

Energy Transfer Mechanisms of $Gd^{3+} \rightarrow Ce^{3+} \rightarrow Tb^{3+}$ and $Ce^{3+} \rightarrow Tb^{3+} \rightarrow Eu^{3+}$ in Mixed $Lu_{1-x}Gd(Y)_xAlO_3$ Perovskites

Artur Majewski-Napierkowski^{1,#}, Vitalii Gorbenko¹, Yuriy Zorenko¹

¹ Faculty of Physics of Kazimierz Wielki University, ul. Pow. Wielkopolskich 2, 85-090 Bydgoszcz, Poland

Mixed perovskite single crystalline films of the $Lu_{1-x}Gd_xAlO_3$ and $Lu_{1-x}Y_xAlO_3$ systems co-doped with Ce^{3+} , Tb^{3+} , and Eu^{3+} were investigated as advanced luminescent materials for scintillation and color-tunable phosphor applications. These hosts are of particular interest due to their high density, structural stability, and favorable electronic environment for rare-earth ion emission centers. The present work focuses on elucidating the mechanisms of competitive energy transfer processes involving Gd^{3+} and Ce^{3+} ions as a sensitizer and Tb^{3+}/Eu^{3+} as activators.

The films of perovskites under study were synthesized using the Liquid Phase Epitaxy technique, enabling precise control of dopant incorporation and crystal quality. Spectroscopic characterization was performed under vacuum ultraviolet (VUV) excitation using synchrotron radiation at the P66 beamline of the PETRA III storage ring (DESY, Hamburg) (Fig.1). This approach allowed direct probing of the UV-VUV excited states of Gd^{3+} , Ce^{3+} , Tb^{3+} , and Eu^{3+} ions, providing detailed insight into their excitation pathways and energy transfer channels.

The emission properties reveals an efficient cascade $Gd^{3+} \rightarrow Ce^{3+} \rightarrow Tb^{3+}$ energy transfer, evidenced by a systematic reduction of Gd^{3+} and Ce^{3+} emission intensity accompanied by a corresponding enhancement of Tb^{3+} green luminescence (Figs.1a,1b). In ternary $Ce^{3+}-Tb^{3+}-Eu^{3+}$ systems, an additional cascade transfer $Ce^{3+} \rightarrow Tb^{3+} \rightarrow Eu^{3+}$ is observed, leading to pronounced yellow-red emission from Eu^{3+} ions (Fig.1a,1c). This process is accompanied by simultaneous quenching of both Ce^{3+} and Tb^{3+} emissions, confirming the role of Tb^{3+} as an intermediate energy relay state.

Time-resolved luminescence measurements further substantiate the presence of efficient non-radiative energy migration pathways, consistent with resonant and cross-relaxation mechanisms between rare-earth centers. The reciprocal intensity evolution of Ce^{3+} , Tb^{3+} , and Eu^{3+} emissions under selective excitation demonstrates strong spectral tunability governed by dopant composition and energy level alignment within the perovskite host lattice.

The integration of synchrotron-based VUV spectroscopy with time-resolved optical analysis provides a comprehensive description of excited-state dynamics in these multi-doped mixed perovskites. The results highlight their potential as highly efficient, composition-tuneable luminescent materials for applications in advanced scintillators, radiation detection systems, and multi-colour photonic devices.

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corresponding author: arthur@ukw.edu.pl

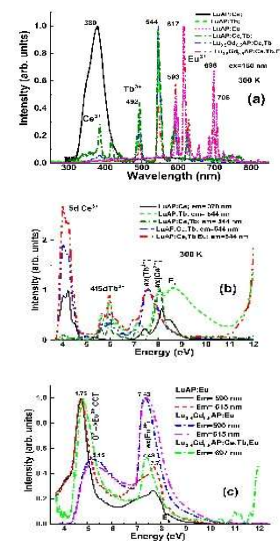


Fig. 1. Emission (a) and excitation spectra of Tb^{3+} (b) and Eu^{3+} (c) luminescence in the studied perovskite films, recorded under synchrotron radiation (SR) excitation in accordance with the figure legends.