Synthesis, Characterization and Thermoluminescecne Properties under High Gamma Irradiation of Aluminates Based Phosphor

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Abstract. For producing new luminescent materials, we take phosphor material $CaYAl_3O_7$ with varying concentration of transition metal Mn^{2+} synthesized by combustion method at 500°C. The synthesized phosphor material characterized for their crystallinity and nature by XRD measurements. The thermoluminescecne response of phosphor exhibit TL spectra at 188°C and detailed analysis of kinetic parameter by de convoluted curve. The parameters show that the order of kinetics is second, also the concentration increase results in the decreased activation energy and frequency factor. We can conclude that the present system of Mn doped phosphor is suitable and compatible for industrial applications such as dosimetry, Scintillation and solid state devices.

Keywords: XRD, thermoluminescence, phosphor.

INTRODUCTION

Thermoluminescecne [TL] properties of aluminates based phosphor with rare earth or transition metal response are suitable for the commercially utilized as dosimeter, environmental safety and scintillation etc. However some constraint to fulfilling the requirements such as glow shape, tissue equivalent of the phosphor and Thermoluminescecne parameters [1-3]. Currently, the yttrium aluminate phosphor with rare earth doped ion Ce^{3+} and Eu^{3+} is being widely studied for the display and solid state lighting devices [4- 7]. Among several options available for preparing phosphor, the combustion method is proven to be better than other methods for preparing aluminate phosphor [9-10]. Our interest is to understand the TL mechanism under high dose response by gamma irradiation up to 100Gy to determine trapping parameters such as activation energy, kinetic order and frequency factor by the Chen's peak shape method, deconvolution method and heating rate [11]. Here we studied alkaline earth aluminate based phosphor ($CaYAl_3O_7:Mn^{2+}$) synthesized by combustion method and the thermoluminescecne properties and stability were studied from the calculation of trapping parameters obtained from the most intense peak of $CaYAl_3O_7$:Mn (0.05 mol%).

EXPERIMENTAL STUDY

The new luminescence phosphor $CaYAl_3O_7$ doped with Mn^{2+} was prepared by combustion method. The starting AR grade materials were taken in stoichiometric amounts and the appropriate weights of [Ca $(NO_3)_2.6H_2O$], [Y $(NO_3)_3.6H_2O$], [Al $(NO_3)_3.9H_2O$] and [$MnCl_2.4H_2O$] (Himedia, 99.99 % purity) were crushed and mixed together. Then urea [CH_2NH_2CO] was added as a fuel. The whole process of combustion was completed in 5-7 minutes. To obtain quantitative information on crystallinity and phase formation, the prepared powder samples were then subjected to X-ray diffraction (XRD) measurements. The XRD patterns were recorded using Bruker D8 advance

spectrometer. For the TL measurements sample was irradiated by γ-irradiation using Co-60 source from 10 to 100Gy. The temperature ranged from 50-450°C and heating rate was 3.6°C/min. The thermally stimulated glow curve was recorded by using TLD 11009 (Nucleonix Sys. Ltd. Hyderabad) instrument.

RESULTS AND DISCUSSION

The crystal structure of Mn^{2+} doped $CaYAl_3O_7$ samples was examined from XRD patterns and is presented in Figure 1. The crystalline size from XRD patterns was calculated by considering the X-ray line broadening of (221) diffraction peak using the standard Debye-Scherrer's formula given as [11]

$$L = \frac{0.9\lambda}{B\cos\theta} \quad (1)$$

where, L is the particle size in nanometer, λ is the wavelength of x-rays used in nanometer, B is the full width at half maximum in radian and θ is the Bragg's angle. After removing the instrumental width, the crystalline size obtained for un-doped $CaYAl_3O_7$ was ~60 nm and $CaYAl_3O_7$:Mn^{2+} doped samples was in the range of ~58 nm. These XRD results indicated that the final product was created in crystalline and homogeneous form.

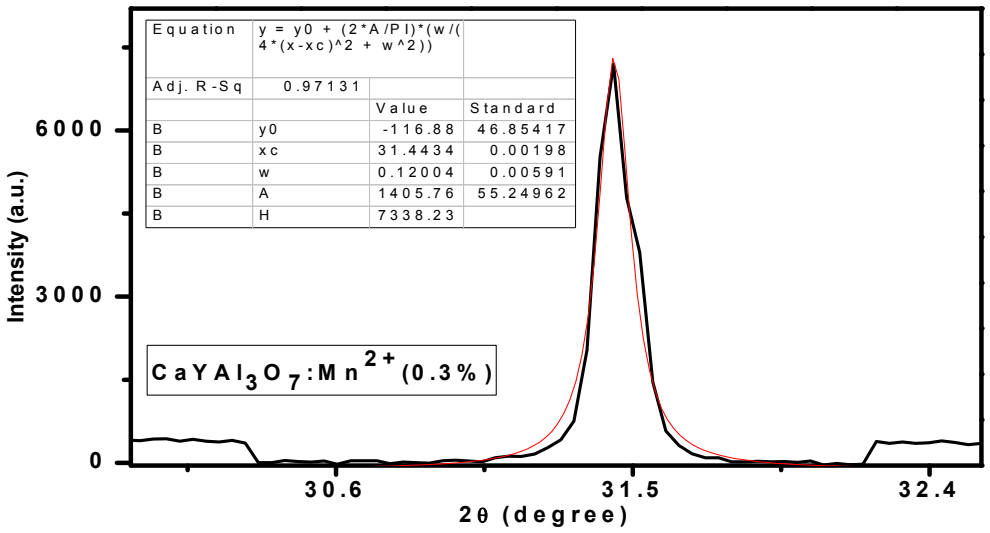

FIGURE 1. XRD pattern of $CaYAl_3O_7$:Mn (0.3mol%).

Trapping Parameters

The trapping parameters associated with the prominent glow peak of $CaYAl_3O_7$ and $CaYAl_3O_7$:Mn(,0.3 and 0.5 mol%) are calculated by using Chen's peak shape method using the de convoluted figure from 2 to 4 . The release of hole/electron from defect centers at the characteristic trap site initiates the luminescence process in these materials. The intensity of the TL glow peaks increases with increase of the gamma dose 100 Gy by Co-60 source.

From the Table 1, the parameters show that the order of kinetics is second, also the concentration increases results in the decreased the activation energy and frequency factor. We can conclude that the combustion method is a suitable method for producing a luminescent phosphor for industrial applications which is suitable and compatible for dosimeter and scintillator at the 100 Gy dose rate.

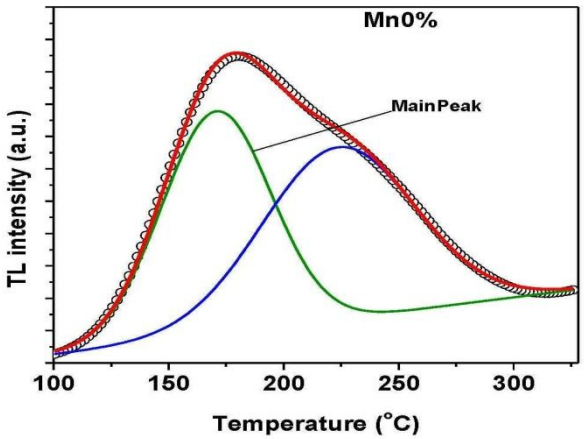

FIGURE 2. TL de convoluted glow curve of $CaYAl_3O_7$: Mn^{2+} (0.0 mol %) with 100Gy.

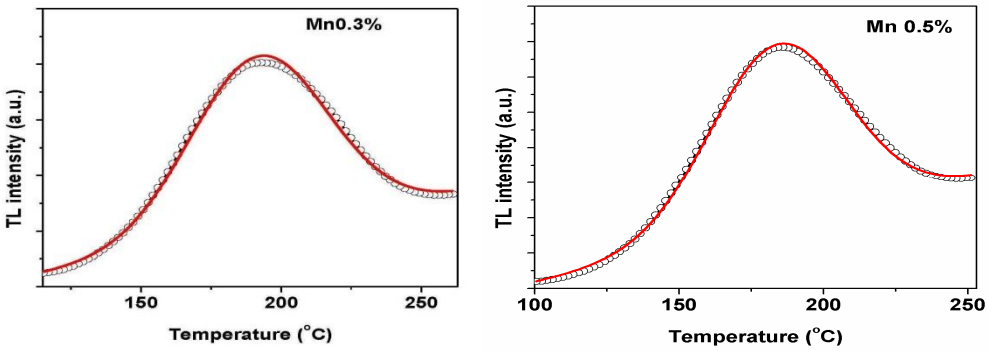

FIGURE 3. TL de convoluted glow curve of (a) $CaYAl_3O_7$: Mn^{2+} (0.3 mol %) and (b) $CaYAl_3O_7$: Mn^{2+} (0.5 mol %) with fixed 100 Gy gamma dose.

TABLE 1. Trapping parameters of $CaYAl_3O_7$: Mn Phosphor exposed by 100(Gy).

Mn conc.	T_1	T_m	T_2	μ_g	E_ω	E_δ	E_τ	Activation energy (E in eV)	Frequency factor (s^{-1})
0%	141	172	201	0.51	0.94	0.87	0.96	0.92	0.5×10^{10}
0.05%	154.7	185.1	230	0.57	0.76	1.03	0.68	0.82	9.2×10^{10}
0.1%	-	-	-	-	-	-	-	-	-
0.3%	161	192	233	0.56	0.78	0.92	0.77	0.82	0.12×10^{9}
0.5%	-	-	-	-	-	-	-	-	-

CONCLUSIONS

The TL glow curve exhibit at Tm ~ 188 ºC and the different trapping parameters of the material carried out. The trap depth was found to be 0.92 eV and frequency factor 12×10^9 to 9.2×10^{10}. The dose response was linear. These results are supporting to study the kinetic parameter of aluminates based phosphor and show the possibility of utilizing this phosphor as scintillation at high dose rate.

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