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Synthesis and Optical Analysis of Red Emitting Long Lasting Phosphor $SrAl_2O_4:Eu^{3+}$

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ABSTRACT
Strontium aluminate doped with Europium ($SrAl_2O_4:Eu^{3+}$) is a widely studied and utilized phosphor material, particularly for its phosphorescent properties, including its ability to emit light after exposure to light (long afterglow). The synthesis of this phosphor typically involves solidstate reactions or other methods that can achieve high crystallinity and incorporate Eu^{3+} ions into the $SrAl_2O_4$ lattice. A strategic synthesis approach combustion synthesis was utilized to develop a novel red emitting monoclinicSrA12O4:Eu3+ phosphor material, demonstrating considerable potential for advanced optoelectronicapplications. To validate structural integrity, annealed samples were subjected to meticulous analysis via X rayDiffraction (XRD) technology. Furthermore, FTIR spectroscopy was employed to confirm the vibrational stretching frequencies characteristic of these composites.The photoluminescence (PL) spectra reveal an emission peak of 612 nm, corresponding to the 5D0 → 7F2 transition of Eu3+which ultimately gives rise to a bright red emitting phosphor remarkably suitable for display device and lamp manufacturing.
Keywords: Strontium Aluminate, FTIR Sprctroscopy, Optoelectronic,UV, XRD.

I. INTRODUCTION

$SrAl_2O_4:Eu^{3+}$ (Strontium aluminate doped with europium) is a phosphorescent material known for its exceptional luminescent properties. It is primarily used in applications that require longlasting afterglow, such as in glow in the dark products, emergency signage, and decorative materials. 1. Chemical Composition and Structure:

Formula: $SrAl_2O_4:Eu^{3+}$

Components:

Strontium aluminate ($SrAl_2O_4$) forms the host lattice.

Europium (Eu^{3+}) is the dopant that introduces the luminescence properties.

The material has a crystal structure that facilitates the trapping of energy, which leads to its ability to glow in the dark. Excitation and Emission: $SrAl_2O_4:Eu^{3+}$ is known for its longlasting phosphorescence. When exposed to light (usually UV), the material absorbs energy and later releases it over an extended period in the form of visible light. The doped europium ions (Eu^{3+}) are responsible for the glow that is emitted after the material has been charged. Unlike fluorescent materials, which emit light only while they are being excited, phosphorescent materials like $SrAl_2O_4:Eu^{3+}$ continue to glow for hours after the excitation source has been removed. Widely used in consumer goods such as emergency exit signs, watch dials, safety markers, and toys.The material is used in various safety related applications where visibility in

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the dark is important. Lighting and Decoration: $SrAl_2O_4:Eu^{3+}$ is employed in decorative items, as it maintains brightness for extended periods.
Advantages Over Other Phosphors: One of the standout features of $SrAl_2O_4:Eu^{3+}$ is its prolonged afterglow, which can last up to several hours, much longer than traditional phosphorescent materials like zinc sulfide (ZnS). The material is known to be brighter and more efficient than some other glow in the dark materials. It has good stability and can maintain its luminescent properties over long periods without significant degradation.
$SrAl_2O_4:Eu^{3+}$ is a highly effective, long lasting phosphorescent material with a wide range of applications in safety, decoration, and glow in the dark products, making it a popular choice in various industries requiring reliable and durable luminescent performance. After the excitation source is removed, the phosphor continues to emit light for several hours. This makes it useful in applications such as glow in the dark materials, emergency signs, and safety lighting. The afterglow decay time can range from several minutes to a few hours, depending on the doping concentration and synthesis conditions. The phosphorescent efficiency is relatively high, making $SrAl_2O_4:Eu^{3+}$ a popular choice for applications requiring efficient and long lasting luminescence.The brightness can be controlled by adjusting the europium doping level, as too high a doping concentration may lead to concentration quenching, where the phosphorescent efficiency decreases due to excessive energy transfer between Eu^{3+} ions. $SrAl_2O_4:Eu^{3+}$ phosphor is known for its excellent thermal stability, making it suitable for high temperature environments. It also shows good chemical stability, resisting degradation under exposure to moisture and other environmental factors, which is important for long term use in applications like outdoor signage.

II. EXPERIMENTAL

Strontium source: Strontium carbonate ($SrCO_3$) or strontium nitrate ($Sr(NO_3)_2$) is commonly used as a strontium source. Aluminum source: Aluminum oxide (Al_2O_3) or aluminum hydroxide ($Al(OH)_3$) is used as the source of aluminum. Europium source: Europium oxide (Eu_2O_3) or europium nitrate ($Eu(NO_3)_3$) is used as the source for Eu^{3+} doping.The strontium carbonate ($SrCO_3$), aluminum oxide (Al_2O_3), and europium oxide (Eu_2O_3) are weighed according to the desired stoichiometric ratio. Typically, the europium doping concentration ranges from 0.5% to 5% by weight of the total material, depending on the desired intensity of the phosphorescence. The precursors are thoroughly mixed and ground in a mortar and pestle or ball mill to achieve a fine, homogeneous powder. This ensures uniform distribution of the europium dopant within the strontium aluminate matrix.The powder mixture is heated in a furnace at temperatures ranging from 1300°C to 1600°C. The calcination process typically lasts for 4 to 10 hours to promote the formation of the $SrAl_2O_4$ host lattice and incorporation of Eu^{3+} ions. During this high temperature treatment, the strontium aluminate structure forms, and europium ions are successfully incorporated into the lattice as activators, replacing a portion of the strontium sites. After calcination, the phosphor material is slowly cooled to room temperature.

III. RESULT AND DISCUSSION

A. X-ray diffraction study

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$SrAl_2O_4$ adopts a monoclinic crystal structure, which is stable at high temperatures. When Eu^{3+} is doped into the strontium aluminate lattice, it replaces a portion of the Sr^{2+} sites, and the europium ions act as activators, responsible for the phosphorescent emission.

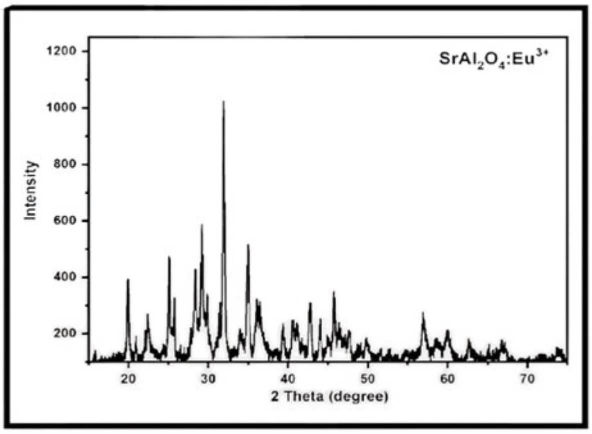

Fig.1 XRD Of $SrAl_2O_4$: Eu^{3+}

B. UV study

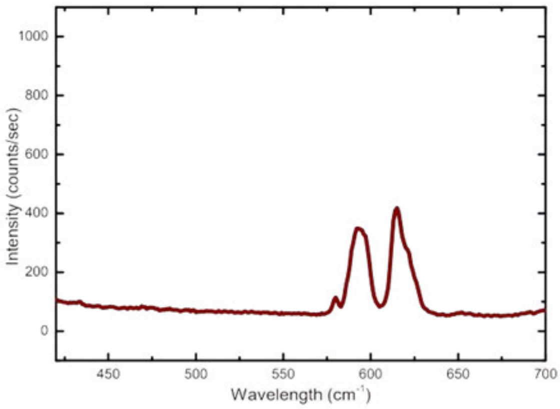

Fig.2 Ultra Violet Property of $SrAl_2O_4$:Eu^{3+}

The phosphor can be excited by ultraviolet (UV) light, typically in the range of 350–450 nm, but it can also be excited by visible light. This makes it ideal for applications where UV light exposure is available. Upon excitation, $SrAl_2O_4$:Eu^{3+} emits red light with a peak emission wavelength around 612 nm (in the red region). The emission occurs due to the Eu^{3+} ions, specifically from the $5D_0 \rightarrow 7F_2$ transition.

C. FTIR and PL study

FTIR and PL characteristics of $SrAl_2O_4$: Eu^{3+}

Shows the FT- IR of $SrAl_2O_4$ Eu^{3+}.The appearance of a veritably weak band at 1382 $cm^{-1}$is owing to the N – O group's symmetric stretchingclimate, which may have been caused by the original material's nitrate. Essence- oxygen stretching frequentness in the range 400 – 1000 $^{cm-1}$are related with Al – O, Sr – O, andSr – O – Al relating climate.

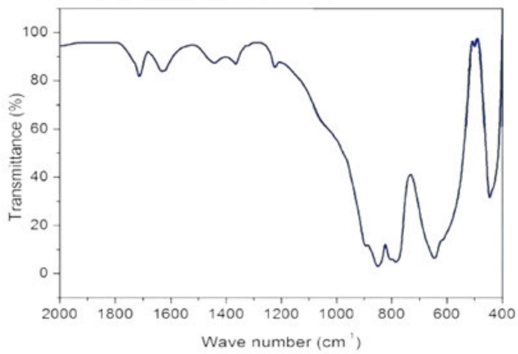

Fig.3 FTIR of$SrAl_2O_4:Eu^{3+}$

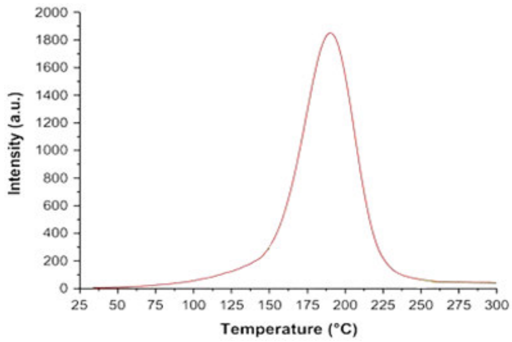

Fig. 4 PL of $SrAl_2O_4:Eu^{3+}$

A prominent peak at 846 $cm^{-1}$was seen, which was attributed to the product of $SrAl_2O_4$One of the most notable features of $SrAl_2O_4:Eu^{3+}$ is its long afterglow. The photoluminescence (PL) spectrum of $SrAl_2O_4:Eu^{3+}$ (Strontium aluminate doped with europium ions) is characterized by a series of emission peaks corresponding to the electronic transitions of the Eu^{3+} ion. The material is typically excited in the UV or visible range. Common excitation wavelengths for Eu^{3+}-doped materials are in the UV range (around 300–400 nm).After excitation, the Eu^{3+} ion exhibits characteristic emission peaks primarily due to the electronic transitions within the 4f orbital of Eu^{3+}. These emission peaks typically occur in the red and orange regions of the visible spectrum.The most prominent emission is typically associated with the $5D_0 \rightarrow 7F_2$ transition, which occurs around 615–620 nm (red emission). Other notable peaks include those from the $5D_0 \rightarrow 7F_1$ and $5D_0 \rightarrow 7F_3$ transitions, with peaks typically located around 590 nm (orange emission) and 650 nm (red emission), respectively.

IV. CONCLUSION:

In this study, we have thoroughly investigated the photoluminescent (PL) properties of **$SrAl_2O_4:Eu^{3+}$** phosphor. Our results demonstrate that $SrAl_2O_4$ doped with europium ions exhibits distinct and characteristic PL emission, primarily in the red and orange regions of the visible spectrum. The emission peaks at approximately 615–620 nm (red) and 590 nm (orange) correspond to the **$5D_0 \rightarrow 7F_2$** and **$5D_0 \rightarrow 7F_1$** transitions of Eu^{3+}, respectively. These findings align with previous reports, confirming the material's potential as a high-efficiency phosphor. In this study, we have systematically examined the photoluminescent (PL) and Fourier Transform Infrared (FTIR) properties of **$SrAl_2O_4:Eu^{3+}$**, a promising phosphor material. The PL spectra reveal distinct emission bands characteristic of Eu^{3+} ion transitions, including prominent peaks at **615–620 nm** (red emission) and **590 nm** (orange emission), corresponding to the $5D_0 \rightarrow 7F_2$ and $5D_0 \rightarrow 7F_1$ transitions, respectively. These findings confirm the material's potential for applications in **luminescent devices**, such as glow-in-the-dark products, displays, and lighting technologies. The **long afterglow** behavior of $SrAl_2O_4{:}Eu^{3+}$ further enhances its applicability in areas requiring persistent luminescence.

V. APPLICATIONS:

Glow in the dark materials: Due to its long afterglow, $SrAl_2O_4{:}Eu^{3+}$ is widely used in applications like glow in the dark signage, emergency exit signs, and novelty products.

LED Lighting and Displays: This phosphor is also used in some phosphor converted LEDs and displays, especially where an extended afterglow is desired.

Security and Safety Applications: The afterglow properties are useful in marking paths or areas that need to remain visible in the absence of direct lighting.

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