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Thermoluminescence of γ-irradiated $SrAl_2O_4$:Dy

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Abstract

Thermoluminescence (TL) properties of γ-irradiated Strontium Aluminate doped with Dy (10% molar concentration) was studied. The phosphor was synthesized by combustion method using urea as a reducer at initiating temperature of 600°C. Dy doped $SrAl_2O_4$ is a good dosimeter having linear response upto 2360 Gy of γ-dose. The kinetic parameter have been calculated using Chen's glow curve method.

Keywords: Thermoluminescence, Strontium Aluminates, Dosimetry, Combustion Synthesis.

INTRODUCTION

It has been a long history since people began to study the phosphorescent materials. However, conventional phosphorescent materials such as ZnS:Cu can hardly have bright light and long after glow time for the applications. The rare earth-activated alkaline earth aluminates are an important class of phosphorescence materials because of their high quantum efficiency in visible region [1], long persistence of phosphorescence, good stability, color purity and good chemical, thermal and radiation resistance [2-6]. The synthesis of oxide phosphors has been achieved by a variety of routes. Combustion process is very simple, safe, energy saving and takes only a few minutes. The method makes use of the heat energy liberated by the redox exothermic reaction at a relative low igniting temperature between metal nitrates and urea as fuel[7-9]. It was found that the $SrAl_2O_4$:Eu^{2+} prepared at initiating temperature 600°C exists as a single phase monoclinic structure [10].

Thermoluminescence is the emission of light from an insulator or semiconductor when they are thermally stimulated following the previous absorption of energy from radiation [11]. It is very important and convenient method of investigating the nature of traps and trapping level in crystals [12].

Thermoluminescence properties of Dy doped $SrAl_2O_4$ has not been reported to the best of our knowledge. In this paper we have reported the Thermoluminescence behavior of γ-irradiated Dy doped (10% molar concentration) $SrAl_2O_4$ phosphor prepared by combustion synthesis at initiating temperature of 600 °C.

EXPERIMENTAL

Analytical grade strontium nitrate $Sr(NO_3)_2$, aluminum nitrate $Al(NO_3)_3.9H_2O$, Dysposium oxide Dy_2O_3 and urea $CO(NH_2)_2$ were used as the staring materials. The starting materials are weighted according to the stoichiometry. First of all Dy_2O_3 is converted into $Dy(NO_3)_3$ by mixing into 2 ml of dil. HNO_3. The weighed quantities of each nitrate and urea were mixed together and crushed into mortar for 1 hour to form a thick paste. The paste is then placed in vertical cylindrical muffle furnace maintained at 600°C. Initially the mixture boils and undergoes dehydration followed by decomposition with the evolution of large amount of gas. The process being highly exothermic continues and the spontaneous ignition occurs. The solution underwent smoldering combustion with enormous swelling, producing white foamy and voluminous ash. The flame temperature, as high as 1400 - 1600 ºC, converts the vapor phase oxides into mixed aluminates. The foamy product can easily be milled to obtain the precursor powder.

Absorption spectra were recorded using Shimadzu UV-1700 UV-Visible spectrophotometer. A routine TL setup (Nucleonix TL 10091) was used for recording TL glow. The samples were irradiated with γ-rays using a ^{60}Co source having an exposure rate of 0.59×10^3 Gy/hr. Finally the samples were wrapped in aluminium foil and kept in dark till the TL studies were carried out. Powder XRD data of the phosphor was collected on a D8 Advance Bruker X-ray diffractor using Co/Kα radiation (λ=1.790 Å).

RESULTS AND DISCUSSIONS
XRD Analysis

The x-ray diffraction patterns (figure1) indicate that the crystal structure of $SrAl_2O_4$:Dy is mainly monoclinic and matches well to the JCPDS data file no. 34-0379. The particle size was calculated using Scherrer formula for different planes which is given in table-1. The average particle size was found to be 11.35 nm.

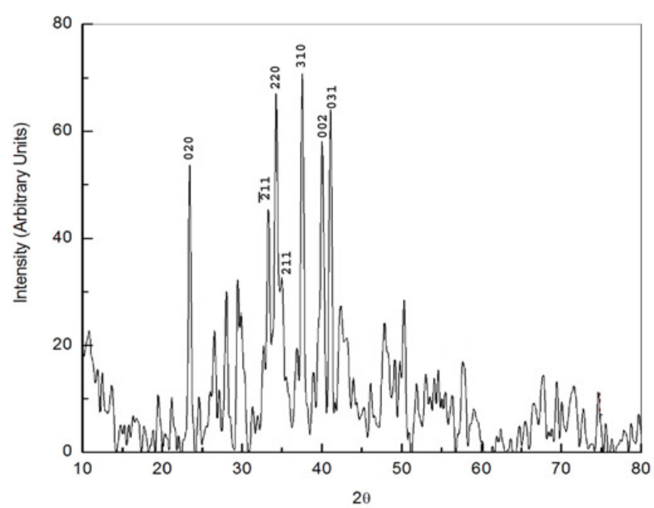

Fig 1. X-ray diffraction pattern of $SrAl_2O_4$:Dy phosphor matched with JCPDS data file no. 34-0379.

Table 1: Calculation of particle size		
2θ	Plane	Size (nm)
37.509	310	9.28
34.244	220	8.78
41.072	031	14.08
40.011	002	14.03
23.419	020	9.43
33.238	$\bar{2}11$	14.82
35.051	211	9.00
Average size = 11.35 nm		

Optical Absorption Spectra

The study of optical absorption is important to understand the behavior of nano-crystals. A fundamental property is the band gap. Optical excitation of electrons across the band gap is strongly allowed, producing an abrupt increase in absorption at the wavelength corresponding to the band gap energy. This feature in the optical spectrum is known as the optical absorption edge. In figure (2) the optical absorption spectra of $SrAl_2O_4$:Dy is shown in the range of 190nm-500nm. It can be seen that the spectra is featureless and no absorption occur for wavelength λ>390nm(visible). By the absorption spectra of the sample the absorption edges was found at λ = 234 nm, thus the bandgap was found to be 5.29 eV.

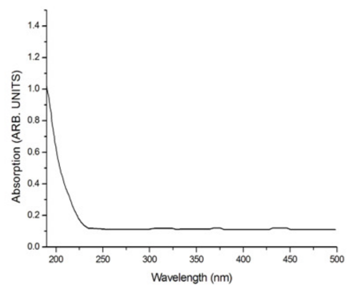

Fig 2. Absorption spectra of $SrAl_2O_4$:Dy having absorption edge 234nm.

The Thermoluminescence Studies

The TL response of γ-irradiated $SrAl_2O_4$:Dy (10%) was recorded in the temperature range between room temperature to 300°C. The TL glow curve of $SrAl_2O_4$:Dy (10%) phosphor with different γ-doses is shown in figure 3. It is clear from the figure that the dose increases the TL-intensity while the temperature corresponding to maximum intensity remains nearly same. The maximum TL-intensity corresponds to 148.15 °C, 151.55 °C, 150.61°C and 151.32°C for the dose value of 295 Gy, 590 Gy, 1180 Gy and 2360 Gy respectively.

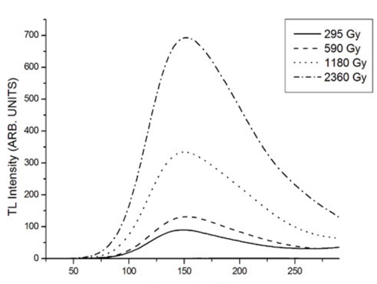

Fig 3. The Thermoluminescence Glow Curve of $SrAl_2O_4$:Dy (10%) phosphor irradiated with different doses of γ-ray.

The order of kinetics was calculated by measuring the symmetry factor $\mu = \frac{\delta}{\omega}$, where δ is half width towards fall-off side of glow curve and ω is half width towards rising side of glow curve. They are calculated as $\delta = T_2 - T_m$, $\omega = T_2 - T_1$ and $\tau = T_m - T_1$, where T_m is peak temperature corresponding to maximum intensity, T_1 & T_2 are temperature on either side of T_m corresponding to half of maximum intensity. The trap depth was calculated by the Chen's equation

$$E_\alpha = C_\alpha \left(\frac{kT_m^2}{\alpha} \right) - b_\alpha (2kT_m)$$

Where E_α is trap depth and C_α and b_α are constants of Chen's equation, α was replaced by δ, ω and τ as per the case. The calculated values of kinetic parameters are listed in Table-2.

Table 2. Kinetic parameter as calculated by Chen's equation

Dose (Gy)	Symmetry Factor (μ)	E	E	E
295	0.68	0.89	0.44	0.42
590	0.65	0.78	0.43	0.39
1180	0.65	0.73	0.39	0.35
2360	0.65	0.73	0.40	0.35

From the value of the geometrical factor it is clear that both the peaks obey general order kinetics. The mean trap depth for the peak comes out to be 0.58 eV, 0.53eV and 0.49 eV for the doses 295, 590, 1180, 2360 Gy respectively.

The addition of Dy as activator produces deep traps at temperature at around 150 °C, which could be useful for dosimetric purpose due to its thermal stability.

The TL-intensity is maximum for 2360 Gy dose, the variation in maximum TL-intensity with γ-dose is shown in figure 4. From the figure it is clear that maximum TL-intensity shows linear response upto the range 2360Gy and hence we suggest the application of $SrAl_2O_4$:Dy (10%) as γ-dosimeter. The Total-TL intensity (integral count) also shows same behavior with γ-dose shown in figure 5.

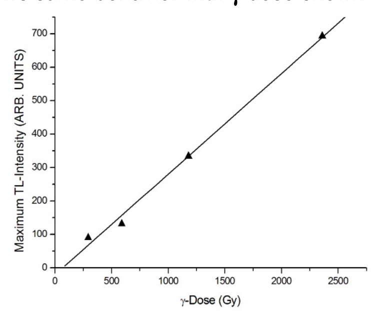

Fig 4. Variation in Maximum TL intensity with γ-dose.

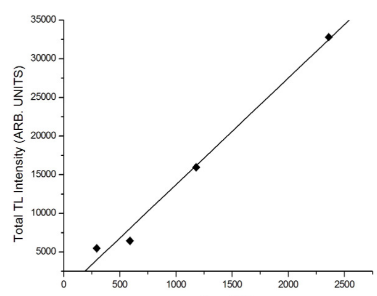

Fig 5. Variation in Total TL-intensity with γ-dose.

CONCLUSION

We have investigated the Thermoluminescence phenomena in the γ-irradiated $SrAl_2O_4$:Dy nano-phosphor (of size 11.35 nm). The phosphor was prepared by combustion method which appears to be a more feasible method for production. The absorption spectra show the absorption edges at λ = 234 nm, thus the band gap of 5.29 eV. The TL intensity of $SrAl_2O_4$:Dy depends upon the γ-dose and it increases with increase in dose. It shows linear response upto 2360 Gy hence found suitable for dosimetric purpose.

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