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Synthesis, structural characterization and photoluminescence of Sm^{3+}-Activated $LiSrPO_4$ phosphors for lighting applications

Younis Hameed, Mir Hashim Rasool *, Mudasir Farooq, Haqnawaz Rafiq, Aadil Bashir

Department of Physics, Islamic University of Science and Technology, Kashmir, 192122, India

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ABSTRACT

$LiSrPO_4$: Sm^{3+} red-emitting phosphors were synthesized by a typical solid-state process using highly pure phosphors to ensure phase purity and uniform dopant distributions. X-ray diffraction (XRD) analysis revealed a well-crystallized monoclinic phase. Photoluminescence (PL) spectra under near-UV stimulation revealed intense red emission from the $^4G_{5/2} \rightarrow {}^6H_j$ (J = 5/2, 7/2, 9/2) transitions of Sm^{3+} ions, with a maximum peak around 600 nm. The CIE chromaticity coordinates revealed a red emission with a maximum color purity of 89.59 % at the optimal dopant level. The color temperature of CCT (approximately 1800 K) indicates the feasibility of warm-lighting applications. These trivalent Sm^{3+}-doped phosphors showed increased emission intensity, indicating their potential as high-efficiency red components for white LEDs.

1. Introduction

White light-emitting diodes (WLEDs), known for their high energy efficiency, long operational lifetime, and compact design, have transformed modern lighting technology to replace incandescent and fluorescent lamps in a wide range of applications [1]. However, many commercial WLEDs exhibit a low color rendering index owing to their weak red emission, making the development of efficient red phosphors essential for improving color quality and warmth [2]. Samarium (Sm^{3+}) is a well-recognized activator for orange–red emission, producing sharp $^4G_{5/2} \rightarrow {}^6H_j$ transitions near 600 nm [3,4]. Unlike transition metal ions, Sm^{3+} features shielded 4f–4f transitions that are relatively insensitive to the host lattice, whereas the emission intensity and efficiency still depend strongly on the crystal field and energy transfer dynamics within the host [5]. Because of these characteristics, Sm^{3+}-doped phosphors have found applications in solid-state lighting, optical displays, and bioimaging [6].

Various host lattices have been explored for Sm^{3+} activation, including aluminates, borates, silicates, and orthophosphates, each demonstrating efficient orange–red luminescence [7–10]. Examples such as Sm^{3+}-activated $YCa_4O(BO_3)_3$ [11], $GdAl_3(BO_3)_4$ [12], and $La_2CaB_{10}O_{19}$ [13] illustrate the importance of selecting structurally stable hosts with suitable coordination environments to optimize emission efficiency. Among phosphate hosts, $LiSrPO_4$ is particularly attractive because of its high chemical stability, moderate synthesis temperature, and three-dimensional network of $[PO_4]^{3-}$ tetrahedra linked through interstitial Li^+ and Sr^{2+} sites, which can accommodate rare-earth substitution [14–17]. Despite these advantages, $LiSrPO_4$ has been scarcely studied as a Sm^{3+} host, providing a strong motivation for the present investigation [18,19].

An additional consideration in activator-doped phosphors is concentration quenching beyond a certain dopant level; the luminescence intensity decreases due to nonradiative energy transfer among neighboring ions. In Sm^{3+} systems, this behavior is often governed by cross-relaxation or multipolar interactions such as dipole–dipole coupling [20–22]. Determining the optimal Sm^{3+} concentration in $LiSrPO_4$ is therefore crucial for achieving maximum emission efficiency while minimizing quenching losses.

In this study, Sm^{3+}-doped LiSrPO phosphors were synthesized via a solid-state reaction route and systematically characterized. Structural phase formation and dopant incorporation were confirmed through XRD and Rietveld refinement and the optical behavior was analyzed using photoluminescence spectroscopy. By examining the dependence of emission properties on Sm^{3+} concentration, this study establishes the relationship between dopant level, emission efficiency, and concentration quenching, demonstrating that $LiSrPO_4$:Sm^{3+} is a promising orange–red phosphor for warm-white LED applications.

* Corresponding author.
E-mail address: hrasool23@gmail.com (M.H. Rasool).

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