
Scientific Dimensions of Indian Knowledge System: Materials Science Perspectives through the Synthesis and Characterization of Rare-Earth Doped Phosphors

U.V.B.B.Krishna Prasad^{1,2}, K.Jyothi³ and KVR Murthy⁴

1 Department of Physics, Adikavi Nannaya University, Rajamahendravaram-533296, A.P, India

2 Department of Physics, Government Degree College, Pithapuram-533450, A.P, India

3 Department of Physics, SVRK Government Degree College for Men, Nidadavole-534301, A.P, India

4 Luminescent Materials Laboratory, Physics Department, Faculty of Science, The M. S. University of Baroda, Vadodara-390002, India

Abstract:

The Indian Knowledge System (IKS) embodies a rich scientific tradition encompassing metallurgy, optics, mineral science, and material processing techniques documented in classical texts such as the Rasaratna Samuccaya and Arthashastra. Ancient Indian scholars demonstrated advanced understanding of material properties, luminescence phenomena, and high-temperature processing, as evidenced in traditional metallurgical practices and mineral-based technologies.

In this context, the present study explores the scientific dimension of IKS through the modern synthesis and characterization of rare-earth doped phosphors. By situating advanced luminescent material research within the broader epistemological and technological framework of IKS, this work highlights the continuity between traditional Indian material sciences and modern solid-state physics. The study emphasizes the relevance of indigenous scientific wisdom in fostering sustainable innovation, interdisciplinary research, and value-based scientific advancement in the 21st century.

The development of high-efficiency luminescent materials is crucial for next-generation solid-state lighting and display technologies. In this study, we investigate the luminescent properties of Ho³⁺-doped Sr₃WO₆, a double perovskite phosphor, synthesized via the solid-state reaction method. X-ray diffraction (XRD) confirms the phase purity and structural integrity of the Sr₃WO₆ host lattice, while scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) provide insight into morphology and elemental composition. The photoluminescence (PL) spectra exhibit strong emissions in the visible region upon ultraviolet (UV) excitation, attributed to intra-4f electronic transitions of Ho³⁺ ions. International Commission on Illumination (CIE) chromaticity coordinates suggest potential applications in white light-emitting diodes (WLEDs). Thermal stability studies reveal that the phosphor maintains high emission intensity at elevated temperatures, making it suitable for practical lighting applications.

Keywords

Holmium-doped Sr_3WO_6 , luminescence, phosphor, solid-state lighting, perovskite, photoluminescence

Introduction

Phosphor materials play a significant role in modern lighting applications, particularly in light-emitting diodes (LEDs) and display technologies. Perovskite-based phosphors have gained attention due to their excellent thermal stability, high quantum efficiency, and tunable luminescent properties. The double perovskite Sr_3WO_6 is an attractive host material due to its wide band gap and structural stability making it suitable for rare-earth (RE) ion doping.

Holmium (Ho^{3+}) is a promising dopant due to its characteristic green and red emissions arising from $^5\text{F}_4 \rightarrow ^5\text{I}_8$ and $^5\text{S}_2 \rightarrow ^5\text{I}_8$ transitions, respectively. These emissions are crucial for achieving high-quality white light when combined with other activators. In this study, we explore the synthesis, structural characterization, and luminescence properties of Ho^{3+} -doped Sr_3WO_6 for illumination applications.

2. Experimental Methodology

2.1 Synthesis of Ho^{3+} -Doped Sr_3WO_6

The $\text{Sr}_3\text{WO}_6:\text{Ho}^{3+}$ phosphor was synthesized using the conventional solid-state reaction method. The starting materials, SrCO_3 , WO_3 and Ho_2O_3 (all of high purity of 99.9%), were weighed according to the stoichiometric ratio and thoroughly mixed in an agate mortar for 3 hours. The mixed powder was then calcined at 1100°C for 6 hours in an alumina crucible to facilitate phase formation. The final product was ground into a fine powder for further characterization.

2.2 Structural and Morphological Characterization

X-ray Diffraction (XRD): The crystallographic structure and phase purity of the synthesized samples were analyzed using XRD with $\text{Cu-K}\alpha$ radiation. The obtained patterns were compared with standard JCPDS data for Sr_3WO_6 to confirm phase formation.

Scanning Electron Microscopy (SEM) & Energy-Dispersive X-ray Spectroscopy (EDS): SEM was used to study the morphology, while EDS confirmed the elemental composition and uniformity.

2.3 Optical Characterization

Photoluminescence (PL) Spectroscopy: The PL excitation and emission spectra were recorded using a spectrofluorometer equipped with a xenon lamp as the excitation source. CIE Chromaticity Analysis: The emission colour was analysed using CIE coordinates to evaluate its suitability for WLED applications.

Thermal Stability: The thermal quenching behaviour was studied by measuring the luminescence intensity at different temperatures.

3. Results and Discussion

3.1 Structural Analysis

The XRD patterns of $\text{Sr}_3\text{WO}_6:\text{Ho}^{3+}$ phosphors matched well with the standard Sr_3WO_6 perovskite phase (JCPDS #26-1136), confirming the successful formation of a single-phase structure. No secondary phases were detected, indicating effective incorporation of Ho^{3+} ions into the lattice. The slight peak shifts observed with increasing Ho^{3+} concentration suggest lattice distortion due to the ionic radius difference between Sr^{2+} (1.18 Å) and Ho^{3+} (1.02 Å).

3.2 Morphology and Elemental Composition

SEM images revealed a well-defined crystalline morphology with particle sizes ranging from 2 to 5 μm . EDS analysis confirmed the presence of Sr, W, O, and Ho elements in the expected stoichiometric ratios, indicating successful doping without significant impurity formation.

3.3 Photoluminescence Properties

The excitation spectrum of $\text{Sr}_3\text{WO}_6:\text{Ho}^{3+}$ exhibited strong absorption in the near-UV region (~350 nm), making it compatible with commercial UV LED chips. The emission spectrum under 350 nm excitation displayed characteristic green (~545 nm) and red (~660 nm) emissions corresponding to the $^5\text{S}_2 \rightarrow ^5\text{I}_8$ and $^5\text{F}_4 \rightarrow ^5\text{I}_8$ transitions of Ho^{3+} , respectively. The optimal Ho^{3+} doping concentration was determined to be 2 mol%, beyond which concentration quenching effects were observed.

3.4 CIE Chromaticity and Colour Purity

The calculated CIE coordinates (x, y) for the $\text{Sr}_3\text{WO}_6:\text{Ho}^{3+}$ phosphor were found to be (0.32, 0.55), placing it in the green-yellow region of the chromaticity diagram. The emission colour could be fine-tuned by co-doping with other rare-earth ions (e.g., Eu^{3+} or Dy^{3+}) for achieving warm white light.

3.5 Thermal Stability

The thermal quenching behaviour showed that the luminescence intensity remained above 80% of its initial value at 150°C, indicating excellent thermal stability suitable for high-power LED applications. The activation energy (ΔE) for thermal quenching was estimated to be ~0.36 eV, confirming minimal non-radiative losses at elevated temperatures.

Conclusion

In this study, we successfully synthesized and characterized Ho^{3+} -doped Sr_3WO_6 double perovskite phosphors. The structural analysis confirmed the formation of a pure perovskite phase, while luminescence studies revealed strong green and red emissions under UV excitation. The phosphor exhibited high thermal stability and favourable CIE coordinates for illumination applications. These results suggest that $\text{Sr}_3\text{WO}_6:\text{Ho}^{3+}$ is a promising candidate for next-generation solid-state lighting and display technologies. Future studies may explore co-doping strategies to achieve full-spectrum white light emission.

United International Journal of Multidisciplinary Research

ISSN: 3048-6726 (UIJMR) Impact Factor: 6.934 (SJIF)

An International Peer-Reviewed and Refereed Multidisciplinary Journal

www.ujmr.in Vol-3, Special Issue-II,2026

5. References:

- J.Kurian, J.Koshy, P.R.S.Wariar, Y.P.Yadava, and A.D.Damodaran, "Synthesis and Characterization of Rare-Earth Barium Antimonates, a New Group of Complex Perovskites Suitable as Substrates for $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ Films," *J.Solid State Chem.*, vol 116.no.1.pp.193-198, Apr.1995.
- C. C. Yu et al., "Enhanced photo luminescence of $\text{Ba}_2\text{GdNbO}_6:\text{Eu}^{3+}/\text{Dy}^{3+}$ phosphors by Li^+ doping," *J. Solid State Chem.*, vol.180.no.11.pp.3058-3065, Nov.2007.
- M.Srinivas, V.Verma. N.Patel, D.Modi, , D.Tawde, and K.V.R.Murthy, "Characterization of newly synthesized Strontium Cerium Niobate nanophosphor," *J.Lumn.*, vol.147, pp.324-327, Mar.2014.
- Singh, R., et al. (2023). "Photoluminescence and Thermoluminescence Studies of Er^{3+} -Doped Sr_3WO_6 Double Perovskite Phosphor for Optical Thermometry and Solid-State Lighting." *Journal of Luminescence*, 255, 119567.
- Xie, Y., et al. (2022). "Luminescence Properties of Sm^{3+} , Na^+ Co-doped Sr_3WO_6 Double Perovskite Phosphor for Near-UV Excited WLEDs." *Materials Research Bulletin*, 150, 111789.