Effect of co-dopant concentration on photoluminescence properties of $Sr_2MgSi_2O_7$: Eu^{2+}, Dy^{3+} phosphor

Ravi Shrivastava, Jagjeet Kaur, Vikas Dubey

Govt. VYT PG Autonomous College, Durg, Chhattisgarh, India
Email: - ravishrivastava95@gmail.com

Abstract- Di-strontium magnesium silicate phosphor doped withdifferent concentrations of Dy^{3+} keeping constant concentration of Eu^{2+}were prepared using solid state reaction technique under a reducing atmosphere.Emission spectra of the said phosphors exhibited a broadbandbearing a peak at 480 nm which verifies the existence of single emission centre due to the transition of betweenany of the sublevels of $4f^6 5d^1$ configuration to $^8S_{7/2}$ level of the $4f^7$ configuration of Eu^{2+}.Emission intensity was optimum for a specific concentration of Dy^{3+}. This specific concentration avails the sufficient number of traps which recombines with the electrons results in emission of radiation in a particular colour.

I. INTRODUCTION

The best afterglow phosphor known till now is $SrAl_2O_4$: Eu^{2+}, Dy^{3+} which is a commercial phosphor and may have afterglow for more than 20 hours. Unfortunately, exposition to water may impair the luminescence properties of these materials which limits their use e.g. in the paints as a pigment. a new kind of long lasting phosphors, Eu^{2+}, Dy^{3+} co-doped silicates $M_2MgSi_2O_7$ (M= Ca, Sr) with afterglow time longer than 20 h has been developed that shown better afterglow in even liquids **[1]**. Eu^{2+} ion acts as the luminescent center, and it is known that some rare earth (R^{3+}) co-dopants enhance the persistent luminescence obtained with Eu^{2+} doping alone. The exact role of the co-dopants and that of other lattice defects is uncertain, but the R^{3+} ions have been suggested to trap holes or electrons or just to create/modify defects due to charge compensation **[2, 3]**. In this paper, $Sr_2MgSi_2O_7$: Eu^{2+}, Dy^{3+} phosphors with the different concentration ratio of dopant and co-dopant were prepared using high temperature the solid state reaction. The Photoluminescence (PL) studies were done to identify the phosphor with best PL intensity. The Thermoluminescence (TL) glow curves of the phosphor, whose PL results were found best, were measured with different decay time for 20 minute of UV exposure. TL glow curves of the same phosphor were measured after various delay times to estimate the persistency of the phosphor.

II. MATERIALS AND METHODS

The phosphor of $Sr_2MgSi_2O_7$:Eu^{2+}, Dy^{3+} powder with different concentration of Dysprosiumwere prepared by solid state reaction technique. The starting materials SiO_2, $SrCO_3$, MgO, Dy_2O_3 and Eu_2O_3 were thoroughly ground for approximately 1 h in a mortar, pre-sintered at 900 ^oC, then fired at 1300 ^oC for approximately 2 h in reducing atmosphere, with H_3BO_3 (1.6mol %) used as flux **[4-5]**. The Photoluminescence (PL) emission spectrumwas measured by a spectrofluorophotometer (SHIMADZU, RF-5301 PC) using the Xenon lamp as excitation source.

III. RESULTS AND DISCUSSION

3.1 XRD Analysis of the sample

For confirmation of prepared sample X-ray diffraction (XRD) characterization of the sample is done using Panalytical Xpert PRO MPD with copper k alpha anode of wavelength 1.5405 Angstrom. The pattern found is as follows:-

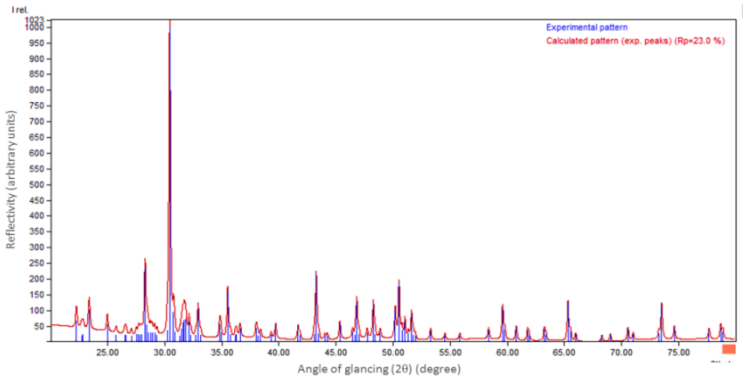

Figure 1 XRD pattern of $Sr_2MgSi_2O_7$ (Eu/Dy = 0.5/1.5)

Figure 1 gives the comparison between XRD pattern of $Sr_2MgSi_2O_7$ (Eu/Dy = 0.5/1.5) prepared and the Standard XRD pattern (COD card No. 96 – 431 – 7124) and Figure of merit while matching these was 0.9194 which illustrate that phase of prepared sample agrees with the standard pattern COD card No. 96 – 431 – 7124. The pattern is characterized by few prominent peaks found at different glancing angles.

The indexing and refinement of lattice parameters are calculated using Celref V3. The refined values of trigonal strontium magnesium silicate were found as; a = 8.0009 A^o, b = 8.0009 A^o, c= 5.1579 A^o, $\alpha=90^o$, $\beta=90^o$ $\gamma = 90^o$ and cell volume = 330.2 $(A^o)^3$, which again signifies the proper preparation of the discussed sample and is shown in Table1.

Table 1 Indexing and lattice parameters of $Sr_2MgSi_2O_7$: Eu, Dy Standard Values

Zero	Lambda	a	b	c	alpha	beta	gamma	Vol.
0	1.5418	8.0107	8.0107	5.1636	90	90	90	331.4
0	0	1	0	1	0	0	0	
Final values	: (Standard errors on 2nd line)							
Zero	Lambda	a	b	c	alpha	beta	gamma	Vol.
0	1.5418	8.0009	8.0009	5.1579	90	90	90	330.2
0	0	0.0061	0	0.0008	0	0	0	

h	k	l	2θ (Obs)	2θ (Cal)	Dif
1	1	1	23.406	23.3375	0.0685
1	2	1	30.457	30.4032	0.0538
0	0	2	34.84	34.7859	0.0541
1	3	0	35.534	35.4793	0.0547
1	0	2	36.64	36.6091	0.0309
1	3	1	39.72	39.6777	0.0423
2	1	2	43.283	43.2432	0.0398
0	4	0	45.376	45.3382	0.0378
1	4	0	46.846	46.8153	0.0307
3	3	0	48.28	48.2574	0.0226
4	1	1	50.261	50.2324	0.0286
3	1	2	50.535	50.5344	0.0006
2	4	0	51.057	51.0494	0.0076
3	3	1	51.622	51.6029	0.0191
2	1	3	59.639	59.6643	-0.0253
2	5	1	65.321	65.3632	-0.0422
4	1	3	73.506	73.6051	-0.0991

There are few extra peaks in observed XRD pattern which could be due a great number of stacking faults induced by the presence of the doping ions and also due to secondary phases and impurities formed during the elaboration process**[6]**.

1.2 Photoluminescence Studies

The excitation and emission spectra of $Sr_2MgSi_2O_7$: Eu, Dy phosphors prepared were shown in **Figure 2**. The excitation spectrum was monitored at a wavelength of 490 nm which shows prominent peaks at 371, and 393 nm. The emission spectra are identical in shape and the

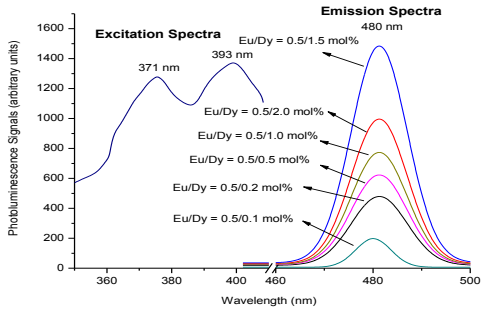

Figure 2 Photoluminescence studies of $Sr_2MgSi_2O_7$: Eu^{2+}, Dy^{3+}

In order to investigate the effect of co-doping ions on photoluminescence properties of the samples, we kept 0.5 mol% of Eu with different concentrations of Dy (0.1, 0.2, 0.5, 1.0, 1.5 & 2.0 mol%). Results given in **Figure 2** expressed that photoluminescence signals increases with increasing concentration of Dy until it reaches 1.5 mol% of Dy then it decreases suddenly. Co-dopant Dy^{3+} ion acts to introduce the trap levels which increases the decay time of the phosphor. It may be predicted that small amount of Dy is not sufficient to form enough trap defects in the $Sr_2MgSi_2O_7$ matrix to trap sufficient electrons. However, if the amount of doped Dy is greater than 1.5 mol %, it may cause the concentration quenching and reduce the emission intensity**[10]**.

IV. CONCLUSION

Photoluminescence curves of $Sr_2MgSi_2O_7$: Eu, Dy expressed broadband emission with optimum intensity in Blue colour region at 480 nm. This emission is assigned to an electronic transition of Eu^{2+} ions, between any of the sublevels of $4f^6\ 5d^1$configuration to $^8S_{7/2}$ level of the $4f^7$ configuration. Photoluminescence Signals of increases with increasing concentration of Dysprosium until it reaches a specific concentration (1.5 mol% in this case) then it decreases. It may be concluded that increasing concentration of Dy availes more numbers of traps. This increase in traps increases the possibilities of recombination, results in increasing PL signals.

bands differ only in intensities. The broadband emission spectra centered at 480 nm (Blue region) observed under the ultraviolet excitation of 365 nm correspond to the Eu^{2+} emission arising due to transitions from any of the sublevels of $4f^6\ 5d^1$ configuration to $^8S_{7/2}$ level of the $4f^7$ configuration but with Eu^{2+} occupying different lattice sites. Since the crystal field can greatly affect the $4f^65d^1$ electron states of Eu^{2+}, it suggests that the crystal field is not changed much with the compositional variation **[7-8]**. Eu^{2+} ion is expected to replace Sr^{2+} site in the tetragonal $Sr_2MgSi_2O_7$ structure since the ionic radii of the eight fold coordinated species are almost same, Sr^{2+} : 0.126 and Eu^{2+} : 0.125 nm **[9]**.

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