

Red Emitting LaSrAlO₄:Sm³⁺ Phosphor For Light Emitting Diode

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ABSTRACT

A red emitting phosphor, Sm³⁺ doped LaSrAlO₄ phosphor has been prepared by the combustion method. Scanning electron microscopy (SEM) and photoluminescence spectra were utilized to characterize the structure and luminescence properties of the as-synthesized phosphors. The morphologies of the phosphor were investigated by scanning electron microscopy (SEM), which indicated that the phosphor had a good quality of surface crystallization. Luminescence properties shows that the phosphor can be efficiently excited by the ultraviolet visible light in the region from 300 to 450 nm, and it exhibits 566 nm and 602 nm emission corresponding to ⁴G_{5/2}→⁶H_{5/2} transition and ⁴G_{5/2}→⁶H_{7/2} transition, respectively. The prepared LaSrAlO₄:Sm³⁺ phosphor might be applicable in green lighting technology.

Keywords: Combustion synthesis, Luminescence, trivalent rare earth, Samarium, LED

INTRODUCTION

Over the last few years, world-wide interest for energy escalates at an ever-increasing rate, there is a new exigency to enhance the competency and feasibility of existing technologies [1]. A comprehensive investigation has been put forward for the affiliation and enhancement of a broad variance of luminescent materials for their use for optical applications and as coating materials of display screens [2]. In view of the fact that first commercial LED (Light Emitting Diode) was found in 1997 by mixing yellow (Y,Ga)₃(Al,Ga)₅O₁₂:Ce³⁺ phosphor with a blue LEDs chip [3].

It is widely known that hosts like borates, phosphates, aluminates, silicates, vanadates, etc. are usually based on profitable phosphors. It is observed that luminescence is very strongly dependent on the host lattice and arise in the electromagnetic spectrum from the ultraviolet region to the red region. Due to the permissible nature of the electronic inter configurational transitions both in the excitation and emission evolved very short decay time and substantial intensity of the luminescence [4]. In the vicinity of various spectroscopic studies, we observed that luminescent materials, the near infrared (NIR) to visible frequency up conversion is mostly studied due to their potential utilizations in various fields such as light emitting devices, multiplex labelling, solid state laser, solar cell, photodynamic therapy, temperature sensing, etc.[5,6]. Rare-earth-doped aluminates such as $\text{Sr}_4\text{Al}_{14}\text{O}_{25}$, CaAl_2O_4 , YAlO_3 and SrAl_2O_4 etc. has been intensively investigated in luminescence because of their potential applications in orange-red UV optoelectronic and microelectronic devices [7,8].

Despite that, luminescence of silicon-based nitride and oxy nitride compounds has been paid less attention due to (i) their deficit of general synthetic routes; (ii) the critical preparation surrounding (high temperature, high N_2 pressure); (iii) the finite knowledge of their crystal structures as a consequence of the problems in crystal growth ;(iv) the massive impression that they are used as high-temperature structural materials [9]. Over the last few decades, researchers shows the interests in the study on spectroscopic properties of trivalent rare earths doped phosphors 'known as luminescent materials'. Due to this trivalent rare-earth ions doped with aluminate phosphors have fascinated high eminence for light-emitting diodes (LEDs) in solid-state lighting applications due to their durability and environment friendliness in analyse with sulphides. Thermally stability, high luminescence efficiency, radiation resistivity, fine particle size, and narrow size distribution are required for the phosphors [10,11]. The emission of light can be achieved by single host lattice either by doping of single rare-earth (RE) or combined RE ions with the suitable host. Among various RE activators, Sm^{3+} is considered as a potential activator ion in many host lattices for the white light emitting device applications. As known,

Sm^{3+} ions can effectively absorb UV light and then emit different colours from green to deep red depending on the surrounding crystal field strength. So, it is important to find chemically and thermally stable suitable host lattice for appropriate doping of Sm^{3+} ion in order to explore its suitability for LED applications [12].

The compound LaSrAlO_4 : Sm^{3+} phosphor as orange-red emitting centre with suitable doping concentration. due to the electronic transitions of ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_j$ ($J = 5/2, 7/2, 9/2$), the afterglow colour of this type of phosphors is a mixture of the three above mentioned electronic transition emissions and have a little different when the concentration of the Sm^{3+} dopant changes by B. Lei et al [13,14]. There is no phase transition for LaSrAlO_4 crystals from melting temperature to a lower temperature, and it has the same structure with high-temperature superconductor YBCO, but LaSrAlO_4 has a lower coefficient of thermal expansion than the other perovskite structure crystals. It can be used to grow films at a lower temperature, and thereby improve the lattice mismatch and reduce stress. Solid state lighting have a very bright future in various lighting applications because of their high energy efficiency and cost effectiveness compared to incandescent bulbs [15].

METHODOLOGY

In this study, LaSrAlO_4 doped with 1 mole % Sm^{3+} was prepared by conventional combustion synthesis. Lanthanum nitrate ($\text{LaN}_3\text{O}_9 \cdot 6\text{H}_2\text{O}$), strontium nitrate ($\text{Sr}(\text{NO}_3)_2$), aluminium nitrate ($\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$), urea (H_2NCONH_2) and samarium (Sm_2O_3) of analytical reagent grade purchased from Merck Chemicals were used as the initial materials, in proper stoichiometry, for complete combustion. For the preparation of this compound, sample was crushed for 15 min in agate mortar and then preheated muffle furnace maintained at a temperature 650°C and the whole reaction was completed within 5 min. After this, the crystalline powder was obtained. This crystalline powder was taken in agate mortar-pastel and grinded to make fine powder. Lastly, the powder used for further characterisation.

RESULTS AND DISCUSSION

3.1 Scanning Electron Microscope (SEM)

Fig 1 shows the morphology of LaSrAlO_4 phosphor. The size and shape of phosphor particles affects the emission intensity and the efficiency of a device. The

size of phosphor particles should be as homogeneous as possible without any aggregates or agglomerates, and the surface should also be as smooth as possible and have a high crystallization degree to improve efficiency. The results show that the crystallized particles aggregated and were irregular.

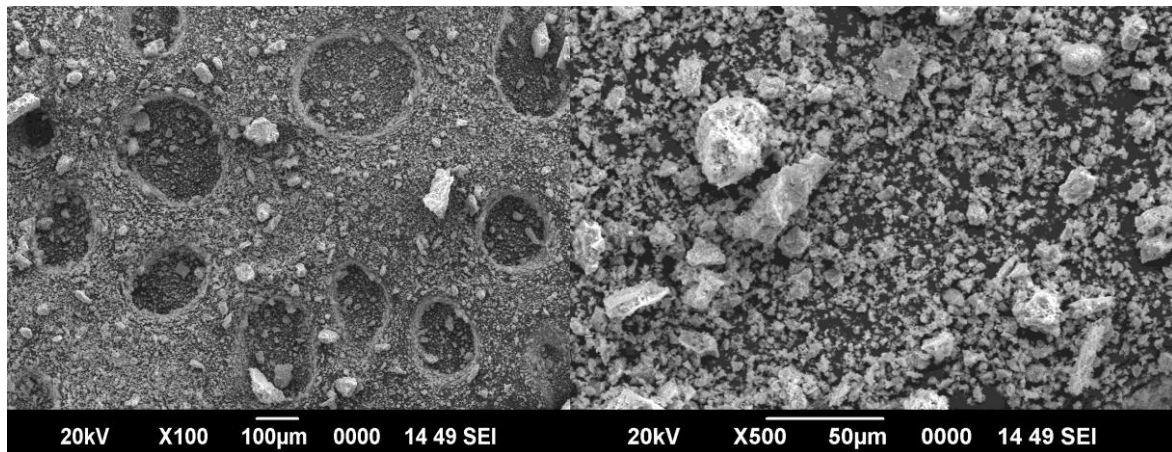


Fig.1. SEM micrographs of LaSrAlO_4 phosphor

3.2 Photoluminescence (PL)

The room-temperature excitation and emission spectra of the rare earth ion Sm^{3+} doped LaSrAlO_4 phosphor is shown in Fig. 2 and Fig 3. PLE spectrum was observed in the wavelength range from 300-500 nm while showing the emission at 566 nm and 602nm, which are the typical f-f transitions of Sm^{3+} ions. The strongest excitation peak observed at 409 nm is assigned to the $^4\text{H}_{5/2} \rightarrow ^4\text{F}_{7/2}$ transition of Sm^{3+} . The emission spectra have been recorded in the range of 550nm to 650 nm by exciting at 409 nm wavelengths. The emission

spectra consist of two bands at 566 nm and 602 nm corresponding to transitions $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{5/2}$ and $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$ of Sm^{3+} ions, respectively. The PLE spectrum of the Sm^{3+} doped LaSrAlO_4 phosphor shows that the synthesized phosphor can be excited efficiently by n-UV and blue light, which matches well with the emission of commercially available n-UV and red orange LED chips. Typical Sm-activated phosphors exhibit charge-transfer absorption of $\text{Sm}^{3+}-\text{O}^{2-}$ interaction or host absorption band in the UV region.

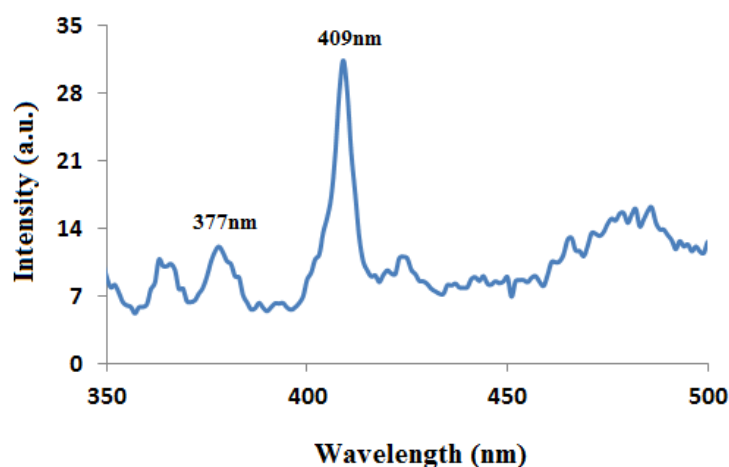


Fig. 2: Excitation spectra of the $\text{LaSrAlO}_4:\text{Sm}^{3+}$ phosphor

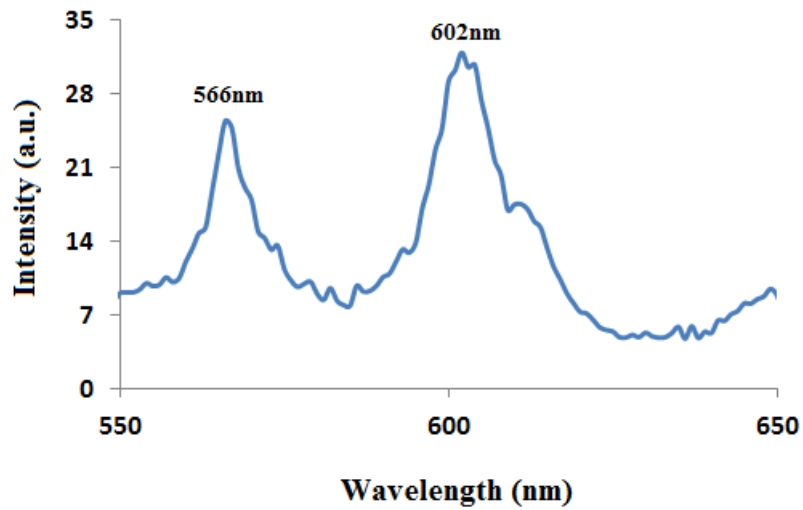


Fig:3: Emission spectra of the LaSrAlO₄:Sm³⁺ phosphor

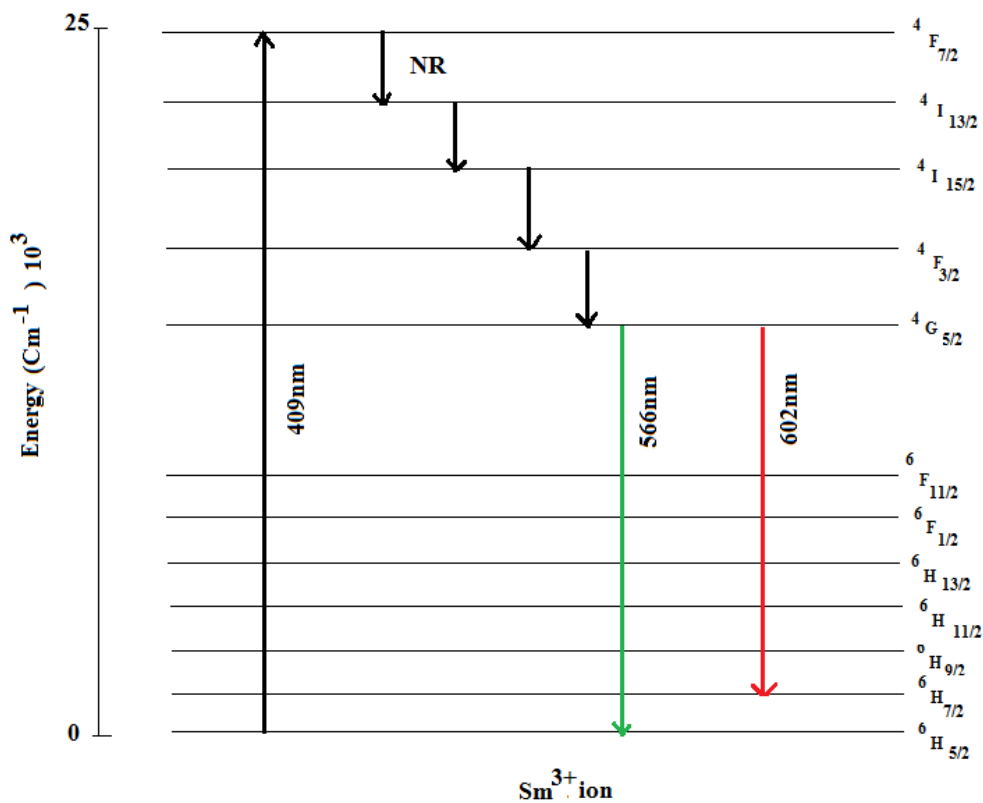


Fig:4: Energy Level Diagram of LaSrAlO₄: Sm³⁺ phosphor

However, only direct excitation of Sm³⁺ ions could be observed in this study, the interaction between Sm³⁺ and the host lattice is very weak, so no energy transfer occurs between Sm³⁺ and host [16]. The Sm³⁺ ions from the higher states make non-radiative transition up to

⁴G_{5/2} level after that the transitions are radiative, as the energy gap between ⁴G_{5/2} → ⁶H_j (j = 5/2, 7/2, 9/2, 11/2) states is sufficient to give green and orange emission [17-19]. To study luminescence properties it is very useful for understanding the energy transfer

mechanism and quenching. Energy transfer is proportional to spectral overlap of sensitizer emission and activator absorption/excitation by Dexter's theory the probability[20]. The energy transfer mechanism is further understood from excitation spectra and lifetime measurements for doped host materials. Fig.4 presents Energy level diagram of LaSrAlO₄: Sm³⁺ phosphor. Sm³⁺ ions in the ground state and jumps to the higher energy levels and there by relaxes non-radiatively to the ground state with enhanced red-orange emission. These spectra are due to transitions within ⁴F₅ configuration.

CONCLUSION

In summary, LaSrAlO₄: Sm³⁺ has been successfully synthesized by means of the combustion synthesis process. The SEM reveals the formation agglomeration of grains. Due to an efficient energy transfer from the Sm³⁺-O²⁻ group to the Sm³⁺ show the characteristic strong emissions at 566nm and 602nm under excitation at 409 nm. These studies indicate a facile route for the development solid state lightning useful in many types of colour display fields, optical applications.

Conflicts of interest: The authors stated that no conflicts of interest.

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