International Journal of Scientific Research and Engineering Development-– Volume 7 Issue 3, May-June 2024
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Structural and Emission Characteristics of Sm^{3+}: $La_2(MoO_4)_3$ Phosphors

Ankoji Parvathala*, N. Suresh Kumar**
*(Department of Physics, JNTUA College of Engineering, Pulivendula, Andhra Pradesh, India
Email: ankphy1@gmail.com)
** (Department of Physics, JNTUA College of Engineering Anantapur, Andhra Pradesh, India
Email: sureshmsc6@gmail.com)

--************************----------------------------------

Abstract:

In present work, we have demonstrated the structural and luminescence properties of 5 mol% Sm^{3+} doped single phase monoclinic structured $La_2(MoO_4)_3$ phosphor samples which are synthesized via solid-stare reaction technique. The phase purity, crystal structure luminescence characteristics are analyzed. The 5 mol% Sm^{3+} active $La_2(MoO_4)_3$ phosphors exhibit a strong intense band centered at 403 nm owing to absorption by Sm^{3+} ions which is confirmed by photoluminescence excitation spectrum. Furthermore, the photoluminescence were monitored under excitation with 403 nm and the prominent emission bands noticed at 564 nm, 603 nm and 647 nm. Hence, all the outcomes suggest that Sm^{3+}: $La_2(MoO_4)_3$ single phased phosphor is well suitable for orange red emitting diodes.

Keywords — Solid-state method, Phosphors, Photoluminescence, Orange red.

--************************----------------------------------

I. INTRODUCTION

Researchers extensively investigating on the present and future generations of white light emission diodes (W-LEDs), field emission displays (FEDs) and plasma display panels (PDPs) that have been occupied by the inorganic phosphor materials which can have superior characteristics of high luminous efficiency, energy saving, chemical stability and eco-friendly [1]. W-LEDs based on phosphor materials and have attractive features as solid-state lighting sources since they can have several advantages over fluorescent and incandescent lamps including cheap cost, high efficiency, energy conservation, high compactness, high thermal stability, good reliability and longer operating life [2]. Currently WLEDs are manufactured by most common way to yellow phosphor (YAG:Ce^{3+}) coated on a InGaN blue emitted LED chip, which have some drawback of low color rendering index (CRI) due to lack of red light emitting ingredient. Hence, many research groups have been paid efforts to synthesize red emitting phosphor suitable for LEDs [3]. Among the rare earth elements, trivalent samarium ion (Sm3+) usually emits orange-red light when excited with blue and near ultraviolet and commonly has elevated emission intensity [4].

In this work, a sequence of Sm^{3+} ion doped $La_2(MoO_4)_3$ phosphor material have been synthesized by solid state method and a systematic investigation carried out through structural photoluminescence properties. The PL studies have been reported the prepared phosphor samples could give a sharp intensity orange-red emission were possible with the excitation of NUV wavelength. The prepared phosphor samples are might be best suitable for commercial orange-red color emitting material for their possible applications in energy and solid-state lighting applications.

II. SYNTHESIS OF PHOSPHORS

With the help of conventional solid-state reaction technique, a series of 5 mol% Sm^{3+} ion doped $La_2(MoO_4)_3$ phosphor was synthesized at elevated temperatures. The beginning materials contain lanthanum oxide (La_2O_3), ammonium molybdate ($(NH_4)_2MoO_4$) and dysprosium oxide (Sm_2O_3) of analytical grade chemicals with 99% purity. Initially, the starting materials were weighed according to stoichiometric equation. After, by using a pestle and mortar the weighed compositions were grinded thoroughly for 60 minutes. The well grinded powders were placed in a ceramic crucible and were annealed at 450 °C for 240 minutes in a furnace. The acquired powder was again grinded for 60 minutes by using pestle and mortar, followed by calcination at 900 °C for 12 h for well collaboration of all the elements by diffusion mechanism. After the heat treatment, all the samples were cooled naturally to room temperature and finally grounded for obtaining the samples in smooth powder form.

The phosphor crystal structure and phase purity were analysed by using PANalytical X'pert X-ray diffraction (XRD) instrument arranged with a PIXcel 1D detector (CuKα, λ=1.5406 Å). Further, the presence of metallic and vibrational bands in the prepared samples was identified by using Fourier transform infrared spectroscopy (FT-IR) (Thermo Nicolet: 6700). In addition, the emission, excitation and decay curves of the prepared Sm3+ ions doped La2(MoO4)3 phosphors were measured by utilizing the fluorescence spectrophotometer (model no. FLS920, Edinburgh Instrument Ltd, UK) arranged with Xenon (Xe) flash lamp (450 W) as light source and photomultiplier (Shimidazu R9287, Hamamatsu Photonics K.K., Hamamatsu, Japan) with range 200-900 nm as detector.

III. CRYSTAL STRUCTURE

Fig. 1 represents the XRD patterns of materials prepared with various concentrations of 5 mol% Sm^{3+} ion doped $La_2(MoO_4)_3$ phosphor. The collected XRD data for all the prepared samples were well matched with the ICSD Ref. code 98-2634, hence it is confirmed that the highly crystalline single phase nature of the sample with monoclinic structure [5]. All the peaks were indexed with their hkl values.

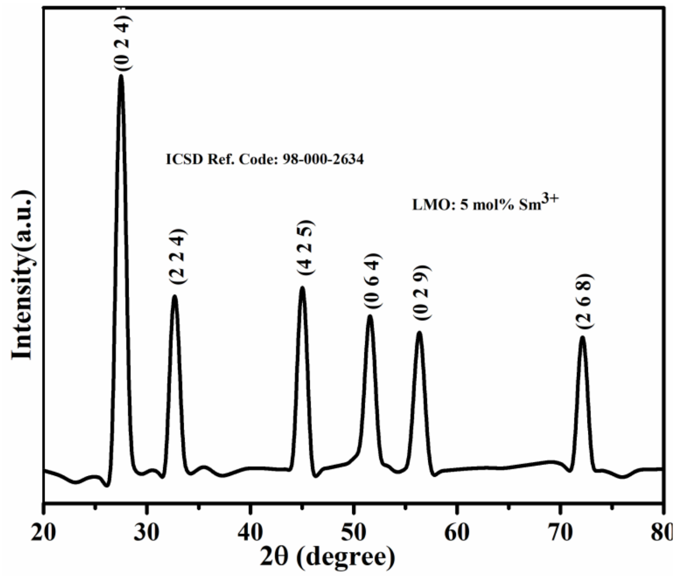

Fig. 1 XRD pattern 5 mol% Sm^{3+} ion doped $La_2(MoO_4)_3$ phosphor.

FTIR Analysis

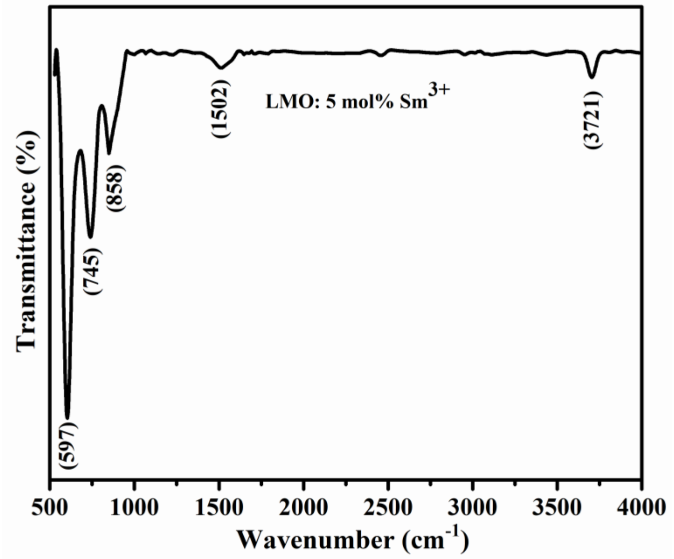

Fig. 2 FTIR spectrum of 5 mol% Sm^{3+} ion doped $La_2(MoO_4)_3$ phosphor.

Fig. 2 depicts the FTIR-spectra of prepared 5 mol% Sm^{3+} ion doped $La_2(MoO_4)_3$ phosphor studied in the region of 500–4000 cm^{-1}. The spectra possess four prominent absorption bands, a very tiny absorption band positioned at 3721 and 1502 cm^{-1} and it is assigned to –OH stretching vibration of the samples. It indicates that -OH content in the samples were very low and this samples are best suitable for enhancing the luminescence properties. Due to Mo-O phonon energy of the host material, a strong absorption band is perceived at 858 cm^{-1} which is attributed owing to asymmetric stretching [6]. Further, due to vibrational mode of Mo-O-Mo bonds the absorption band is perceived at 745 cm^{-1} in lower energy region. Further, absorption band observed at 597 cm^{-1} is assigned to La-O-Mo vibration bands [7]. From this study, it is confirmed that all the prepared samples possessing the metallic bonds and monoclinic structure.

Photoluminescence Analysis

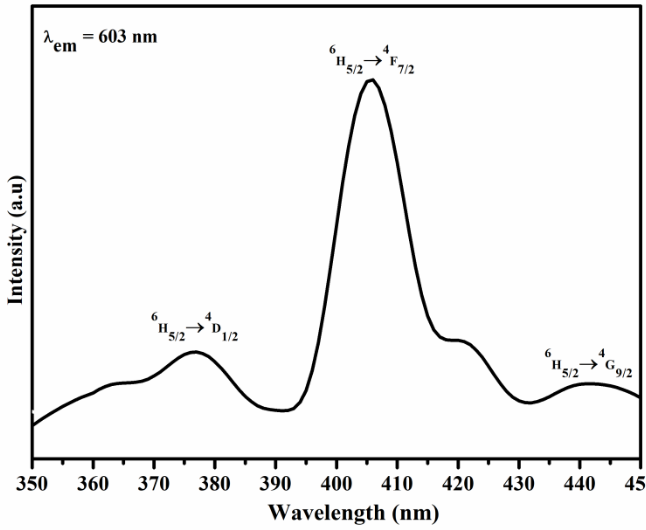

Fig. 3 Excitation spectrum of 5 mol% Sm^{3+} ion doped La$_2$(MoO$_4$)$_3$ phosphor.

The emission and excitation of 5 mol% Sm^{3+} ion doped La$_2$(MoO$_4$)$_3$ phosphor was investigated by using spectrofluorimeter. As shown in the Fig. 3, the excitation spectrum of 5 mol% Sm^{3+} ion doped La$_2$(MoO$_4$)$_3$ phosphor was monitored at 603 nm and it consist of 3 excitation bands. The excitation bands were identified and assigned to respective transitions of Sm^{3+} ion, such as $^6H_{5/2} \rightarrow {}^4D_{1/2}$ at 375 nm, $^6H_{5/2} \rightarrow {}^4F_{7/2}$ at 403 nm, and $^6H_{5/2} \rightarrow {}^4G_{9/2}$ at 445 nm [7, 8]. All these bands were excitation transitions from ground state to higher energy states of Sm^{3+} ion. Among all these transitions, the band at $^6H_{5/2} \rightarrow {}^4F_{7/2}$ at 403 nm has the highest intensity and hence the emission spectra of phosphor samples were monitored under excitation with 403 nm wavelength.

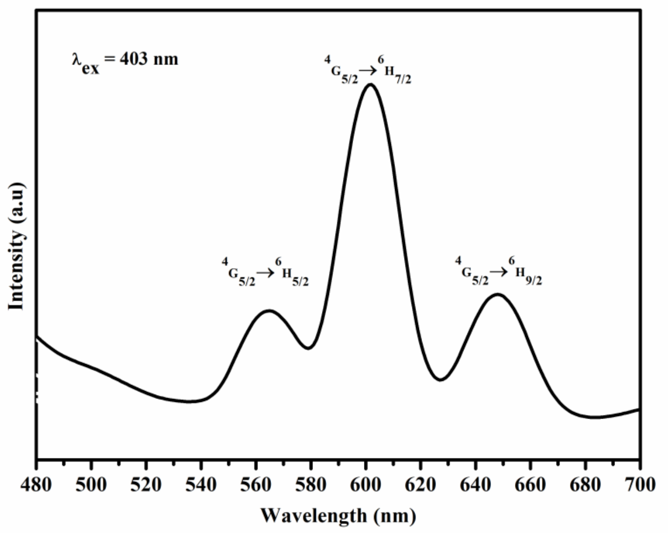

Fig. 4 Emission spectrum of 5 mol% Sm^{3+} ion doped La$_2$(MoO$_4$)$_3$ phosphor.

The photoluminescence emission spectra of 5 mol% Sm^{3+} ion doped La$_2$(MoO$_4$)$_3$ phosphor recorded in the range of 480-700 nm. Fig. 4 shows the emission spectra of 5 mol% Sm^{3+} ion doped La$_2$(MoO$_4$)$_3$ phosphor sample monitored at an excitation wavelength 403 nm. The identified emission bands were raised due to the intra 4f transitions of Sm^{3+} ion, which were ascribed to $^4G_{5/2} \rightarrow {}^6H_{5/2}$ at 565 nm, $^4G_{5/2} \rightarrow {}^6H_{7/2}$ at 603 nm and $^4G_{5/2} \rightarrow {}^6H_{9/2}$ at 647 nm [9, 10]. Among these emissions, the transition corresponding to $^4G_{5/2} \rightarrow {}^6H_{7/2}$ has the strongest emission intensity at 601 nm.

IV. CONCLUSION

The solid-state reaction technique was used to synthesize the Sm^{3+} activated La$_2$(MoO$_4$)$_3$ phosphor materials. The structural and photoluminescence characteristics of the prepared phosphors were reported in detail. All the prepared samples are crystalline in monoclinic structure and well matched with the ICSD Ref. code 98-2634. FTIR-spectra depict the existence of Mo-O-Mo and La-O-Mo bonds in the host material and Sm^{3+} doped samples. The identified emission bands were raised due to the intra 4f transitions of Sm^{3+} ion, which were ascribed to $^4G_{5/2} \rightarrow {}^6H_{5/2}$ at 565 nm, $^4G_{5/2} \rightarrow {}^6H_{7/2}$ at 603 nm and $^4G_{5/2} \rightarrow {}^6H_{9/2}$ at 647 nm [11]. Among these emissions, the transition corresponding to $^4G_{5/2} \rightarrow {}^6H_{7/2}$ has the strongest emission intensity at 601 nm. All these results strongly recommend that the prepared phosphors are the prominent candidates for the applications in W-LED and optoelectronic devices.

REFERENCES

[1] A. Balakrishna, O. M. Ntwaeaborwa, *Sens. Actuators*, B. 2017, vol. 242.
[2] I. P. Sahu, D.P. Bisen, N. Brahme, *Displays*, 2015, vol. 38.
[3] Z. Ci, Q. Sun, S Qin, M. Sun, *Phys. Chem. Chem. Phys.*, 2014, vol. 16.
[4] H. Wu, Zhenyu Sun, Shucai Gan, Linlin, Solid State Sci., 2018, vol. 85.
[5] L. Zhao, Y. Shang, Y. Li, L. Huang, Ruijin Yu, *J. of Lumin*., 2019, vol. 207.
[6] P. Kaur, S. Kaur, G. Pal Singh, D. P. Singh, *Solid State Communications*, 2013, vol. 171.
[7] J. T. Ingle, A. B. Gawande, R. P. Sonekar, S. K. Omanwar, Yuhua wang, Lei zhao, *J. Alloys Compd*., 2014, vol. 585.
[8] P. Gupta, A. K. Bedyal, V. Kumar, Y. Khajuria, E. Coetsee-Hugo, O. M. Ntwaeaborwa, H. C. Swart, *Opt. Mater.* 2014, vol. 36.
[9] J. Tauc, A. Menth, *J. Non-Cryst. Solids,* 1972, Vol. 8.
[10] Z. Cui, R. Ye, D. Deng, *J. Alloys Compd,* 2011. Vol. 509.
[11] C. Wang, Jing Jiang, Ge Zhu, Shuangyu Xin, *Optical Mater.,* 2018, vol. 86.