Tunable Short-Wave Infrared Ni^{2+} Emission via Crystal Field Engineering

Mikołaj Kamiński[1,#], Ru-Shi Liu[2], Sebastian Mahlik[1]

[1] Institute of Experimental Physics, Faculty of Mathematics, Physics and Informatics, University of Gdansk, Wita Stwosza 57, 80-308 Gdansk, Poland
[2] Department of Chemistry, National Taiwan University, Taipei 106, Taiwan

Phosphor-converted infrared light-emitting diodes (pc-LEDs) are emerging as attractive alternatives to conventional semiconductor-based infrared emitters, as well as traditional infrared light sources such as tungsten halogen lamps and laser diodes, offering improved thermal stability, broader spectral coverage, and enhanced versatility. In particular, broadband short-wave infrared (SWIR) emitters operating within the 900 – 1700 nm range are highly desirable for applications in spectroscopy, anti-counterfeiting, optical communications, and noninvasive biomedical imaging.Among transition-metal activators, Ni^{2+} is especially promising because of its broad SWIR emission spanning approximately 1000 – 1700 nm. Moreover, Cr^{3+}/Ni^{2+} codoped systems exhibit enhanced luminescence due to efficient energy transfer between both ions. Here, we investigate $MgGa_2O_4:Cr^{3+},Ni^{2+}$ phosphors modified by Al^{3+}, Sn^{4+}, and In^{3+} cation substitution [1,2] to elucidate the influence of crystal field strength on the optical properties and thermal stability of Ni^{2+} emission. The study combines high-pressure spectroscopy, temperature-dependent luminescence measurements, and luminescence kinetics analyses. Crystal field engineering is achieved through both external pressure applied using a diamond anvil cell and chemical pressure induced by substitution with smaller Al^{3+} ions or larger Sn^{4+} and In^{3+} ions. Increasing Al^{3+} concentration and applying high-pressure increases the crystal field strength, leading to a blueshift of the Ni^{2+} spin-allowed $^3T_2 \rightarrow {}^3A_2$ emission. In contrast, Sn^{4+} and In^{3+} incorporation weakens the crystal field and induces a pronounced redshift of the broadband Ni^{2+} emission. The results demonstrate that cation substitution offers an effective strategy for tailoring broadband Ni^{2+} SWIR emission while balancing spectral tunability and luminescence efficiency.

[1] K.-C. Chen, M.-H. Huang, W.-T. Huang, M. Kamiński, D.-H. Cherng, K.-M. Lu, G. Leniec, S. Mahlik, R.-S. Liu, *Advanced Optical Materials* 2025, *13*, 2500393.
[2] Y.-C. Huang, S.-E. Chen, C.-F. Tsao, Y.-H. Lin, M. Kamiński, N. Majewska, G. Leniec, E. Mijowska, H.-C. Wang, D.-H. Cherng, T.-W. Yeh, S. Mahlik, R.-S. Liu, *Advanced Optical Materials* 2026, *14*, e03799.

corresponding author: mikolaj.kaminski@ug.edu.pl