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Research Article

Structural, spectroscopic, photoluminescence quenching, and thermal stability analysis of trivalent dysprosium activated $LiZnPO_4$ for solid-state lighting applications

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ABSTRACT

This study used a solid-state reaction method to produce Dy^{3+}-doped $LiZnPO_4$ (LZP: xDy^{3+}) white emitting phosphor material. This work offers a thorough examination of the thermal stability, luminescence characteristics, structural-spectroscopic characterization, and synthesis of LZP: xDy^{3+} (x = 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, and 0.07) phosphors in an endeavor to develop phosphor materials for use in white-light-emitting diode (WLED) technology. The prepared phosphor material has been investigated through powder X-ray diffraction (XRD), Diffuse Reflectance (DR) spectra, Fourier Transform Infrared Spectroscopy (FTIR), Field Emission Scanning Microscopy (FE-SEM), Photoluminescence emission (PL), and photoluminescence excitation (PLE) analysis. The findings of Rietveld Refinement (RR) analysis and powder XRD verify the phase purity and monoclinic structure of the generated phosphor. The energy band gap values are examined using DR spectra plots, and it is found that the observed values range from 3.1 to 3.2 eV. Using an excitation wavelength of 351 nm, photoluminescence emission spectra are recorded between 450 and 700 nm to investigate the emission properties of the resulting powders. Three distinctive peaks can be identified at 480 nm (blue band), 573 nm (yellow band), and a very less intense 667 nm (Red band), which correspond to $^4F_{9/2} \rightarrow {}^6H_{15/2}$, $^6H_{13/2}$, and $^6H_{11/2}$, respectively. The three emission bands fuse to produce a white light. The concentration quenching mechanism for LZP: xDy^{3+} was explored, and the dependency of luminescence intensity on Dy^{3+} concentration was examined. The color graphs of CIE show that the emission color is located in the white zone (0.3, 0.4), demonstrating the unique emission of the Dy^{3+}-doped powders. It has been found that the CCT values obtained are approximately 5000 K, and the usual values for color purity are 90 %. The aforementioned results show that the materials prepared could be efficiently used for interior solid-state lighting applications.

1. Introduction

Modern solid-state lighting (SSL) and photovoltaic technology have advanced to the point that it is now feasible to address the modern era's constantly growing energy scarcity. This problem could be related to the inefficient operation of gadgets that use a lot of energy but generate little output [1]. These days, WLEDs are taking the place of conventional bright and luminous lamps because of their superior uses, which include energy harvesting, long lifespan, eco-friendliness, and portability [2]. Phosphors, or luminescent materials, are the type of materials that give off light radiation and are composed of a dopant (an activator) and a host material (a host matrix). [3]. Trivalent rare earth (RE)-doped phosphor powders are used in current solid-state lighting fixtures since they are essential for the creation of light-emitting diode (LED) components [4]. RE have unique electronic arrangements with a partially filled 4f subshell covered by $5s^2$ and $5p^6$ electrons, they are particularly effective at boosting the productivity of phosphor materials [5,6]. Such phosphor materials can shift the frequency of light from one higher to one lower using different electronic transitions [7].

The white light generation has been studied in phosphates, silicates [8], Borates [9], Halides, Double sulphides, and other host matrix types. Materials containing phosphate and having the generic formula $A^IB^{II}PO_4$ ($A^I = Li^+$, Na^+, K^+, and $B^{II} = Mg^{2+}$, Ca^{2+}, Sr^{2+}, Ba^{2+}, Zn^{2+}) doped with RE ions have garnered a lot of consideration due to their remarkable luminescence characteristics [10]. Researchers believe that the reason for phosphate's superior thermal and hydrolytic durability is

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