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Rietveld-refined structural and optical properties of Dy³⁺ doped Li₂NaPO₄ nanophosphors as an efficient photoluminescent material

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Rare-earth (RE) doped materials have emerged as promising candidates for photonic and optoelectronic applications due to their outstanding luminescent properties. Among these, lanthanide-activated phosphate-based phosphors stand out for their unique combination of mechanical, optical, electrical, magnetic and chemical characteristics, alongside their eco-friendliness, cost-effectiveness and chemical stability. In the present study, Dy³⁺ doped nalipoite –Li₂NaPO₄ nanophosphors were successfully synthesized using a low-cost combustion technique at 650 °C, with dopant concentrations ranging from 0 to 5 mol.%. X-ray diffraction (XRD) confirmed the formation of a pure orthorhombic phase with P m n b space group, and the crystallite size was estimated using the Debye Scherrer equation. Surface morphology and elemental composition were analyzed via scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDAX), while the oxidation states of the elements were investigated using X-ray photoelectron spectroscopy (XPS). The nanophosphors exhibited a wide band gap ranging from 3.64 to 3.84 eV, making them suitable for optoelectronic applications such as LEDs and laser diodes. Upon 390 nm excitation, Dy³⁺ ions exhibited characteristic emissions at 483 nm (blue), 574 nm (yellow), and 668 nm (red), with the most intense luminescence observed at 2 mol.% Dy³⁺ doping. A concentration quenching effect was noted at higher dopant levels, attributed to quadrupole-quadrupole interactions between Dy³⁺ ions. The chromaticity coordinates, derived from the CIE 1931 diagram, support the applicability of these phosphors in display technologies. Overall, the results highlight the potential of Dy³⁺ doped Li₂NaPO₄ nanophosphors for future advancements in solid-state lighting and display systems.

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