Synthesis and Luminescence Studies of Eu^{2+} doped $MgSiO_3$ Inorganic Phosphors for Energy Storage Phosphors

Amol Nande

Guru Nanak College of Science, Ballarpur

Abstract

The inorganic luminescence materials are widely studies for several applications including displays, light emitting didoes, energy storage etc. In this research work, the authors have synthesized $MgSiO_3:Eu^{2+}$ inorganic phosphor using modified solid state reaction method. The prepared samples were sent for photoluminescence to study emission and excitation properties. The emission and excitation properties show broad peak which are suitable for long lasting luminescence behaviour. Thus, this material can be a good candidate for energy or data storage material. Along with experimental measurements, the emission spectra can be stimulated suing theoretical model. The both emission spectra matched with each other.

Keywords: Luminescence, Eu^{2+}, EVI parameter, Silicates.
Received 02 February 2024; First Review 05 March 2024; Accepted 25 March 2024

*** Address of correspondence**
Dr. Amol Nande
Assistant Professor, Department of Physics
Guru Nanak College of Science, Ballarpur, India

Email: nande.av@gmail.com

How to cite this article
Amol Nande, Synthesis and Luminescence Studies of Eu2+ doped MgSiO3 Inorganic Phosphors for Energy Storage Phosphors, J. Cond. Matt. 2024; 02 (01):24-26

Available from:
https://doi.org/10.61343/jcm.v2i01.141

Introduction

Luminescent materials are the inorganic and organic materials which are the combination of host compound and dopant materials [1]. These materials produce light energy under the excitation of external source like light or electricity [1]. These materials are referred as phosphors. These materials are highly used in LEDs, lasers, displays, pharmaceuticals etc [2, 3]. The rare-earth materials like Ce^{3+} and Eu^{2+} are very sensitive to around crystal field environment and produce broad emission under the excitation of particular wavelength [4, 5]. The emission of Eu^{2+} doped inorganic phosphors is generally due to the parity allowed 4f-5d transitions. Also, persistent or broad emission inorganic phosphors always have strong quantum yield value and high storage capacity [6]. Thus, these materials show prominent applications in the field of energy storage.

Terraschke et al. [6] provide a detail review based on 321 research paper and suggest that Eu^{2+} ions have electron transition between $4f^6$ to $4f^7$ energy states which are strongly influenced by host lattice. Thus, Eu^{2+} based inorganic phosphors open for many applied applications. Wang et al. [7] studied $LaSrAl_2O_3:Eu^{2+}$ inorganic phosphors and suggests the phosphor can be a good material for optical storage device. Li et al. [8] synthesized $SrAl_2O_4:Eu^{2+}$, Dy^{3+} inorganic phosphors and study the effect of Pb^{2+} ions on them. The work suggests that the material can be a promising material for information storage applications.

In this work, we synthesized $MgSiO_3:Eu^{2+}$ compound using modified solid state reaction method. The excitation and emission spectra for the sample have been studied. Further, the theoretical emission spectra are stimulated using Electronic-Vibrational Interacting parameters.

Method and Synthesis

All starting reactants for the preparation of $MgSiO_3:Eu^{2+}$ inorganic phosphors were analytical reagent grade. The inorganic phosphor was prepared using modified solid-state reaction method. The phosphor was obtained using magnesium carbonate ($MgCO_3$), silicic acid ($SiO_2.9H_2O$) and Eu_2O_3 in HNO_3 as raw materials. All stoichiometrically weighed out materials were mixed together and crushed for an hour. The mixture later heated to 800 °C for 6 hours; after 6 hours the mixture cooled down and crushed for another one hour. Afterwards, the mixture gain heated for 900 °C for 12 hours. After 12 hours, the sample kept for cooling to reach to room temperature. Once sample reached to room temperature it crushed for another hours using mortar pastel and powder sent for characterizations.

Result and Discussion

The excitation spectrum for the phosphor is measured for

456 nm emission wavelength, as shown in Figure 1 (black lines). The observed broad excitation spectrum observed between 260 nm to 400 nm. The observed excitation peak was centered at 329 nm which corresponds to ($^8S_{7/2}$) $4f^7$ ground state → $4f^65d^1$ Excited state [9, 10]. The broad excited band suggests the phosphor can be excited using near-Ultra Violet wavelength. It further suggests that Eu^{2+} is the only luminescent center and occupied the same sites in the lattice producing symmetry excited peaks.

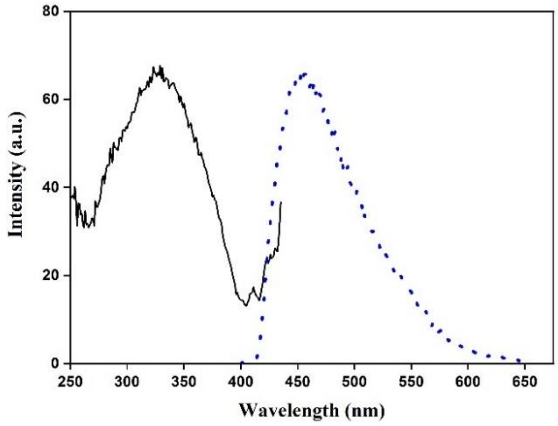

Figure 1: Excitation and emission spectra of $MgSiO_3:Eu^{2+}$ inorganic phosphor

The emission spectrum for the phosphor is measured for 329 nm excited wavelength, as shown Figure 2 (blue dotted line). The emission spectrum showed a broad peak between 410 nm to 650 nm and the peak centered at 456 nm. The emission observed in blue region corresponding to $4f^65d$ configuration to the $^8S_{7/2}$ level of the electronic configuration.

The experimental emission graph can be stimulated by calculating electron-vibrational interaction parameters such as stokes shift, Huang-Rhys factor, effective phonon energy and zero phono line position [11, 12]. The parameters ultimately used to stimulate emission parameter using following equation [13] –

$$I = \frac{e^{-S} S^m}{m!} \left(1 + S^2 \frac{e^{\frac{\hbar w}{kT}}}{m+1} \right)$$

$$m = \frac{\Delta E}{\hbar w}; \Delta E = E_0 - E$$

Here, m is the effective number of phonons occurred during emission transition. E_0 is the zero-phonon energy. S is Huang-Rhys coupling constant. $\hbar$, w, k, T, and E are Plank's constant, angular velocity, Boltzmann constant, temperature, and energy at a given wavelength respectively. The stimulated emission peak is shown in Figure 2.

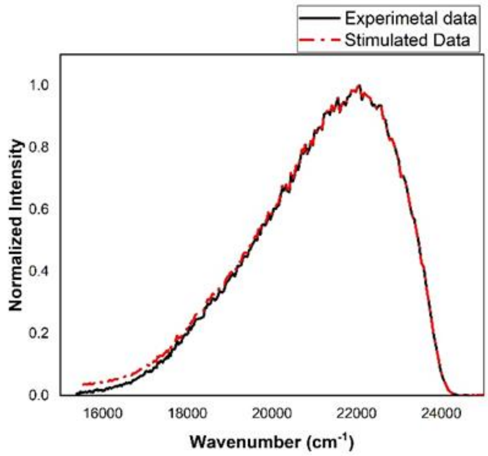

Figure 2: Experimental and stimulated emission spectra for $MgSiO_3:Eu^{2+}$ inorganic phosphor

The estimated value of S and $\hbar w$ are 2.71 and 758 cm^{-1}, respectively. From figure it is clear that there is a good matched with experimental and stimulated data.

Conclusion

The synthesized $MgSiSO_3:Eu^{2+}$ inorganic phosphors successfully made using modified solid state reaction method. The excitation and emission spectra confirmed the luminescence was due to Eu^{2+} rare-earth metal ions. The excitation spectrum was broad and was due to $^8S_{7/2}$ state → $4f^65d^1$ state and emission spectrum was also broad which was due to $4f^65d^1$ state → $^8S_{7/2}$ transition. This confirms the doping occurred in the phosphor successfully. Further, the electron-vibration interaction study showed that the experimental emission spectrum can be stimulated using theoretical model. This phosphor shows promising results and can be used for LEDs and storage devices.

Acknowledgement

The author like to thank Gondwana University, Gadchiroli for providing fund to carry out present research work under minor research scheme (reference letter No. /GUG/DIIL/612/2020).

References

1. G. Blasse, *"The physics of new luminescent materials"*, Materials chemistry and physics, vol. 16, pp. 201-236, 1987.
2. C. Ronda, *"Challenges in application of luminescent materials, a tutorial overview (invited review)"*, Progress In Electromagnetics Research, vol. 147, pp. 81-93, 2014.
3. C. Zhang and J. Lin, *"Defect-related luminescent materials: synthesis, emission properties and applications"*, Chemical Society Reviews, vol. 41, pp. 7938-7961, 2012.

4. S. Wang, Z. Song, Y. Kong, and Q. Liu, *"Relationship of Stokes shift with composition and structure in Ce^{3+}/Eu^{2+}-doped inorganic compounds"*, Journal of Luminescence, vol. 212, pp. 250-263, 2019.
5. D. Geng, M. Shang, Y. Zhang, H. Lian, and J. Lin, *"Color-tunable and white luminescence properties via energy transfer in single-phase $KNaCa_2$ (PO_4) 2: A (A= Ce^{3+}, Eu^{2+}, Tb^{3+}, Mn^{2+}, Sm^{3+}) phosphors"*, Inorganic chemistry, vol. 52, pp. 13708-13718, 2013.
6. H. Terraschke and C. Wickleder, *"UV, Blue, Green, Yellow, Red, and Small: Newest Developments on Eu^{2+}-Doped Nanophosphors"*, Chemical Reviews, vol. 115, pp. 11352-11378, 2015/10/28 2015.
7. B. Wang, H. Wang, J. Huang, J. Zhou, and P. Liu, *"Trap distribution and photo-stimulated luminescence in $LaSrAl_3O_7$:Eu^{2+} long-lasting phosphors for optical data storage,"* Journal of the American Ceramic Society, vol. 103, pp. 315-323, 2020.
8. P. Li, Y. Tian, F. Huang, L. Lei, M. Cai, S. Xu, et al., *"Highly efficient photo stimulated luminescence of Pb^{2+} doped $SrAl_2O_4$:Eu^{2+}, Dy^{3+} borate glass for long-term stable optical information storage"*, Journal of the European Ceramic Society, vol. 42, pp. 5065-5073, 2022/09/01/ 2022.
9. K. N. Shinde, *"Luminescence in Eu^{2+} and Ce^{3+} doped $SrCaP_2O_7$ phosphors"*, Results in Physics, vol. 7, pp. 178-182, 2017/01/01/ 2017.
10. H.-S. Roh, S. Hur, H. J. Song, I. J. Park, D. K. Yim, D.-W. Kim, et al., *"Luminescence properties of $Ca_5(PO_4)$.2SiO_4:Eu^{2+} green phosphor for near UV-based white LED"*, Materials Letters, vol. 70, pp. 37-39, 2012/03/01/ 2012.
11. S. A. Pardhi, G. B. Nair, R. Sharma, and S. Dhoble, *"Investigation of thermoluminescence and electron-vibrational interaction parameters in $SrAl_2O_4$: Eu^{2+}, Dy^{3+} phosphors"*, Journal of Luminescence, vol. 187, pp. 492-498, 2017.
12. P. D. Bhoyar and S. Dhoble, *"Study of electron vibrational interaction parameters in chlorophosphate activated with Eu^{2+} ion,"* Materials Chemistry and Physics, vol. 147, pp. 488-491, 2014.
13. A. R. Kadam, G. C. Mishra, M. Michalska-Domanska, and S. Dhoble, *"Theoretical analysis of electron vibrational interaction (EVI) parameters in 5d states of Eu^{2+} activated $BaSiF_6$ downconversion phosphor"*, Journal of Molecular Structure, vol. 1229, p. 129505, 2021.