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# Synthesis and Photoluminescence characterization of $ZnAl_{12}O_{19}$ : $Sm^{3+}$ Phosphor for W-LED

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**ABSTRACT**

The combustion process was used to create an effective $ZnAl_{12}O_{19}$:$Sm^{3+}$ phosphor with reddish emission. Using scanning electron microscopy, the structural and morphological characteristics of the phosphor have been studied. Samarium ions are found in trivalent oxidation states, as demonstrated by the photoluminescence spectrum. The as-prepared phosphor exhibits strong visible red emission at 615 nm under 405 nm excitation. It has been discovered that a concentration of 1.5 mol% $Sm^{3+}$ ions produce the strongest visible red emission. The synthesized phosphors 615 nm (x = 0.680, y = 0.319) and 661 nm (x = 0.730, y = 0.269) CIE colour chromaticity coordinates are located in the red area of the chromaticity diagram. All of these findings support the suitability of $Sm^{3+}$-doped $ZnAl_{12}O_{19}$ phosphor for lighting and display applications.

**Keywords** : Rare earth doped, Combustion, phosphor, W-LED, CIE-Coordination.

## I. INTRODUCTION

Nowadays luminous materials are being used in so many different industries, researchers are beginning to focus on this sector. It has been demonstrated that zinc aluminate ($ZnAl_{12}O_{19}$), which has a hexa-aluminate structure, is an appropriate host for rare earth ions, and it has been reported that $Ce^{3+}$ and $Eu^{3+}$ rare earth ions have been doped $ZnAl_{12}O_{19}$ phosphors via combustion synthesis [1].

Due to their multicolor emissions, rare earth ions have played a vital role in the creation of phosphors. For instance, in most hosts, $Pr^{3+}$, $Eu^{3+}$, and $Sm^{3+}$ could serve as the emission centers of red lights, and their emissions are independent of the crystal field around them [2]. The use of luminescent materials is common in a variety of fields, including display technology, CRO tubes, radiation dosimetry, solid state lighting, X-ray imaging, Hg discharge lamps, LEDs, optical paints, optical amplifiers, and lasers [3–6]. They are also utilized as luminescent stains for biomedical analysis, medical diagnosis, and cell imaging.

For usage in solar concentrators, some luminous materials have been created [7]. The partially filled 4f shells are a rare earth element with special characteristics not found in other elements. There are numerous X-$Al_{12}O_{19}$ systems, including $CaAl_{12}O_{19}$, $BaAl_{12}O_{19}$, $SrAl_{12}O_{19}$, $LaAl_{12}O_{19}$, and $ZnAl_{12}O_{19}$ [8-11,1]. The synthesis and characterization of $ZnAl_{12}O_{19}$ doped with $Sm^{3+}$ at various concentrations, including 0.5%, 1.0%, 1.5%, and 2%, are the main components of this study.

## II. Experimental

The materials can be prepared using a variety of chemical and physical techniques. The combustion synthesis method stands out among these techniques since it is simple, quick, and requires little assembly. As a result, we decided to prepare the samples using the combustion synthesis approach. The combustion synthesis with 99.9 AR grade precursors was used to create the new $Sm^{3+}$ $ZnAl_{12}O_{19}$ phosphors. $Zn(NO_3)_26H_2O$, $Al(NO_3)_39H_2O$, $Sm_2O_3$, and urea as a fuel agent were the precursors employed in the synthesis. The stoichiometric ratio was used to weight each of these precursors. With warm heating, the weighted $Sm_2O_3$ was dissolved in 2 mL of nitric acid. The generated $Sm_2O_3$ combination was then put into the furnace, which was kept at a temperature of 650°C, along with a homogenous mixture of $Zn(NO_3)_26H_2O$, $Al(NO_3)_39H_2O$, and the urea employed as the fuel agent. The mixture was ignited as a result of different gases were released upon ignition, and foamy material was produced. The prepared material was ground to get a sample of nano size. By using various techniques, these prepared samples are further described and investigated.

## III. Results and Discussion

### Photoluminescence studies

### Excitation spectrum of $ZnAl_{12}O_{19}$:$Sm^{3+}$ phosphor

Figure 1 displays the $ZnAl_{12}O_{19}$:$Sm^{3+}$ produced by combustion synthesis photoluminescence excitation spectrum. The EM spectrum with a fixed emission wavelength of 615 nm exhibits a number of prominent peaks in the visible spectrum. The wavelengths of 363 nm, 377 nm, 405 nm, and 419 nm correspond to the four peaks of the excitation spectrum in the visible area. The transitions to $^6H_{5/2} \rightarrow {}^4D_{3/2}$, $^6H_{5/2} \rightarrow {}^6P_{7/2}$, $^6H_{5/2} \rightarrow {}^4F_{7/2}$ and $^6H_{5/2} \rightarrow {}^4M_{19/2}$ are all responsible for these excitation peaks, which are all f-f absorption transitions of $Sm^{3+}$ [12–16].

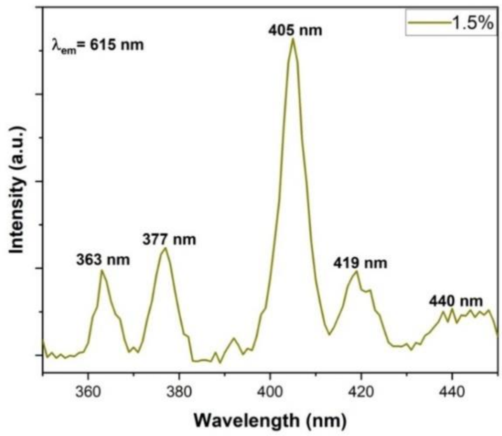


**Fig 1 Excitation Spectra of $ZnAl_{12}O_{19}$:$Sm^{3+}$ at ($\lambda_{em}$=615 nm)**

### Emission spectrum of $ZnAl_{12}O_{19}$:$Sm^{3+}$ phosphor

As depicted in Figure 2, the emission spectra were captured at room temperature using excitation wavelengths of 405 nm. In accordance with the $^4G_{5/2} \rightarrow {}^6H_{5/2}$, $^6H_{7/2}$, and $^6H_{9/2}$ transitions, the emission spectra show emission peaks at 563, 615, and 661 nm, respectively [17,18]. The $^4G_{5/2} \rightarrow {}^6H_{7/2}$ transition, which corresponds to the most strong emission peak for the $Sm^{3+}$ doped $ZnAl_{12}O_{19}$ phosphor at 615 nm, is a partly magnetic dipole (MD) and electric dipole (ED) transition, with the ED predominating [19].

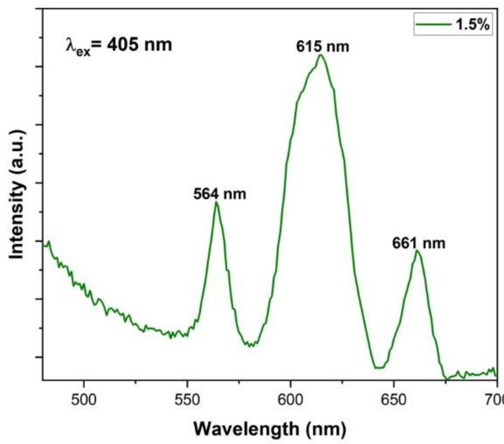


**Fig 2 Emission Spectra of $ZnAl_{12}O_{19}$:$Sm^{3+}$ at ($\lambda_{ex}$=405 nm)**

The emission intensities of the peaks climb together with the doping concentration from 0.5mol% to 1.5mol%, and then they start to fall. The general consensus is that as $Sm^{3+}$ ion concentration rises, photoluminescence (PL) will as well. When $Sm^{3+}$ ions are concentrated, quenching occurs above 1.5 mol%. This causes the emission intensity to drop. A higher $Sm^{3+}$ ion concentration causes non-radiative contact between the ions, which increases resonant energy transfer. The energy eventually reaches a trap from which it is dissipated by non-radiative processes rather than by the emission of visible light [20,21]. The higher concentration causes the distance between $Sm^{3+}$ ions to decrease, which facilitates the transfer of energy by resonance process from one ion to another ion.

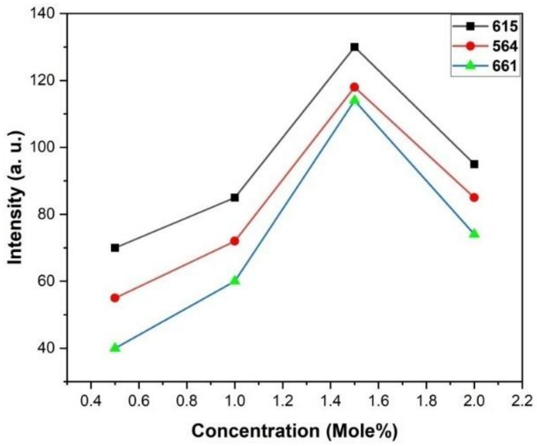


**Fig. 3 Concentration Quinching of $Sm^{3+}$ Doped $ZnAl_{12}O_{19}$**

## Chromatocity Analysis

The colour coordinates for the $ZnAl_{12}O_{19}:Sm^{3+}$ phosphor's wavelengths at 564 nm (x = 0.401, y = 0.596), 615 nm (x = 0.680, y = 0.319), and 661 nm (x = 0.730, y=0.269) are identified and plotted in Fig. 4 using the commission international de L'Eclairage (CIE) 1931 chromaticity diagram. Two of these three coordinates fall within the red region. The $ZnAl_{12}O_{19}:Sm^{3+}$ phosphors may therefore be suitable as materials for reddish luminescence.

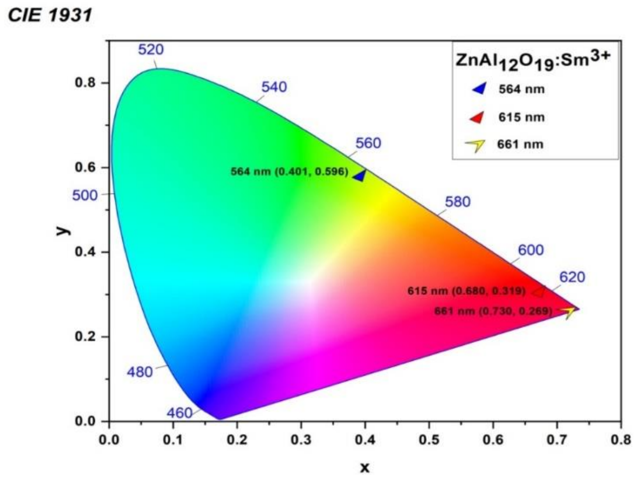


**Fig. 4. CIE chromaticity diagram $ZnAl_{12}O_{19}:Sm^{3+}$ phosphor**

## SEM studies

$ZnAl_{12}O_{19}:Sm^{3+}$ phosphor was subjected to SEM measurement in order to examine its morphological properties. Fig. 5 displays the outcomes. $ZnAl_{12}O_{19}:Sm^{3+}$ phosphor displayed aggregated particles with erratic shapes. On the surface of some of the larger particles, some smaller ones could also be visible. These larger particles may have developed as a result of tiny particles aggregating. The typical particle size is between 2-10 μm. They are therefore appropriate for a variety of lighting applications [22].

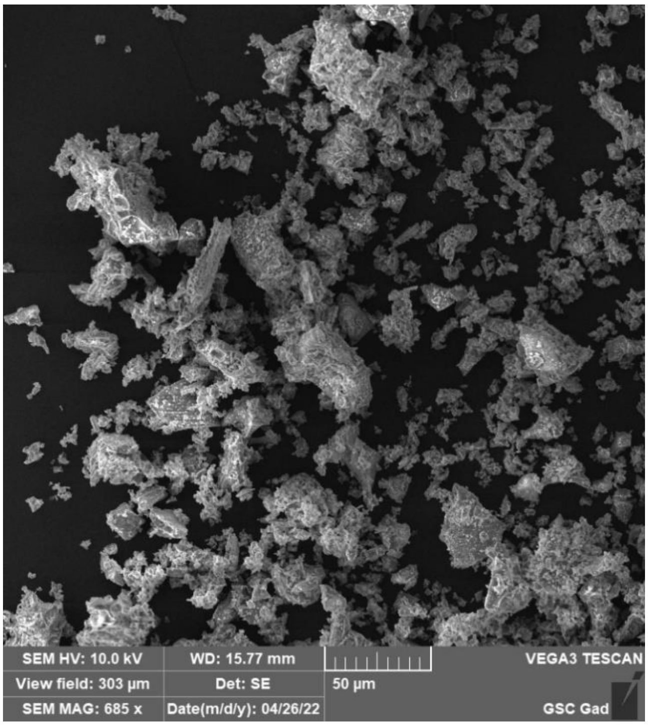


**Fig. 5 SEM image of $ZnAl_{12}O_{19}$ host**

## IV. Conclusion

For the first time, trivalent samarium doped $ZnAl_{12}O_{19}$ phosphors were created by a combustion synthesis procedure. The $ZnAl_{12}O_{19}:Sm^{3+}$ phosphors could be efficiently stimulated by NUV and blue light with strong reddish emissions, according to the excitation and emission spectra. When $Sm^{3+}$ concentration reached 2 mol%, the concentration quenching occurred. The morphology of $ZnAl_{12}O_{19}$ belongs to irregular shape and the size is about 2–10 μm. The findings revealed a prospective use for $ZnAl_{12}O_{19}:Sm^{3+}$ phosphors in producing red and white light for LEDs, optical imaging systems, and displays.

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