Synthesis and Optical Characteristics of Green Emitting $(Y,Gd)Al_3(BO_3)_4$:Tb Phosphor for PDP application

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Abstract

An new green phosphor, $(Y,Gd)Al_3(BO_3)_4$:Tb was synthesized by flux assisted solid reaction and its VUV excitation and emission characteristics were examined. The luminance of $(Y,Gd)Al_3(BO_3)_4$:Tb at 147 nm excitation was higher than that of YBO_3:Tb, while keeping the spectra and decay time of Tb ion same as those of YBO_3:Tb.

1. Objective and background

Plasma display panels (PDPs) was regarded as the most promising candidates for large size flat panel displays (FPD) [1-4]. But, PDPs are facing stiff competition from its famous sandwich duo, LCD in the 40- to 44-inch range, where production is rising rapidly. The competition naturally leads to the technology breakthrough and the price declining. However, PDP is of emissive type, which is familiar to old generation accustomed to CRT. PDP used the visible rays from the phosphors excited by vacuum ultraviolet rays (VUV) radiation of 147nm and 172nm, which were generated by discharging mixed gas in R, G, and B cells [3-8]. The luminous efficiency of a PDP depends upon various factor including materials such as phosphors, gas mixture, dielectric layer, reflective layer, cell dimension and shape, size and shape of electrodes, address waveforms, operating voltage, etc. [10-11]. Anyway, the R, G, B phosphors determine the high-quality images of PDP.

The green component is very important, as the human eye perceives more towards the green in the visible spectrum. Green phosphor also improves the color point of white light and also boosts the overall brightness of the display device. Refractory oxide compounds with aluminate, silicate or borate groups have strong absorption in the VUV region [5-9]. Manganese-activated zinc silicate phosphor is conventionally used in PDPs as a green emitting component due to its availability and high quantum efficiency. However, compared with red and blue emitting phosphors, zinc silicate exhibits a wide spectrum of emission with low color purity, long persistence, and fast saturation with VUV flux.

On the other hand, due to their quantum efficiency and stability at high temperatures, Tb-activated green emitting borate and phosphate phosphors have been well studied and are widely used in compact fluorescent lamps [12-13]. Also, borate-based Tb-activated green phosphor improved the uniformity of the discharge characteristics in ac PDPs.[14] To overcome the blue peak and to take advantage of the superior morphology and longer life of borate and phosphate phosphors, a blend of zinc silicate and yttrium borate phosphor is being used in the manufacture of large-area PDPs. The blending ration of YBO_3:Tb to Zn_2SiO_4:Mn reaches 50% from 20%.

The objective of this work is to find green phosphors with good luminance by selecting a host lattice, which will support Tb-activator. We believe that Tb-activator guarantees to solve saturation issue at high frequency driving and high luminance.

2. Results

Phosphor powder of $(Y,Gd)Al_3(BO_3)_4$:Tb were prepared by conventional solid state reaction. Source materials with proper amounts of Y_2O_3(Kojundo Korea 99.99%), Gd_2O_3(Aldrich 99.99%), Al_2O_3(Aldrich 99.9%), Tb_4O_7(Aldrich 99.9%), and H_3BO_3(Kojundo Korea 99.99%) were heated at high temperature. The mixture were heated in an alumina crucible at 180℃, which is the melting point for boric acid, for 30min before heating at high temperature.

The VUV excitation spectra of $(Y,Gd)Al_3(BO_3)_4$:Tb phosphor are shown in Fig. 1. The VUV excitation spectrum shows strong absorption at 147nm, 173nm. Comparing with the excitation spectrum of $(Y,Gd)Al_3(BO_3)_4$:Tb phosphor, the position of the VUV band-gap absorption edge for both Zn_2SiO_4:Mn and YBO_3:Tb are very similar to each other. The emission spectra of YBO_3:Tb, , Zn_2SiO_4:Mn, $(Y,Gd)Al_3(BO_3)_4$:Tb phosphor are shown Fig. 2. In Tb-activated phosphors, the emission can be divided into three spectral regions, 485 to 495nm, 535nm to 555nm, 580nm to 590nm. The fluorescent from Tb-activated phosphors mainly occurs in the transitions $^5D_3 \rightarrow {}^7F_j$ and $^5D_4 \rightarrow {}^7F_j$ (where j=1, ···6, the 7f ground state is split into seven levels by spin-orbit coupling).

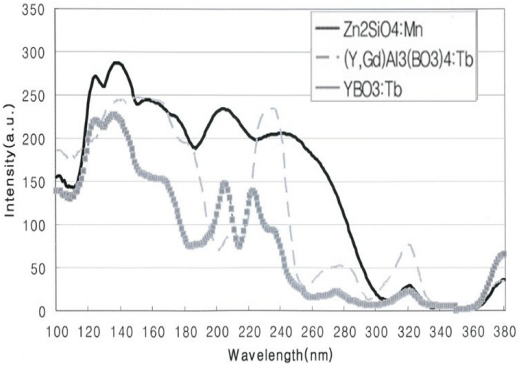

Fig.1. The vacuum UV excitation spectra of Zn_2SiO_4:Mn, YBO_3:Tb, $(Y,Gd)Al_3(BO_3)_4$:Tb phosphor.

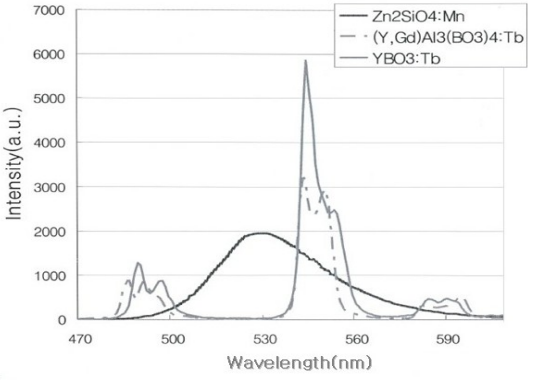

Fig.2. Emission spectra of Zn_2SiO_4:Mn, YBO_3:Tb, $(Y,Gd)Al_3(BO_3)_4$:Tb phosphor.

The spectral energy distribution of Tb emission strongly depends on Tb concentration. A weak

emission peak in the blue region corresponds to $^5D_{3,2}$ levels of Tb^{3+} whereas the peaks in the green region correspond to the $^5D_4 \rightarrow {}^7F_5$ transition.

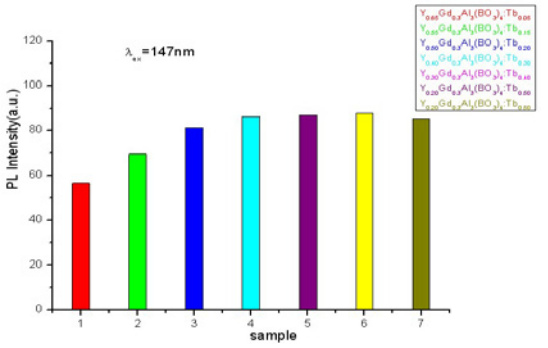

Fig.3. The change of PL intensity for host lattice ratio of (Y,Gd)$Al_3(BO_3)_4$:Tb phosphor.

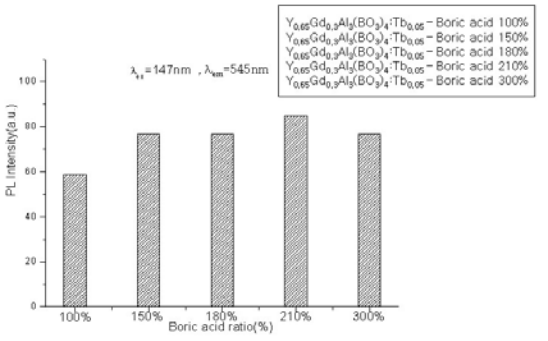

Fig.4. The change of PL intensity for additional ratio of boric acid of (Y,Gd)$Al_3(BO_3)_4$:Tb phosphor.

At lower Tb concentrations, when the cross relaxation probability is small, the transition $^5D_3$ state dominates as a blue emission. At higher concentrations of Tb, the cross relaxation mechanism produced rapid population $^5D_4$ state at the expense of $^5D_3$, giving a strong emission in the green region. With the increase of Tb concentration, the intensity of the blue peak decreases [15]. The emission spectra obtained 545nm with 147nm excitation, the change of photoluminescence intensity for each component are shown in Fig.3. Figure 4 shows the Photoluminescence intensity of (Y,Gd)$Al_3(BO_3)_4$:Tb under the VUV (147nm) excitation in case that the ratio of boric acid is different.

3. Impact

We prepared the (Y,Gd)$Al_3(BO_3)_4$:Tb phosphors by conventional solid state reaction. Vacuum ultraviolet excitation and photoluminescence characteristics of new green phosphor, (Y,Gd)$Al_3(BO_3)_4$:Tb are investigated.

Table 1. Optical Properties of Blending G-phosphor [16]

	CIE x/ y	L	LS
Zn2SiO4:Mn	0.250/0.701	100%	70%
YBO3:Tb	0.328/0.610	85%	90%
80% Zn2SiO4:Mn + 20% YBO3:Tb	0.266/0.698	90%	75%
50% Zn2SiO4:Mn + 50% YBO3:Tb	0.289/0.656	90%	80%

(L and LS stand for luminance and Luminance saturation, respectively.)

To take better position in TV market, picture quality of PDP should be realized. The important features are the luminance and color coordinate. In green phosphor, CIE x should be getting lower, while CIE y higher. As of now, any phosphor materials better than Zn_2SiO_4:Mn has not been reported, yet. The alternative was the use of blending phosphor. Table 1 shows the important feature of blending phosphor. Here, note that color coordinate and luminance itself are getting worse as Tb-doped phosphor is increasing. Luminance of (Y,Gd)$Al_3(BO_3)_4$:Tb phosphor are higher than that of YBO_3:Tb phosphor. Therefore, we believe that if the prepared phosphor, (Y,Gd)$Al_3(BO_3)_4$:Tb is applied to the panel,

portion of Tb-doped phosphor could be decreased, which leads to improvement of color coordinate and enhance the picture quality while keeping luminance high.

4. References

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