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Pushing the Boundaries of Phosphor-Converted Infrared Light-Emitting Diode Technology: Creating Compact Infrared Light Sources for the Future

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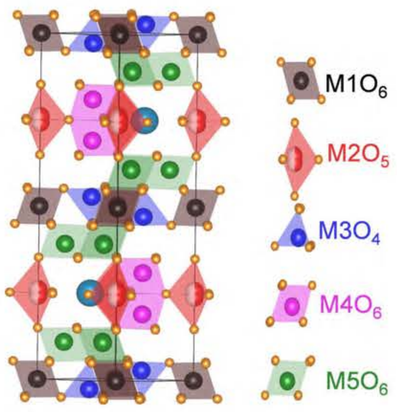
Abstract

Near-infrared (NIR) radiation plays a pivotal role in diverse industrial applications and modern technological advancements. Our study introduces innovative strategies for enhancing the performance of phosphor-converted NIR light-emitting diodes (pc-NIR LEDs). By leveraging Cr^{3+}–Cr^{3+} ion pairs within magnetoplumbite-type structured phosphors, tunable NIR broadband-centered emission (740–820 nm) is achieved through Ga incorporation. The resulting pc-NIR LED device demonstrates an impressive 85% internal quantum efficiency and maintains thermal stability up to 500 K. In a subsequent investigation, the study delves into the SWIR range (1000-1700 nm) by facilitating an energy transfer process between Cr^{3+}–Cr^{3+} and Ni^{2+} ions, enabling simultaneous NIR (774 nm) and SWIR (1030 nm) emissions. This breakthrough offers the potential for a SWIR pc-LED device with substantial radiant flux under blue light excitation. In short, this research marks significant strides in highly efficient pc-NIR and pc-SWIR LED devices, holding promising applications in various industries, including industrial spectroscopy, medical imaging, and optical communication.

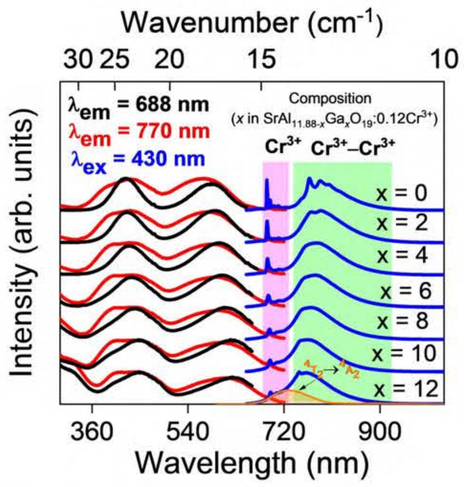
Research Focus

NIR Phosphors (Cr^{3+}–Cr^{3+} Ion Pair)

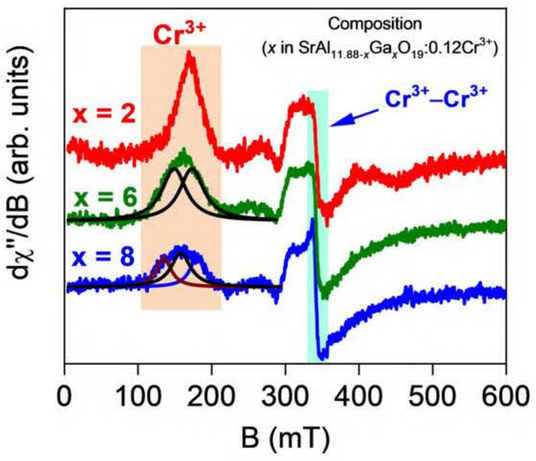
Crystal Structure



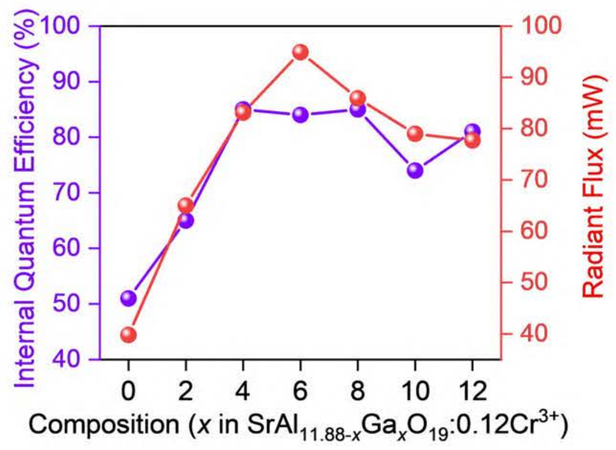
Photoluminescence



Electron Paramagnetic Resonance

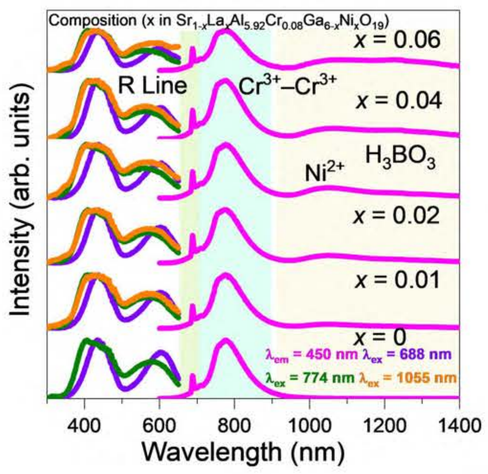


Pc-NIR LED and Quantum Efficiency

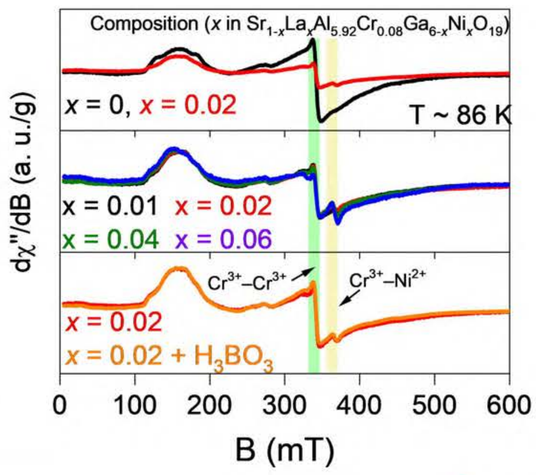


SWIR Phosphors (Cr^{3+}–Cr^{3+} Ion Pair → Ni^{2+})

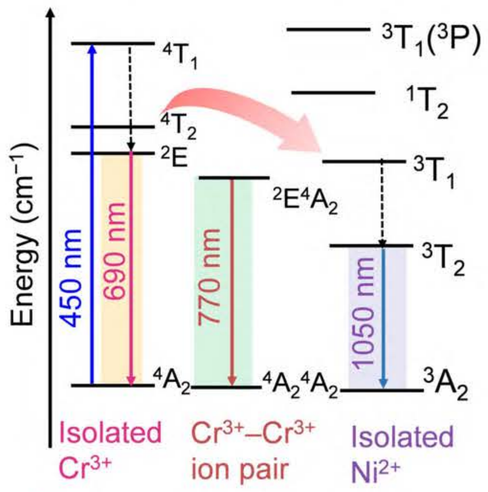
Photoluminescence



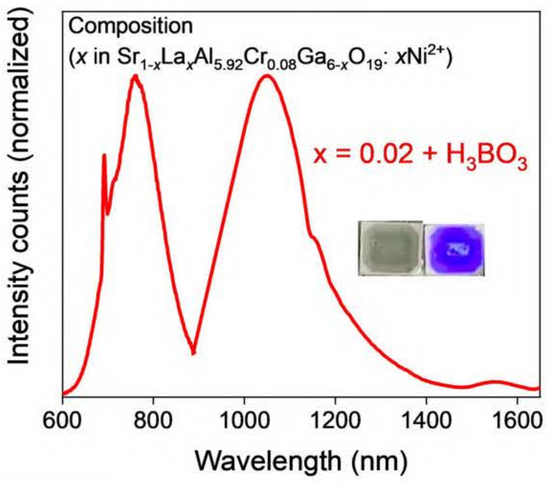
Electron Paramagnetic Resonance



Energy Transfer Diagram



Pc-SWIR LED



Conclusion

The focus on inorganic phosphors with blue light excitability, particularly addressing the challenge of balancing spectral distribution and thermal stability around Cr3+ ions, was undertaken in our study to design phosphor-converted light-emitting diodes (pc-LEDs) as efficient infrared light sources. The Magnetoplumbite structure was explored, revealing a solid-solution series ($SrAl_{11.88-x}Ga_xCr_{0.12}O_{19}$) with a notable Cr^{3+}–Cr^{3+} ion pair at x = 6, demonstrating high efficiency and thermal stability. Furthermore, an energy transfer process between Cr^{3+}–Cr^{3+} and Ni^{2+} ions extended the spectral distribution, showcasing the potential for short-wave infrared emission. This research significantly advances the development of practical pc-NIR and pc-SWIR LEDs.

Selected Publications

1) **V. Rajendran**, K C Chen, W T Huang, M Kamiński, M Grzegorczyk, S Mahlik, G Leniec, K M Lu, D H Wei, H Chang, and R S Liu. ***ACS Energy Lett.* 2023, *8,* 2395 – 2400**.
2) **V. Rajendran,** K C Chen, W T Huang, N Majewska, T Lesniewski, M Grzegorczyk, S Mahlik, G Leniec, S M Kaczmarek, W K Pang, V K Peterson, K M Lu, H Chang, and R S Liu. ***ACS Energy Lett.* 2023, *8,* 289 – 295**.
3) **V. Rajendran**, M H Fang, W T Huang, N Majewska, T Lesniewski, S Mahlik, G Leniec, S M Kaczmarek, W K Pang, V K Peterson, K M Lu, H Chang, and R S Liu. ***J. Am. Chem. Soc. 2021, 143, 19058 – 19066***
4) **V. Rajendran**, H Chang, and R S Liu Phosphor-Converting LED for Broadband IR, **Phosphor Handbook: Novel Phosphors, Synthesis, and Applications, CRC *Press: Boca Raton, 2022; Vol. 2, pp 87–130***
5) **V. Rajendran**, M G Fang, R S Liu, H Chang, K M Lu, Y S Lin, C Y Kang, G N D Guzman, and S F Hu, "Phosphor, method for preparing phosphor, optoelectronic component, and method for producing optoelectronic component" ***US10683454B2 (16 June 2020), EP3502208A1(26 June 2019), CN109943332B (30 November 2021), and TWI683455B (21 January 2020).***