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Synthesis and characterization of $Sr_4Al_{14}O_{25}$:Dy phosphor.

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ABSTRACT

It is observed that white light radiation can be achieved by combining green, blue and red light emitting diodes. These diodes are synthesized using inorganic and organic phosphors. In this work we have studied $Sr_4Al_{14}O_{25}$ inorganic material by doping different Dy concentrations by combustion method. We have performed XRD data analysis to confirm the formation of the prepared samples. To study luminescence properties which have performed photoluminescence study. The studied work showed that the prepared inorganic phosphor can be used in violet and in green emission color band. Further the intensity of the phosphor can be increase by increasing Dy concentration. The intensity of the phosphor can be increase 10 time by changing Dy concentration from 0.1% to 0.2 %.

Keywords: Rare-earth, luminescence, inorganic phosphors, emission, Combustion synthesis

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INTRODUCTION

As luminescence is very old research fields but every day it bringing a new and interesting science in our field. It is observed that luminescent materials are used to in modern day lightings. Many inorganic as well as organic materials show interesting luminescent properties with different emission and excitation properties. The luminescence behavior in inorganic materials can be enhanced by doping rare-earth materials.

Their luminescence behavior is due to their various energy levels which allow 4f – 4f or 5d – 4f transitions.[1, 2] These transitions are responsible for characteristics emission from ultra-violet to infra-red region in electromagnetic spectrum due to relaxation of excited state electrons to their ground state after absorption of light. The rare-earth doped materials are used in various technological applications such as light emitting diodes, field emitting displays, biomarker etc. [3-6]

Luminescence phosphors are inorganic and organic materials with an inner host lattice and optically excited activators like 3d or 4f ion. These are materials are used for white light emitting diodes which are energy saver and pollution free compared to tradition light systems. Previous study on luminescence materials showed that dysprosium (Dy) is a suitable material for white light LEDs.[7-10] The emission spectrum of Dy3+ rare earth contains varieties of luminescence bands which are $^6H_{15/2} \rightarrow {}^6P_{3/2}$ at 328 nm, $^6H_{15/2} \rightarrow {}^6P_{7/2}$ at 354 nm, $^6H_{15/2} \rightarrow {}^6P_{5/2}$ at 369 nm, $^6H_{15/2} \rightarrow {}^4I_{13/2}$ at 390 nm, $^6H_{15/2} \rightarrow {}^4G_{11/2}$ at 430 nm, $^6H_{15/2} \rightarrow {}^4I_{15/2}$ at 455 nm, $^6H_{15/2} \rightarrow {}^4F_{9/2}$ at 476 nm, $^6H_{13/2} \rightarrow {}^4F_{9/2}$ at 570 nm and $^6H_{11/2} \rightarrow {}^4F_{9/2}$ at 650 nm transitions. Combination of these transitions produces white light emitting diodes.[10-12]

In this work, we present Dy doped $Sr_4Al_{14}O_{25}$ inorganic material due to its chemical and thermal stability. The work is focus around synthesis and characterization of $Sr_4Al_{14}O_{25}$:Dy inorganic phosphors. The inorganic phosphors are synthesized using combustion method which was confirmed using XRD measurement. Later the samples were taken for photoluminescence.

METHODOLOGY

The $Sr_4Al_{14}O_{25}$:Dy samples were synthesized using traditional combustion synthesis method. Analytical grade of $Sr(NO_3)_2$, Al_2O_3, Dy_2O_3 and urea were used as starting materials. Based on stoichiometric calculated, particular amount of substance is estimated for each compound. The mixture grounded in an agate mortar and then synthesized using combustion process.

RESULTS AND DISCUSSION

Characterization

XRD analysis

The prepared samples were taken for characterization to confirm the formation of $Sr_4Al_{14}O_{25}$ compound. Figure 1 depicts XRD pattern for $Sr_4Al_{14}O_{25}$: Dy with 0.1 % (blue) and 0.2 % (green) of Dy. The analysis of XRD measurements is qualitative and it is based on relative peak intensities. X-ray diffractometer (Bruker, model D-8 Advance) with monochromator CuKα radiation (λ=1.54187 A°)

The peak position of prepared samples matches with standard $Sr_4Al_{14}O_{25}$ compound with ISDD number 52 – 1876. The dominating peaks are at angle (2θ) 25.43 and 35.86 with (h k l) values (420) and (820) respectively. From the standard file, it can be concluded that the structure of the prepared sample is orthorhombic structure with sub group Pmma and having α – phase. This data is agreed with previous research work.[13] Moreover, Peak position at 28.672 and 43.402 are matches with standard Dy ICDD data with file number 89 – 2926. The peak intensity at angle 43.402 increases with increasing dopant confirmation which suggests that the dopant concentration increases in sample two (green curve in Figure 1). The prepared $Sr_4Al_{14}O_{25}$ have the same crystal size due to fact that ionic radius of Sr2+ nearly matches with Dy3+ ionic radius. Therefore it can be easily replaceable in the phosphor formation.

From the above discussion it is clear that prepared $Sr_4Al_{14}O_{25}$ have orthorhombic structure with Pmma subgroup and intensity of Dy peak increases with increasing its concentration.

Photoluminescence study

Figure 2 shows PL spectra of $Sr_4Al_{14}O_{25}$:Dy phosphor with doping concentration of 0.1 % (brown line) and 0.2 % (green) line. It is observe that emission peak positions occurs at the same wavelength but intensity of the phosphors increases with doping concentration.

The fitted Gaussian fits are obtained at peak positions 370 nm, 386 nm, 407 nm, 450 nm and 508 nm. These suggest that the emission spectra are spread over a wide range of wavelengths. The peak positions 370 nm, 390 nm, and 407 nm are in violet band and it is obtained due to $^6H_{15/2} \rightarrow {}^6P_{5/2}$ and $^6H_{15/2} \rightarrow {}^4I_{13/2}$ transitions. However, 450 nm and 508 nm wavelength obtained due to $^6H_{15/2} \rightarrow {}^4I_{15/2}$ and $^6H_{15/2} \rightarrow {}^4F_{9/2}$ transitions. The data is consistent with previous work.[14, 15] it is interesting to note that the intensity of emission spectra is increased 10 time by simply increasing doping concentration of Dy from 0.1 % to 0.2 %.

This suggests that with increasing doping concentration the intensity of the emission spectra increases and for both the concentrations the entire spectra centered at the same point. The spectra are spread over different bands from violet to green color band.

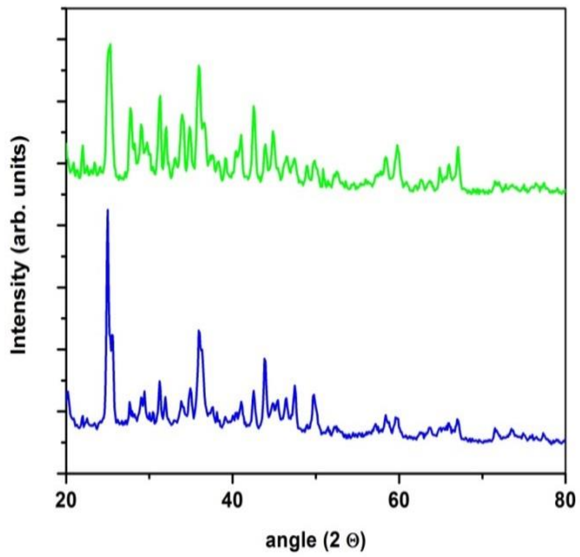

Figure 1 XRD- patterns of $Sr_4Al_{14}O_{25}$:Dy; 0.1 % (blue) and 0.2 % (green) of Dy.

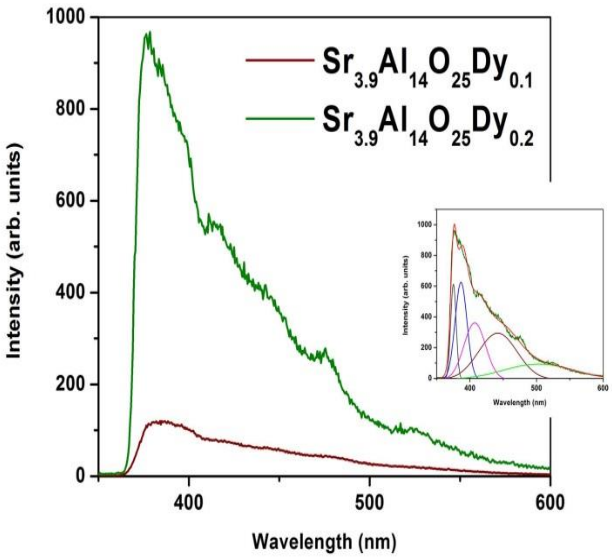

Figure 2 PL spectra of $Sr_4Al_{14}O_{25}$:Dy phosphor with doping concentration of 0.1 % (brown line) and 0.2 % (green) line. Insect Gauss fits at different position for 0.2 % concentration $Sr_4Al_{14}O_{25}$:Dy phosphor.

CONCLUSION

From the data analysis it is confirmed that $Sr_4Al_{14}O_{25}$:Dy phosphor is formed. The intensity of emission spectrum increases with increasing doping concentration which suggests that we have successfully added Dy3+ ion to the prepared $Sr_4Al_{14}O_{25}$ compound. More work is required to come up with specific result but this phosphor is definitely used in violet and green color region.

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

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