Spectroscopic and Photoelectric studies: Insights into Quenching Phenomena of NIR materials

Natalia Majewska, Sebastian Mahlik

Institute of Experimental Physics, Faculty of Mathematic, Physics, and Informatics, University of Gdańsk, Wita Stwosza 57, 80-308 Gdańsk, Poland

Due to their potential applications in biology, Cr^{3+}-activated luminescent materials have recently gained significant attention worldwide. These materials, capable of producing either sharp-line or broadband spectra, are promising candidates for phosphor-converted infrared light-emitting diodes (pc-NIR LEDs) and have found use in food freshness, quality, and composition analysis. One of the primary objectives is to identify materials exhibiting efficient broadband near-infrared (NIR) luminescence. Understanding the quenching phenomena, which may be related to the crossing point between the ground state and excited state or to autoionization, is crucial for designing efficient NIR materials.

Ga_2O_3 activated by Cr^{3+} ions are promising material for NIR sources, characterized by efficient NIR luminescence in the 650–900 nm range, peaking at 740 nm. Here, luminescence and photoelectric studies are presented for Cr^{3+}-activated Ga_2O_3 modified with In^{3+}. Incorporating In^{3+} into the Ga_2O_3 matrix, with its larger ion radius, has enabled us to shift the maximum emission to 850 nm. In the excitation spectra, three bands were observed in the UV-Vis range. The band at 250-300 nm likely arises from overlapping emissions associated with band-to-band transitions, charge transfer (CT), and transitions to the higher state Cr^{3+} $^4T_1(4P)$ from the ground state $^4A_2$. Two additional bands in the visible range correspond to transitions $^4A_2 \rightarrow {}^4T_2$ and $^4A_2 \rightarrow {}^4T_1$ of Cr^{3+}. Similar transitions were observed in the photoconductivity spectrum, indicating the role of Cr^{3+} dopants in photocurrent generation. Furthermore, a shift towards longer wavelengths in the broad band between 250-300 nm was observed, indicating that as the In^{3+} concentration increases, the energy bandgap decreases.

Luminescence intensity measurements at different temperatures revealed that Ga_2O_3:Cr^{3+} luminescence remains stable within the temperature range of 100-400 K but begins to decrease at higher temperatures. With increasing In^{3+} concentration, luminescence intensity starts to decrease even at lower temperatures, indicating earlier quenching of the sample. Analysis of temperature-dependent decay times confirms this trend, indicating non-radiative quenching of luminescence. Conversely, a reverse trend was observed in the photocurrent measurements, where the excitation spectrum intensity increases with temperature. Significant differences were also observed in the behavior of photocurrent intensity depending on In^{3+} content. Specifically, for materials with indium doping, photocurrent intensity increases significantly faster with temperature compared to Ga_2O_3:Cr^{3+}. These findings suggest that thermal quenching in these materials is not solely related to the crossing of the ground and excited state parabolas but is also associated with autoionization processes.

corresponding author: natalia.majewska@ug.edu.pl