

Color-Tunable Luminescence of Dy-, Tb-, and Eu-Doped Borate Glasses for Phosphor Applications

M. Kushlyk¹, I. Medvid^{1,#}, B. Mahlovanyi², D. Slobodzyan¹, Ya. Shpotyuk^{1,2}, A. Luchechko¹

¹Ivan Franko National University of Lviv, 1 Universytetska St., Lviv 79007, Ukraine

²Institute of Physics, University of Rzeszow, 35-959, Rzeszow, Poland

Rare-earth-doped borate glasses are promising phosphor materials for solid-state lighting due to their high optical transparency, chemical stability, and homogeneous dissolution of luminescent activators, especially rare-earth ions. In this work, color-tunable borate glass phosphors based on the B₂O₃-ZnO-SrO-CaO-MgO system doped with Dy³⁺, Tb³⁺, and Eu³⁺ ions were synthesized and studied for potential applications in light-emitting devices.

The glass samples were prepared by the conventional melt-quenching method using high-purity starting materials, followed by annealing at 450–500°C to reduce internal mechanical stresses and stabilize the amorphous network. Physical characterization showed systematic changes in density and molar volume upon rare-earth doping, indicating the successful modification of the host borate matrix with activator ions. The influence of rare-earth ion type, concentration, co-doping strategy, and excitation wavelength on the optical and photoluminescent properties of the obtained glasses was analyzed. UV-Vis-NIR absorption spectroscopy revealed characteristic intra-configurational *4f-4f* transitions of Dy³⁺, Tb³⁺, and Eu³⁺ ions. Judd-Ofelt analysis of selected samples provided information on the local symmetry, covalency of rare-earth-ligand bonds, and radiative transition probabilities. Photoluminescence studies demonstrated that Dy³⁺-doped glasses had characteristic blue and yellow emission bands associated with transitions from the ⁴F_{9/2} excited state to the ⁶H_{15/2} and ⁶H_{13/2} levels. This enables near-white light emission under excitation at 350 nm, which corresponds to the ⁶H_{15/2} → ⁶P_{7/2} transition. Tb³⁺-doped samples produce green emission, mainly due to ⁵D₄ → ⁷F₁ transitions, while Eu³⁺ ions provide intense orange-red emission dominated by the hypersensitive ⁵D₀ → ⁷F₂ transition.

Co-doping with Dy³⁺/Tb³⁺ and Dy³⁺/Eu³⁺ enables controlled tuning of the emission color via energy-transfer processes and selective excitation. In particular, Dy³⁺ can act as a sensitizer for Tb³⁺ emission, significantly increasing green luminescence intensity, whereas Dy³⁺/Eu³⁺ co-doping allows the emission to be shifted from cold-white or near-white toward orange-red depending on the excitation wavelength and dopant ratio. The calculated CIE 1931 chromaticity coordinates confirm that the emission color of the synthesized borate glasses can be tuned over a broad spectral range, including near-white, green, and red regions.

corresponding author: ivanna.medvid@lnu.edu.ua