

## Luminescence Properties of Rare Earth $\text{Sm}^{3+}$ Doped $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$ Phosphor for white light emitting diode

R. M. Yerojwar<sup>1</sup>, N.S. Kokode<sup>2</sup>, C.M. Nandanwar<sup>3</sup>

<sup>1</sup> MohsinbhaiZaweriMahavidyalaya, Desaiganj(Wadsa), Gondwana University, Gadchiroli, Maharashtra, India, yerojwar@gmail.com

<sup>2</sup>Principal NevjabaiHitkariniMahavidyalaya, Bramhapuri, Gondwana University, Gadchiroli, Maharashtra, India, drns.kokode@gmail.com

<sup>3</sup>Nevjabai HitkariniMahavidyalaya, Bramhapuri, Gondwana University, Gadchiroli, Maharashtra, India, chandrasahyanandanwar@gmail.com

**ABSTRACT-** The luminescence characteristics of  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  doped with rare earth  $\text{Sm}^{3+}$  produced through combustion synthesis. To investigate the luminescence characteristics, the phosphors photoluminescence (PL) spectra were also obtained. The PL spectra show significant orange-red emission at 567 nm and 614 nm for the produced materials using a 405 nm excitation, which is attributable  $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{5/2}$  and  $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$  transition of rare earth  $\text{Sm}^{3+}$ . The optimum concentration of  $\text{Sm}^{3+}$  ions in  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  was discovered to be 1.5 mole %, above which concentration quenching was observed. The colour coordinates of  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphor are (x,y) of (0.532, 0.467) and (0.677, 0.322). All of these results point to the suitability of  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphor doped with  $\text{Sm}^{3+}$  ions for display and w-LED.

**Keywords:** Aluminate, phosphors, Photoluminescence, combustion method, w-LED

### 1. INTRODUCTION

Photoluminescent materials are used in a variety of applications, ranging from conventional fluorescent lights to energy-saving lamps to white light emitting diodes (w-LED) [1], [2]. Phosphor hosts include oxides, nitrides, sulphates, borates, phosphates, fluorides, sulphide, and others. Because of its outstanding qualities, alkaline earth metal aluminate has recently gained widespread interest. Phosphors using alumina as the host that have been doped with rare earth ions now have a wide range of uses. For instance,  $\text{AlO}_3$ :  $\text{Ce}^{3+}$  [3] (R: Y, Gd) as a scintillator

material,  $\text{SrAl}_2\text{O}_9$ : $\text{Mn}^{4+}$  [4], [5] as a red emitting phosphor in LED,  $\text{SrAl}_2\text{O}_4$ :  $\text{Eu}^{2+}$ ,  $\text{Dy}^{3+}$  [6], [7] as a long afterglow luminous material, and  $\text{BaMgAl}_{10}\text{O}_{17}$ :  $\text{Eu}^{2+}$ ,  $\text{CeMgAl}_{10}\text{O}_{17}$ :  $\text{Tb}^{3+}$  as lamp phosphors.  $\text{CaMgAl}_{10}\text{O}_{17}$ , a  $\beta$ - $\text{Al}_2\text{O}_3$  structure, is composed of positive ions with a high radius and closely packed spinel, resulting in good chemical stability and brightness. In general, RE elements such as  $\text{Sm}^{3+}$  are injected into the host lattice to induce the distinctive emissions associated with these RE ions 4f-4f transitions [8]-[10].

A near-UV excitation source with tricolour (blue, green, and red) phosphor may also be used to provide white light with enhanced CRI [11]. Near ultra violet (n-UV) excitable tricolour phosphors have various drawbacks, including low luminous efficiency due to the mixing of multiple coloured phosphors, each of which has a distinct degradation rate [12]. Red ( $\text{Y}_2\text{O}_3$ : $\text{Eu}^{3+}$ ) phosphor has a 1/8 efficiency of blue ( $\text{BaMgAl}_{10}\text{O}_{17}$ : $\text{Eu}^{2+}$ ) or green ( $\text{ZnS}$ : $\text{Cu}^+$ ,  $\text{Al}^{3+}$ ) phosphor [9], [10]. As a result, it is critical to create new orange-red producing phosphors in order to get white light with a higher CRI. Among all lanthanides, samarium ( $\text{Sm}^{3+}$ ) ion is promising because it improves the intensity of a red component in the generation of white light [13], [14]. A series of  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphors were manufactured using a combustion technique with dopant concentrations ranging from 0.5-2 mole %. The luminous characteristics of the  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphor were thoroughly investigated for use in lighting and w-LEDs.

## 2. EXPERIMENTAL

The combustion process was used to create the  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphors. All of the beginning materials used in the experiment are of AR quality. Calcium nitrate, magnesium nitrate, aluminum nitrate, samarium oxide, and urea were employed as starting ingredients. Samarium oxide is transformed to nitrate form by combining it with a suitable amount of dilutenitric acid. The mixes were all combined in a stoichiometric ratio. In a mortar, the solution was combined with the dopant. The clear solution that resulted was then transferred to a crucible; the furnace was held at  $550^\circ\text{C}$  for five hours before being lighted and burnt with a flame, giving abundant powders of components. Using a pestle and mortar, this crystalline powder was crushed into a fine powder. The obtained fine powders were annealed for 3 hours at  $600^\circ\text{C}$  and then rapidly cooled to room temperature before being used for further characterisation. The PL measurements were taken with a Shimadzu RF5301PC Spectrofluorophotometer. Each measurement used the same quantity of sample 2 gm. Excitation and emission were measured with a spectral slit width of 1.5 nm.

## 3. RESULTS AND DISCUSSION

### 3.1. Photoluminescence Properties of $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$ Phosphor

The excitation spectra of the  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  phosphors were recorded in the spectral range (350 - 425) nm and monitored at an emission wavelength of 614 nm, as shown in Fig. 1. These spectra exhibit many narrow and strong excitation peaks at 364 nm, 378 nm, 405 nm, and 418 nm attributable to transitions from ground state  $^6\text{H}_{5/2}$  to excited states  $^4\text{D}_{3/2}$ ,  $^4\text{D}_{1/2}$ ,  $^4\text{F}_{7/2}$ , and  $^4\text{M}_{19/2}$  resulting from f-f transitions of  $\text{Sm}^{3+}$  ions [15]-[18]. The best excitation peak occurs at 405 nm, which corresponds well to the NUV LED chip [19].

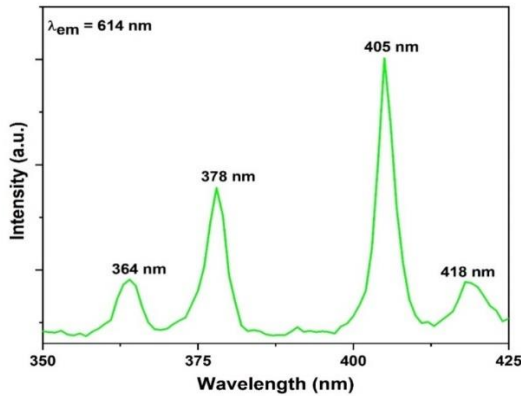


Fig. 1. Photoluminescence Excitation Spectra of  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  Phosphors ( $\lambda_{\text{em}} = 614 \text{ nm}$ )

The emission spectra of the  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  phosphors obtained in the spectral range (550 - 650) nm are shown in Fig. 2. The  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphors exhibit emission peak 583 nm (orange) and 614 nm (red) transitions from the  $^4\text{G}_{5/2}$  excited state. Among the transitions are the  $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{5/2}$  (583 nm) orange emission band and the  $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$  (614 nm) red emission band. This magnetic dipole (MD) transition occurs in  $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{5/2}$  permitted, and this electric dipole (ED) transition occurs in  $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$  [20].

The emission spectra ( $\lambda_{\text{ex}} = 405 \text{ nm}$ ) of  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  phosphor with various  $\text{Sm}^{3+}$  concentrations are shown in Fig. 3. When the concentration of  $\text{Sm}^{3+}$  is changed, the profiles of the emission spectra remain constant [21]. The intensity of the emission increases with increasing  $\text{Sm}^{3+}$  concentration, reaching a maximum at 1.5 mole %, and thereafter decreases with increasing  $\text{Sm}^{3+}$  dose [22]. The inset shows the intensity of these two emission lines as a function of  $\text{Sm}^{3+}$  concentration, as well as how the orange and red emission lines fluctuate [23].

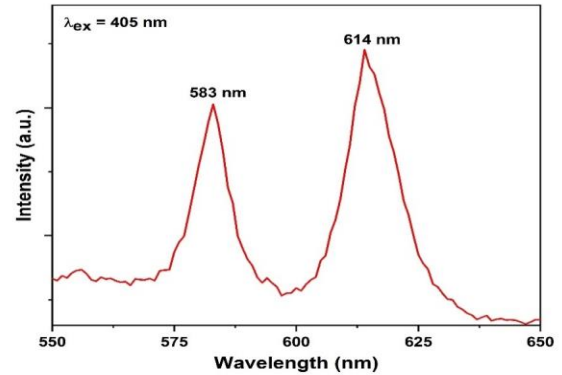


Fig.2. Emission Spectra of  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  Phosphor where  $\lambda_{\text{ex}} = 405 \text{ nm}$

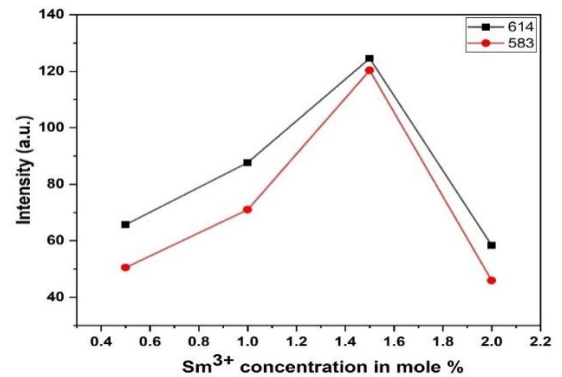


Fig. 3. Variation in the Intensity (614 nm) as function of the  $\text{Sm}^{3+}$  ion concentration in  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  Phosphor

### 3.2. Chromatic Properties of $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$ Phosphor

Using the International Commission on Illumination (CIE) 1931 colour coordinates, the emission spectra are utilised to evaluate the phosphors lighting performance. Fig. 4. depicts the CIE 1931 Chromaticity coordinates of  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:1.5\text{Sm}^{3+}$  phosphor. The  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  phosphor has chromaticity coordinates (x, y) of (0.532, 0.467) and (0.677, 0.322). showing that it emits orange and red light [24].

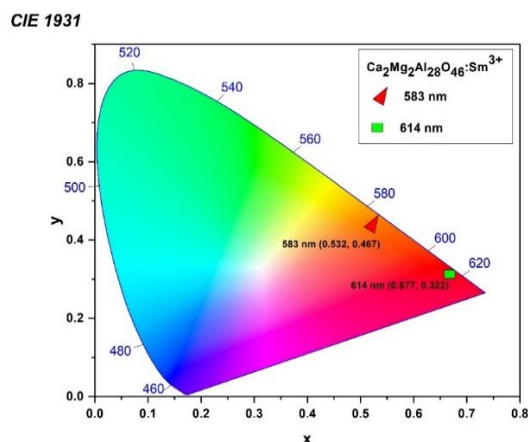


Fig. 4. Chromaticity diagram of CIE 1931 shows chromatic coordinates for the  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}:\text{Sm}^{3+}$  Phosphor

### 4. CONCLUSIONS

The combustion method was used to produce  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  powder phosphor. The PL spectra show significant orange-red emission at 567 nm and 614 nm for the produced materials using the 405 nm excitation, which is attributable to the rare earth  $\text{Sm}^{3+}G_{5/2} \rightarrow {}^6H_{5/2}$  and  ${}^4G_{5/2} \rightarrow {}^6H_{7/2}$  transitions. Beyond 1.5 mole %  $\text{Sm}^{3+}$ , concentration quenching has been obtained.  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphor has colour coordinates (x, y) of (0.532, 0.467) and (0.677, 0.322). These findings suggest that  $\text{Sm}^{3+}$  doped  $\text{Ca}_2\text{Mg}_2\text{Al}_{28}\text{O}_{46}$  phosphors might be used as red emitters in lighting and w-LED.

### ACKNOWLEDGEMENT

We are grateful to Dr. N. S. Kokode, Principal, Nevjabai Hitkarini College, Bramhapuri who has honestly helped me and gave inspirational support which were the most precious contribution for the completion of work.

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