Chemical tuning of photo- and persistent luminescence of Cr^{3+}-activated β-Ga_2O_3 by alloying with Al_2O_3 and In_2O_3

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This study details the effects of alloying monoclinic β-Ga_2O_3 with Al_2O_3 and In_2O_3 on the photoluminescence, thermoluminescence, and persistent luminescence properties of Cr^{3+} ions. Our investigation provided information on the characteristics and properties of the Cr^{3+} multicentres present in the β-Al_2O_3-Ga_2O_3 and β-Ga_2O_3-In_2O_3 solid solutions. The research results show how the host matrix and Cr3+ ions are related, providing insights for designing and optimizing new materials with specific optical properties, which can be used as long-persistent phosphors or cryogenic luminescent temperature sensors.

To achieve this, we prepared a series of samples using the sol-gel citrate method, with nominal compositions of $(Ga_{1-x}Al_x)_2O_3$:Cr(0.05at.%), Ca(0.5at.%) (x = 0; 0.1; 0.2), $(Ga_{1-x}In_x)_2O_3$:Cr(0.05at.%), Ca(0.5at.%) (x = 0.05; 0.1; 0.15; 0.2; 0.3; 0.4; 0.5). The samples were calcined at temperatures up to 1500°C.

This work presents a systematic investigation of the photoluminescence (PL) and thermoluminescence (TL) properties of Cr^{3+} in β-Al_2O_3-Ga_2O_3 and β-Ga_2O_3-In_2O_3 solid solutions. We analysed the luminescence properties of the materials at temperatures ranging from 4.4 to 350 K. In particular the PL spectra, PL excitation spectra, diffuse reflection (DR), and PL decay time were examined. We analysed the materials phase composition and crystal structure using powder X-ray diffraction (XRD) data and scanning electron microscope (SEM) to gain a comprehensive understanding.

Obtained results showed that by adjusting the chemical composition of the host lattice, we can fine-tune the thermometric performance of the studied phosphors. This adjustment enables control of the temperature range and the maximal specific sensitivity of the decay time luminescence thermometers based on the studied Cr^{3+}-doped $(Ga\text{-}Al)_2O_3$ and $(Ga\text{-}In)_2O_3$ solid solutions. The studied materials have significant potential for use in cryogenic luminescence thermometry.

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