Luminescence properties of $YVO_4:Eu^{3+}$ thin film phosphor deposited by RF magnetron sputter deposition technique

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Abstract

$YVO_4:Eu^{3+}$ thin film phosphor samples have been deposited by using RF magnetron sputter deposition technique with various deposition temperatures. The Effect of deposition temperature (room temperature to 450 ^oC) on morphological, crystal structure, and luminescence properties of $YVO_4:Eu^{3+}$ thin film phosphor has also been investigated. As the deposition temperature increases, the size of crystal grain and surface roughness of thin film increases principally and its crystallinity also increases. It is found that the as-deposited $YVO_4:Eu^{3+}$ thin film excited either photon or electron shows typical luminescence spectra successfully. CIE color coordinates of $YVO_4:Eu^{3+}$ thin film phosphor with increasing deposition temperature moved towards more reddish region.

1. Introduction

YVO_4 is an attractive host lattice for several lanthanide ions to produce efficient phosphors emitting a variety of color [1, 2]. Especially, europium doping gives a red emission in YVO_4 with three main groups of lines at 593 nm ($^5D_0 \rightarrow {}^7F_1$), 619 nm ($^5D_0 \rightarrow {}^7F_2$), and 700 nm ($^5D_0 \rightarrow {}^7F_4$). Recently $YVO_4:Eu^{3+}$ phosphor is considered as a candidate for red phosphor for flat panel displays (FPDs) because of its good color purity [3].

Until now, some studies on powder or thin film-type $YVO_4:Eu^{3+}$ phosphors prepared by solid-state reaction, wet chemical method, and pulsed laser deposition etc., have been reported. However, very few literature is available on $YVO_4:Eu^{3+}$ thin film phosphor prepared by RF magnetron sputter deposition. RF magnetron sputter deposition is very well known thin film deposition technique, which has many advantages in terms of target fabrication, deposition speed, control of deposition atmosphere.

In the present study, we have investigated the morphological, crystal structure and luminescence properties of $YVO_4:Eu^{3+}$ thin film phosphor. Especially, effect of deposition temperature on luminescence property of $YVO_4:Eu^{3+}$ thin film phosphor samples deposited by RF magnetron sputter deposition and their luminescence mechanism has been studied.

2. Experimental

$YVO_4:Eu^{3+}$ films were deposited on p-type Si (100) wafer by RF magnetron sputter deposition. The 4 inch $Y_{0.95}VO_4:Eu_{0.05}$ target prepared by Kojundo Chemicals, Japan was used. The deposition was done at various temperatures and the base pressure in the process chamber was below 5×10^{-6} torr. For deposition of the phosphor films, RF power was fixed at 150 W and working pressure was 6×10^{-3} torr, and 30 % O_2/Ar mixture gas ratio was used for all deposition process in order to compensate the compositional discrepancy between target and thin film occurring during the deposition of $YVO_4:Eu^{3+}$. The film thickness was fixed at 1000 Å, in order to compare the crystal structure and luminescence properties of each film. All the thin films prepared were characterized by SEM, AFM, XRD, photoluminescence (PL) and cathodoluminescence (CL) analysis.

3. Results and discussion

Figure 1 shows SEM images of as-deposited $YVO_4:Eu^{3+}$ thin films deposited at different deposition temperatures. Surface morphology of the thin films deposited at room temperature (RT) was flat and there is no crystal grain. On the other hand, the films deposited at temperatures higher than 150 °C show clear crystal grains. The shape of crystal grain has been changed to round and the size has been increased with increasing deposition temperature. In order to investigate the surface morphology in depth and quantify the degree of roughness, AFM analysis has been carried out.

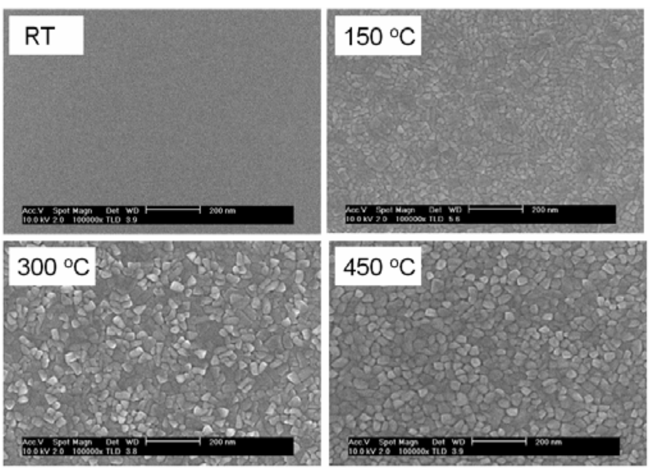

Fig. 1 SEM images of as-deposited $YVO_4:Eu^{3+}$ thin films with deposition temperature.

AFM image (Fig. 2) of the as-deposited thin film shows a flat surface except sparsely dispersed small dots and this result coincides with the SEM image. The thin films deposited at temperatures higher than 150 °C show very rough surface which may be due to the formation of crystal grain. Roughness of as-deposited $YVO_4:Eu^{3+}$ thin films as a function of deposition temperature was quantified through the analysis of AFM images. As-deposited $YVO_4:Eu^{3+}$ thin film at 300 °C showed the roughest surface. The RMS roughnesses at RT, 150, 300, and 450 °C were 0.9, 3.4, 5.0, and 3.3 nm, respectively.

Figure 3 shows the XRD patterns of the film deposited at different deposition temperatures. The film deposited at RT shows no specific XRD peaks. Considering the surface morphology observed in the

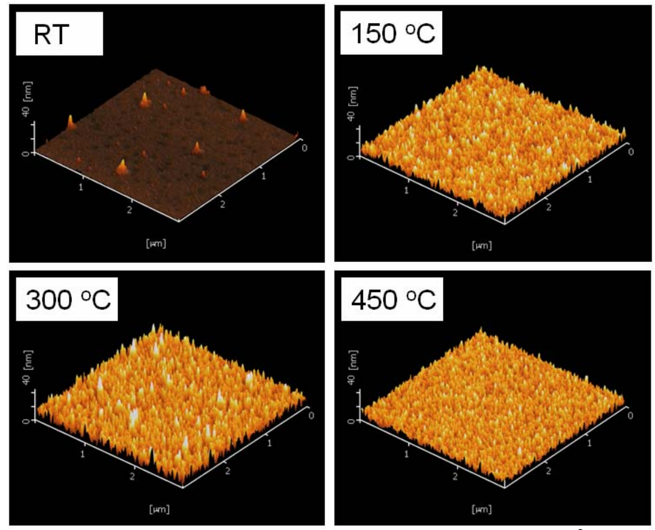

Fig. 2 AFM images of as-deposited $YVO_4:Eu^{3+}$ thin films with different deposition temperature.

SEM and AFM images, it could be concluded that the phase is amorphous. The films deposited at temperatures higher than 150 °C show typical XRD patterns of YVO_4 tetragonal phase. From the analysis of XRD peak from (200) plane, it was found that full width at half maximum (FWHM) decreased from 0.635 ° (at 150 °C) to 0.382 ° (at 450 °C) as the deposition temperature increases. This FWHM data verified the fact that the higher deposition temperature, the higher crystallinity of the films.

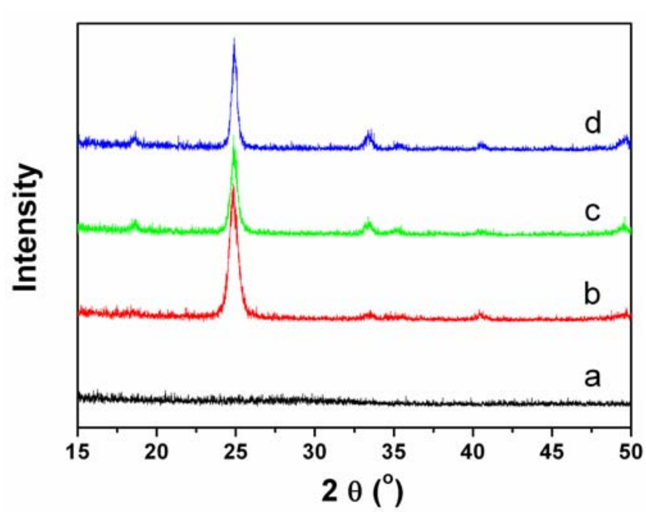

Fig. 3 XRD patterns of as-deposited $YVO_4:Eu^{3+}$ thin film phosphors with deposition temperature ; (a) RT, (b) 150 °C, (c) 300 °C, and (d) 450 °C.

Figure 4 shows (a) PL and (b) CL spectra of $YVO_4:Eu^{3+}$ thin film phosphors with deposition temperature, respectively. It was found that the trend of luminescence intensity was almost the same. The intensity of the films deposited at RT is found to be less, which could be attributed to the weak crystallinity of thin film. As deposition temperature increases up to 300 °C, the luminescence intensity increases rapidly. Above 300 °C, increase rate decreased and saturated. $YVO_4:Eu^{3+}$ thin film phosphor deposited at 450 °C shows the strongest PL and CL intensity.

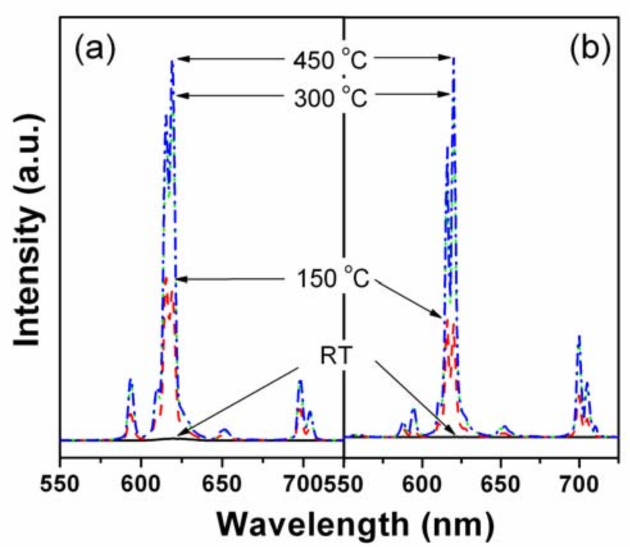

Fig. 4 (a) PL (λ_{ex}=270 nm) and (b) CL spectra of as-deposited YVO_4: Eu^{3+} thin film phosphors with deposition temperature.

As shown in Fig. 5, when the deposition temperature increases, the thin film ($YVO_4:Eu^{3+}$) phosphor shows more reddish color. $YVO_4:Eu^{3+}$ thin film phosphor deposited at 450 °C shows the most reddish color of (0.665, 0.333) which is better than that of the powder phosphor prepared by solid-state reaction, (0.651, 0.336).

Figure 6 show the PL excitation (PLE) spectra of $YVO_4:Eu^{3+}$ thin film phosphor. The strongest absorption peak was found near 270 nm which does not significantly differ from that isolated by vanadate ions dissolved in solution [4]. The absorption peak can be assigned into the $^1A_1 \rightarrow ^1T_1$ ($t_1 \rightarrow 2e$) transition of the VO_4^{3-} ion.

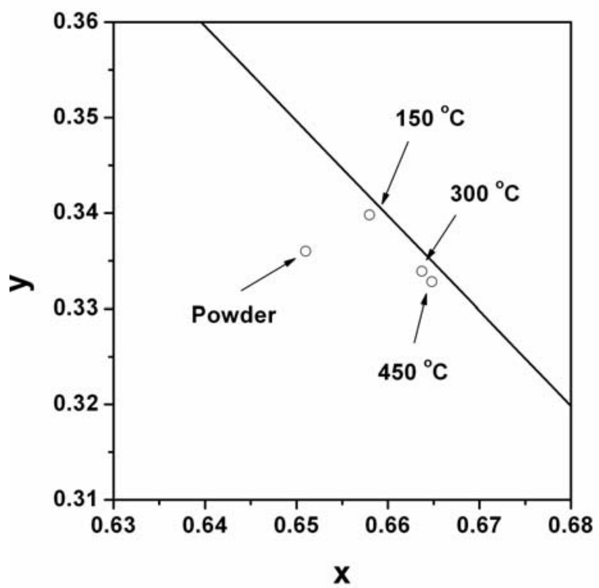

Fig. 5 CIE color coordinates of as-deposited $YVO_4:Eu^{3+}$ thin film phosphors with deposition temperature

Generally, it has been known that the $^1A_1 \rightarrow ^1T_1$ transition is forbidden. If the size of the particles decreases and the deformation of the structure increases, $^1A_1 \rightarrow ^1T_1$ transition can be allowed [5]. Based on the morphological data of SEM and AFM image, increased $^1A_1 \rightarrow ^1T_1$ transition in our experiment may be due to small grain size of $YVO_4:Eu^{3+}$ phosphors.

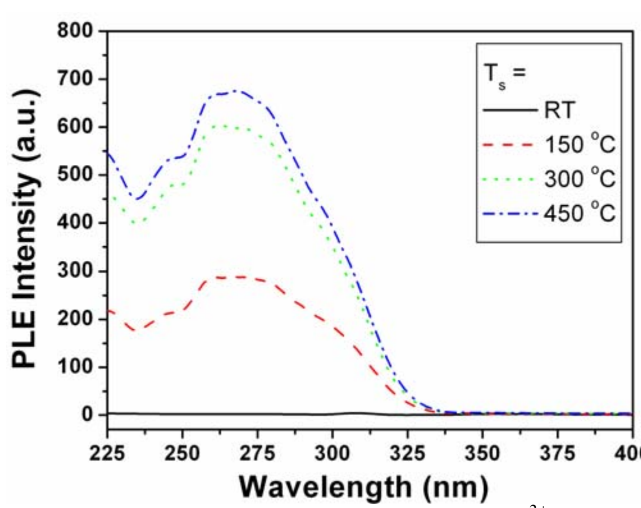

Fig. 6 PLE spectra of as-deposited YVO_4: Eu^{3+} thin film phosphor with deposition temperature. (λ_{em}=619 nm).

4. Summary

We have studied morphological, crystal structure, and luminescence properties of $YVO_4:Eu^{3+}$ thin film phosphors deposited by RF magnetron sputter deposition. As the deposition temperature increased, the size of crystal grain and surface roughness increased principally. Their crystallinities were also improved with increasing deposition temperature. In terms of PL and CL spectra, luminescence intensities were increased with increasing the temperature up to 300 ^{o}C rapidly. Above 300 ^{o}C, the increase rate of luminescence intensity decreased and saturated. $YVO_4:Eu^{3+}$ thin film phosphor deposited at 450 ^{o}C shows the most reddish color of CIE coordinate (0.665, 0.333) which is better than that of the powder phosphor prepared by solid state reaction, (0.651, 0.336). As a result, it was found that $YVO_4:Eu^{3+}$ thin film phosphor deposited at a higher temperature shows better crystallinity and luminescence property.

5. References

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