Dalton
Transactions

PAPER

View Article Online
View Journal

Check for updates

Cite this: DOI: 10.1039/d4dt01020e

Structural, photoluminescence and energy transfer investigations of novel $Dy^{3+} \rightarrow Sm^{3+}$ co-doped $NaCaPO_4$ phosphors for white-light-emitting diode applications†

Mudasir Farooq,[a] Haqnawaz Rafiq,[a] Irfan Nazir,[b] Seemin Rubab[c] and Mir Hashim Rasool *[a]

Received 8th April 2024,
Accepted 3rd July 2024

DOI: 10.1039/d4dt01020e

rsc.li/dalton

In this study, Dy^{3+}-doped and Dy^{3+}/Sm^{3+} co-doped $NaCaPO_4$ white-emitting polycrystalline phosphor samples were synthesized using a solid-state reaction method. The samples were characterized by powder X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), Field-emission scanning electron microscopy (FE-SEM), and Photoluminescence (PL) analysis. The phase purity characterization and crystal structural analysis were done using the Rietveld refinement-based FullProf Suite software. The Rietveld refinement result confirms single-phase formation for both Sm^{3+} and Dy^{3+}/Sm^{3+} co-doped $NaCaPO_4$ samples with an orthorhombic structure and with a monotonic change in lattice parameters with doping. The PL studies of the Dy^{3+}-doped samples revealed two emission bands. However, at 352 nm, the Dy^{3+}/Sm^{3+}-co-doped samples revealed distinctive emission bands for both ions. The emission peaks at 480 nm (blue) and 573 nm (yellow) are related to the $^4F_{9/2} \rightarrow {}^6H_{15/2}$ and $^4F_{9/2} \rightarrow {}^6H_{13/2}$ transitions of Dy^{3+} ions; however, the emission peaks at 600 nm and 647 nm are attributed to the $^4G_{5/2} \rightarrow {}^6H_{7/2}$ and $^4G_{5/2} \rightarrow {}^6H_{7/2}$ transitions of Sm^{3+} ions. The intensity of the Dy^{3+} emissions decreased as the Sm^{3+} levels increased but the emission intensity of the Sm^{3+} ions increased. The co-doping of Sm^{3+} ions in Dy^{3+}-doped phosphors results in unique characteristics due to the energy transfer (ET) from $Dy^{3+} \rightarrow Sm^{3+}$ ions. The effectiveness of this ET from $Dy^{3+} \rightarrow Sm^{3+}$ ions is positively correlated with the dopant amounts of the Sm^{3+} ions. The interaction mechanisms have been identified as dipole–dipole based on Dexter's energy transfer and Readfield's approaches. All decay curves can be adequately fitted *via* bi-exponential functions, suggesting the movement of energy between $Dy^{3+} \rightarrow Sm^{3+}$ ions. Temperature-dependent PL measurements and CIE color coordinate analysis reveal excellent luminescent properties, making these Dy^{3+}/Sm^{3+} co-doped phosphors advantageous for white light-emitting diode (WLED) technologies.

1. Introduction

Advancements in contemporary solid-state lighting (SSL) and photovoltaic technological devices have made it possible to address the gradually increasing scarcity of energy in the modern era. This issue may be attributed to the inefficient performance of devices that consume a significant amount of energy but generate minimal outputs.[1] White light-emitting diodes (WLEDs) are gaining popularity due to their portability, environmental friendliness, life expectancy, and exceptional luminescence effectiveness.[2,3] Research is underway to explore the use of WLEDs, which offer energy reduction and an extended lifespan as a potential replacement for traditional incandescent bulbs and cathode fluorescent lamps.[4] Rare-earth ions based on 4f–4f or 5d–4f transitions generate colors and luminescent materials (phosphors), the applications of which in modern civilization have been extensively studied. Rare-earth ions doped with inorganic phosphors are increasingly utilized as luminescent transporters in WLEDs because of their stability and crucial role in synthesizing sensitive thermoluminescence and photoluminescence phosphors.[5,6] Researchers are increasingly focusing on luminous materials containing rare-earth ions because of their interest in white-light and medical technology.[7,8]

The rigid tetrahedral three-dimensional structure of orthophosphates, with a general formula $A^IB^{II}PO_4$ ($A^I = Li^+, Na^+, K^+$;

---

[a] Department of Physics Islamic University of Science and Technology, Awantipora, Kashmir-192122, India. E-mail: hrasool23@gmail.com, mudasirphysics336@gmail.com
[b] Department of Chemistry, University of Kashmir, Srinagar – 190006, India
[c] Department of Physics, National Institute of Technology, Hazratbal, Srinagar, Jammu and Kashmir-190006, India

† Electronic supplementary information (ESI) available. See DOI: https://doi.org/10.1039/d4dt01020e