
PREFACE

Luminescent materials, commonly referred to as phosphors, have garnered significant attention in scientific research due to their extensive applicability in diverse fields such as lighting, sensors, solar cells, and biomedical imaging. Phosphors are typically composed of a crystalline or amorphous host lattice embedded with specific dopants. These dopants introduce additional energy levels into the host lattice, enabling tailored emission properties for targeted applications. Among various dopants, lanthanide (Ln^{3+}) ions stand out for their unique optical properties, including upconversion and downconversion luminescence. Their well-shielded 4f transitions, combined with long luminescence lifetimes, high photostability, and sensitivity to environmental factors, make lanthanides invaluable in advanced optical materials.

Phosphors have been developed using various host lattices, such as phosphates, borates, vanadates, tungstates, molybdates, and garnets. Each host exhibits distinct structural, thermal, and chemical properties that influence luminescence performance. Among these, molybdate-based hosts like CaMoO_4 (calcium molybdate) have emerged as exceptional candidates, particularly for optical temperature sensing and latent fingerprint detection. The tetragonal scheelite structure of CaMoO_4 , with its low phonon energy and broad energy bandgap, offers high thermal and chemical stability, making it suitable for lanthanide doping.

The present thesis focuses on exploring lanthanide-doped CaMoO_4 optical materials for dual applications: contactless temperature sensing and latent fingerprint detection. Optical temperature sensing utilizing thermally coupled and non-thermally coupled levels in lanthanide-doped phosphors is a promising alternative to traditional methods, offering

advantages such as non-invasive measurement, high sensitivity, and operation over a broad temperature range. Lanthanide ions, such as Er^{3+} , Ho^{3+} , Tm^{3+} , and Yb^{3+} , embedded in the CaMoO_4 host, enable precise temperature sensing through their unique luminescent responses to temperature variations. Additionally, this thesis explores the use of upconversion luminescence properties of lanthanide-doped CaMoO_4 for latent fingerprint detection, a critical aspect of forensic science. These materials convert near-infrared excitation into visible light, producing vibrant, high-contrast images of latent fingerprints on various substrates. This technique addresses challenges associated with traditional fingerprint detection methods, such as low visibility and poor contrast on complex backgrounds, by leveraging the color-tunable and dual-mode emission properties of the doped CaMoO_4 phosphors.

The findings of this thesis contribute to the broader understanding of CaMoO_4 as a versatile optical material, advancing its potential for practical applications in both temperature sensing and forensic imaging. Through a combination of material synthesis, advanced characterization techniques, and application-specific investigations, this work lays the groundwork for the development of next-generation luminescent materials. Detailed synthesis procedures and characterization techniques are discussed in Chapter 2. The thesis is divided into six Chapters. The brief explanation of each Chapter is given below:

Chapter 1 introduces the foundational concepts, providing a historical overview of luminescent materials and the evolution of phosphors. The role of lanthanides in optical applications is discussed, with a focus on their unique spectroscopic properties and emission mechanisms. The chapter also examines the structural and optical characteristics of the CaMoO_4 host, highlighting its suitability for lanthanide doping. Applications in optical

thermometry and latent fingerprint detection are introduced, establishing the motivation and scope of the research.

Chapter 2 details the synthesis and characterization techniques used in this thesis. A comprehensive description of the hydrothermal, solid-state, and sol-gel combustion methods employed to prepare lanthanide-doped CaMoO_4 phosphors is provided. Characterization techniques of phosphor materials such as X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Raman spectroscopy, and photoluminescence analysis are discussed in detail by including their working phenomenon. Additionally, the software used for the data analysis named FullProf, ImageJ, color calculator CIE 1931, and OriginPro 9.0, etc., are briefed.

Chapter 3 investigates and compare the temperature sensing capabilities of $\text{Er}^{3+}/\text{Yb}^{3+}$ doped CaMoO_4 phosphors in both bulk and nanoparticle forms. This chapter also discussed the detailed structural and optical characterization of pristine CaMoO_4 and $\text{Er}^{3+}/\text{Yb}^{3+}$ doped CaMoO_4 phosphors. The results reveal enhanced temperature sensitivity in the nanoparticle-based samples, attributed to their reduced particle size and improved energy transfer efficiency. The chapter demonstrates the potential of nanoscale CaMoO_4 materials in developing high-sensitivity optical thermometers.

Chapter 4 explores the impact of Bi^{3+} co-doping on the temperature sensing performance of $\text{Er}^{3+}/\text{Yb}^{3+}$ doped CaMoO_4 phosphors. The reitveld refinement of optimised $\text{Er}^{3+}/\text{Yb}^{3+}$ doped CaMoO_4 and $\text{Bi}^{3+}/\text{Er}^{3+}/\text{Yb}^{3+}$ doped CaMoO_4 has been done for the detailed structural analysis. The addition of Bi^{3+} ions introduces structural asymmetry, enhancing upconversion emission and temperature sensitivity. The findings highlight the role of co-

doping in optimizing the luminescent properties of CaMoO₄ phosphors for advanced sensing applications.

Chapter 5 focuses on the multifunctionality of CaMoO₄: Ho³⁺/Tm³⁺/Yb³⁺ phosphors, demonstrating their applicability in non-thermally coupled level (NTCL)-based temperature sensing and latent fingerprint visualization. The chapter highlights the high sensitivity and color-tunable emissions of these materials, which enable precise temperature sensing and high-contrast fingerprint imaging under near-infrared excitation.

Chapter 6 consolidates the findings of the thesis, emphasizing the adaptability of CaMoO₄ as a robust host matrix for functional lanthanide doping. The chapter discusses the broader implications of the research and proposes future directions, including the optimization of material properties and exploration of additional applications in emerging optical technologies.

This thesis advances the understanding of lanthanide-doped CaMoO₄ materials and underscores their potential in addressing challenges in temperature sensing and forensic science. I hope this thesis inspires further research in the field of optical materials and their interdisciplinary applications.