Luminescence and energy transfer processes in $LuNbO_4$:Bi,Eu

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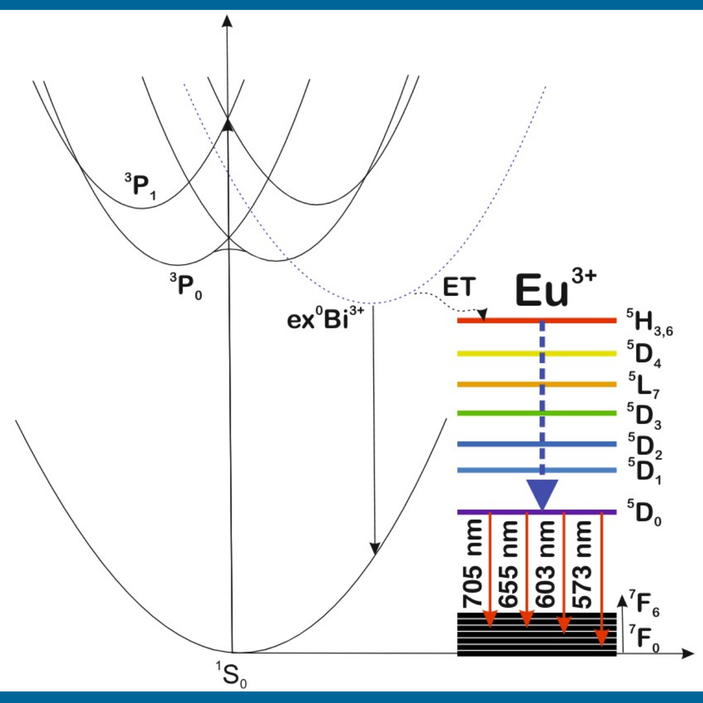
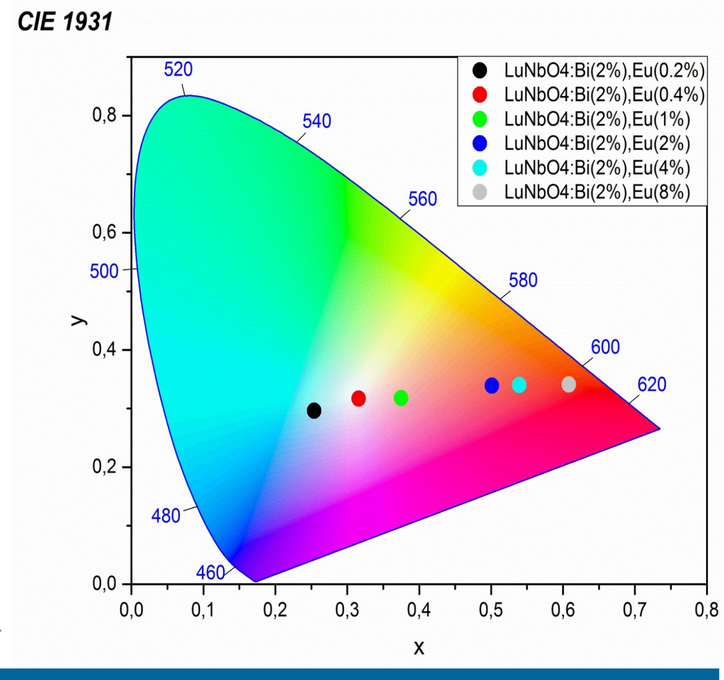
Motivation and aim of the work

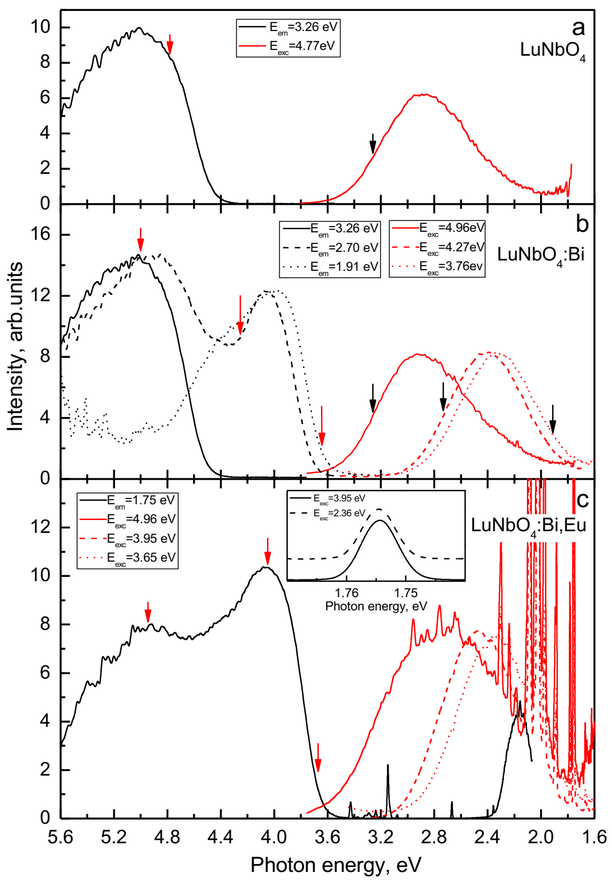
The interest in Bi^{3+}-doped compounds increased drastically in recent years due to their possible applications as scintillator and phosphor materials suitable for X-ray screens, white light-emitting diodes, solar cells, dosimeters, etc. The compounds co-doped with Bi^{3+} and different trivalent rare-earth (RE^{3+}) ions were found to be potentially applicable as spectral converters for solar cells and solid-state light sources of new generation, so-called white light-emitting diodes (WLED), owing to strong absorption in the ultraviolet spectral region, intense broad visible Bi^{3+}-related emission bands, and effective $Bi^{3+} \rightarrow RE^{3+}$ energy transfer, resulting in the appearance of the luminescence covering a wide spectral range from blue to red.

Recently, a detailed and systematic investigation of the Bi^{3+}-related luminescence in $YNbO_4$:Bi, $LuNbO_4$:Bi, and $GdNbO_4$:Bi microcrystalline powders with different Bi^{3+} contents was carried out [1]. Two broad visible Bi^{3+}-related emission bands were observed in the emission spectrum of the Bi^{3+}-doped niobates. The analysis of temperature dependences of their decay time and the values of the corresponding relaxed excited states (RES) parameters allowed us to conclude their exciton-like origin. The absence of the ultraviolet emission, arising from the radiative decay of the triplet RES of a Bi^{3+} ion, and the exciton-like origin of the visible Bi^{3+}-related emissions indicate that the triplet RES of both the Bi^{3+} ion and the $\{Bi^{3+}–Bi^{3+}\}$ dimer are located inside the conduction band of the investigated niobates.

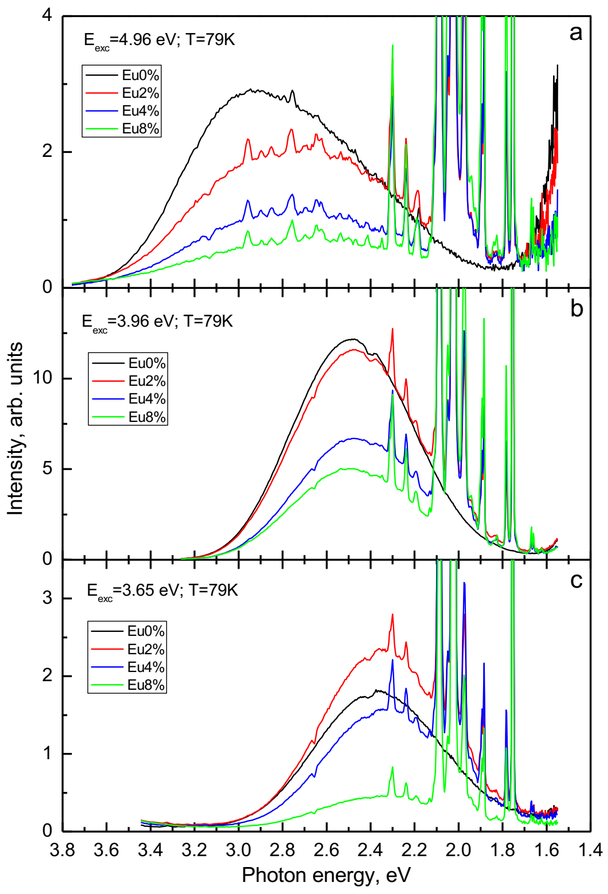




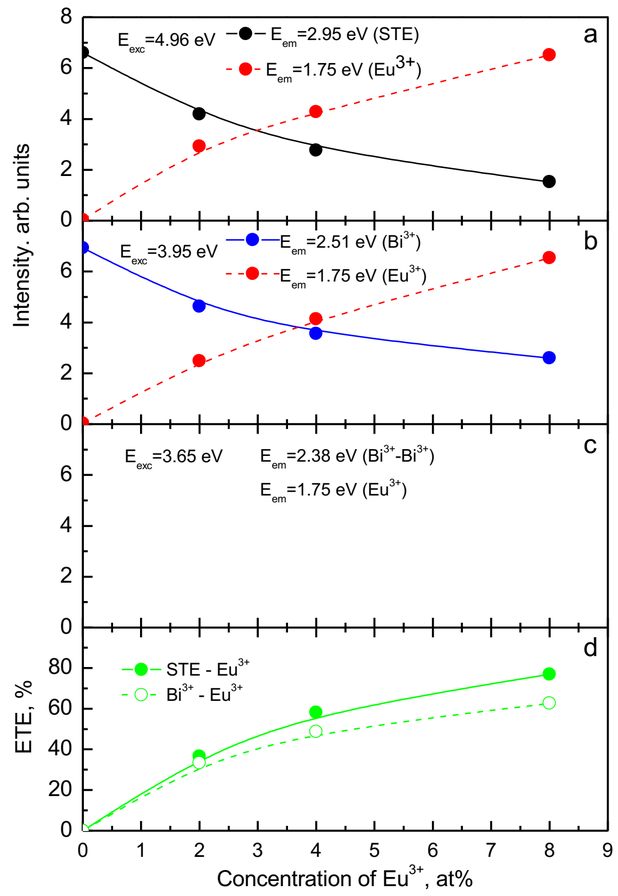
Experimental results



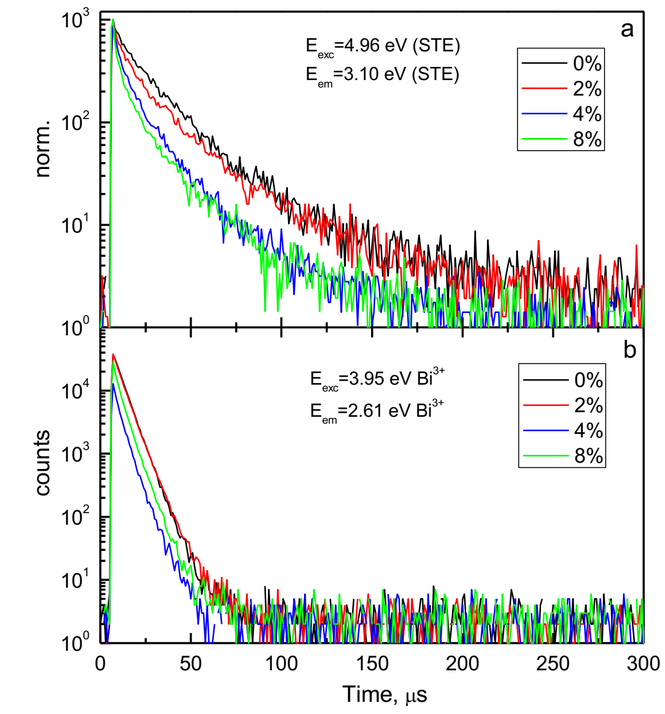
Emission (red lines) and excitation (black lines) spectra of (a) $LuNbO_4$, (b) $LuNbO_4$:Bi, and (c) $LuNbO_4$:Bi,Eu measured at 79 K. In the inset the 1.76 eV emission of Eu^{3+} measured under excitation in the absorption bands of Bi^{3+} (E_{exc} = 3.95 eV, solid line) and Eu^{3+} (E_{exc} = 2.36 eV, dashed line).



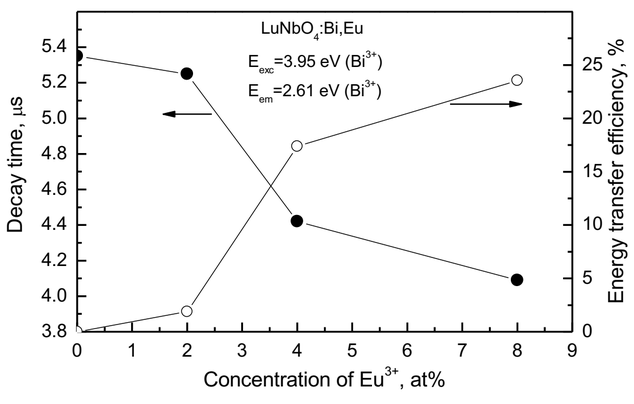
Emission spectra of $LuNbO_4$:Bi, Eu measured at 79 K for the samples with different nominal Eu^{3+} concentrations. (a) E_{exc} = 4.96 eV, (b) E_{exc} = 3.96 eV, (c) E_{exc} = 3.65 eV.



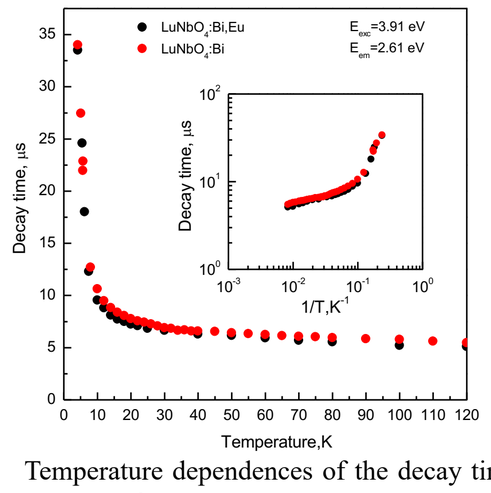
Dependences on the nominal Eu^{3+} concentration measured for (a,b,c) the maximum intensity of the intrinsic (black circles), Bi^{3+}-related (blue circles) and Eu^{3+} (red circles) emissions of $LuNbO_4$:Bi,Eu. Dependences of the energy transfer efficiency (ETE) on the nominal Eu^{3+} concentration measured for the STE $\rightarrow Eu^{3+}$ (green solid line), ex^{0}Bi^{3+} $\rightarrow Eu^{3+}$ (green dashed line) and ex$^0\{Bi^{3+} – Bi^{3+}\} \rightarrow Eu^{3+}$ energy transfer in $LuNbO_4$:Bi,Eu. T = 79 K.



Decay curves of (a) the intrinsic and (b) the Bi^{3+}-related emission measured at 79 K for the single-phase $LuNbO_4$:Bi, Eu samples with different nominal Eu^{3+} concentrations.



Dependences on the nominal Eu^{3+} concentration measured for the decay time of the Bi^{3+}-related luminescence (filled circles) and for the corresponding energy transfer efficiencies (empty circles) in $LuNbO_4$:Bi, Eu. T = 79 K.



Temperature dependences of the decay times of the Bi^{3+}-related emission in $LuNbO_4$:Bi (red filled circles) and $LuNbO_4$:Bi, 4%Eu (black filled circles).

The values of color rendering indexes (CRI), quantum yields (QY), $Bi^{3+} \rightarrow Eu^{3+}$ energy transfer efficiences (ETE), correlated color temperatures (CCT) and CIE chromaticity coordinates (x,y) obtained for the investigated $LuNbO_4$:Bi, Eu samples with different nominal Eu^{3+} concentrations.

Eu^{3+} (%)	QY, %	ETE, %	CRI, %	CIE, x;y	CTT, K
0.2	18.8 ± 0.7	-	90	0.254, 0.296	9511
0.4	17.9 ± 0.6	-	76	0.316, 0.317	5206
1	25.1 ± 0.7	-	58	0.375, 0.318	2874
2	26.2 ± 0.6	32	53	0.501, 0.339	1529
4	29.1 ± 2.0	47	45	0.539, 0.340	1237
5	41.9 ± 2.1	60	35	0.608, 0.341	1091

Conclusion

In $LuNbO_4$:Bi,Eu, sample obtained results indicate the presence of energy transfer from the intrinsic and Bi^{3+}-related centers to Eu^{3+} ions by the non-radiative (resonance) energy transfer process.

The values of a color rendering index (CRI) of 76%, quantum efficiency of ≈18%, and correlated color temperature (CCT) of 5206 K are achieved for the $LuNbO_4$:2% Bi^{3+},0.4 % Eu^{3+} powder with the best CIE chromaticity coordinates (x = 0.316, y = 0.317).

References

1) M. Baran, K. N. Belikov, A. Kissabekova, A. Krasnikov, A. Lushchik, E. Mihokova, V. Tsiumra, L. Vasylechko, S. Zazubovich, Ya. Zhydachevskyy, J. Alloys and Compounds 859, 157800.