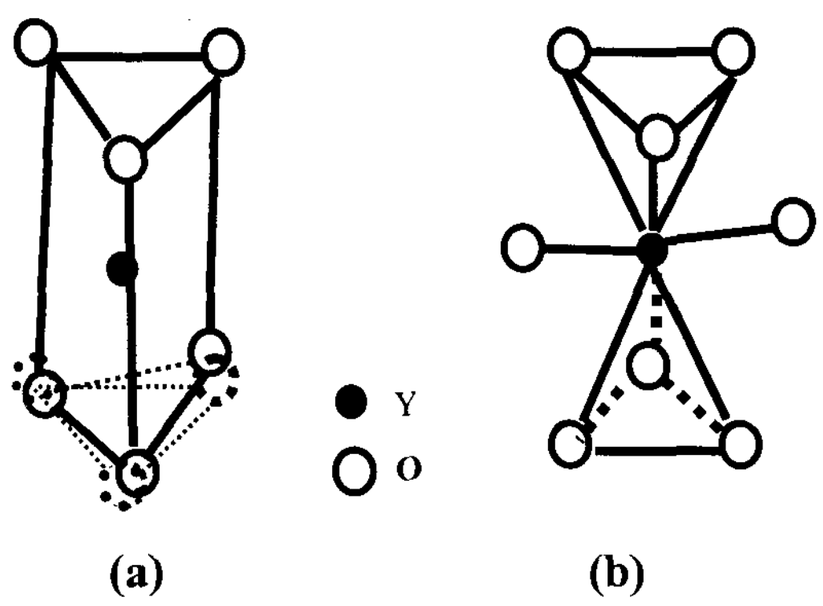

Fig. 3. (a) Y-center trigonal prism of $YAl_3(BO_3)_4$ and (b) Y-center trigonal bicapped antiprism in YBO_3.

4. Conclusion

A new host lattice for the europium activator for PDP red phosphors with excellent color purity is proposed. The host lattice, $(Y,Gd)Al_3(BO_3)_4$ offers the noncentrosymmetric sites for Eu^{3+} activator. The red phosphor, $(Y,Gd)Al_3(BO_3)_4:Eu^{3+}$ exhibits a pure red color with CIE chromaticity coordinates of (0.67, 0.33), whereas the color coordinates of $(Y,Gd)BO_3:Eu^{3+}$ being (0.64, 0.36). Luminescent chromaticity coordinates of the NTSC (National Television Standard Committee) red is (0.67, 0.33). Hence, $Y_{0.65}Gd_{0.35}Al_3(BO_3)_4:Eu^{3+}$ phosphor is an excellent new red phosphor for PDP applications.

5. Acknowledgement

The author thanks Drs. Chong-Hong Pyun and Byung-Yong Yu at KIST for the measurement of the VUV excitation spectra.

6. References

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