Concentration-Dependent Emission Spectra in Cr^{3+}:GGG Transparent Nanoceramics

Paweł Głuchowski* and Mykhailo Chaika

Institute of Low Temperature and Structure Research PAN, Okolna 2, Wroclaw 50-422, Poland

The problem and results

In recent years, Cr-doped garnets have attracted a lot of attention due to their unique properties. Interpretation of spectroscopic properties of Cr^{3+} ions in garnets is difficult due to the variation of the crystal field strength over a large range, resulting in the presence of Cr^{3+} ions in octahedral sites with different local crystal field strengths. This is also relevant for nanostructured materials such as Cr^{3+}-doped nanopowders. Despite the large number of works, a lot of questions remain concerning the luminescence properties of Cr^{3+} ions in nanomaterials.

In the present work [1], we report the study of the optical properties of Cr^{3+}:GGG nanoceramics synthesized by the high isostatic pressure (HIP) method at relatively low temperature. Cr:GGG nanoceramics doped with 0.1 at.%, 0.2 at.%, and 0.3 at.% of chromium ions were obtained.

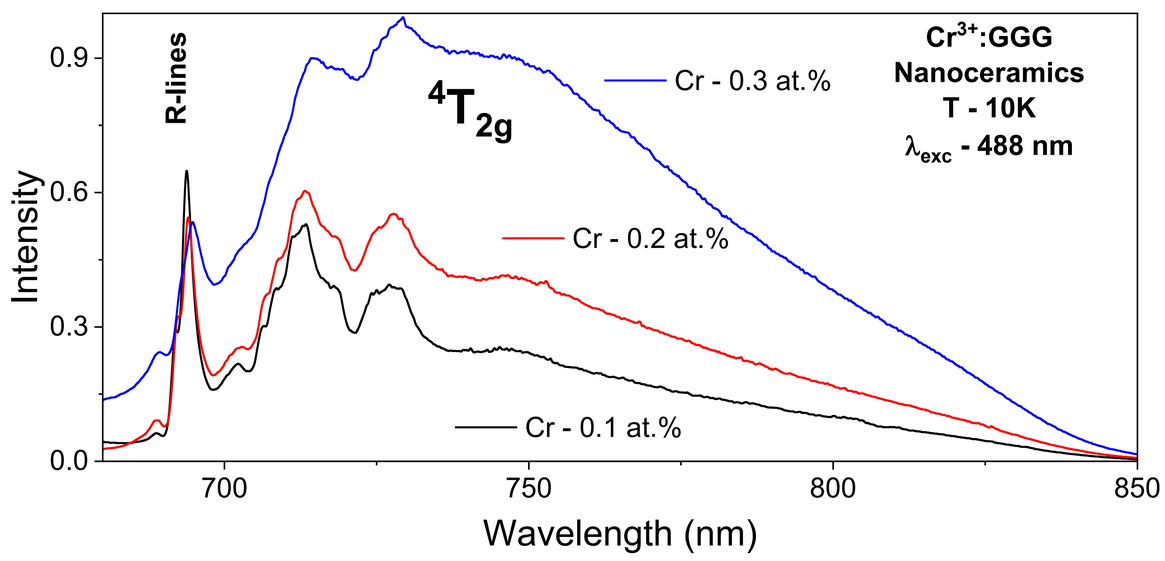
. The synthesized nanoceramics consist of crystallites with an average size of 17 nm and an average lattice parameter of ~12.40 Å. High-temperature emission spectra show the presence of at least four different CrO_6 optical active centers in Cr:GGG nanoceramics. The presence of satellites of R-lines confirms uniform distribution of local crystal fields around different chromium ions. The change in the concentration of Cr^{3+} ions does not influence the room-temperature optical properties of Cr:GGG nanoceramics. Excitation and emission spectra, and lifetimes were the same for the investigated samples. No difference in the calculated Racah parameters was detected for different Cr^{3+} concentrations.

The low-temperature emission spectra depend on the chromium content, and the increase in Cr^{3+} concentration caused an increase in the ratio of broadband $^4T_{2g}(^4F)$ emission intensity to overall Cr^{3+} emission. At the same time, no difference was detected in the peak position and width of $^4T_{2g}(^4F) \rightarrow {}^4A_{2g}(^4F)$ broadband emission. The difference in the low-temperature emission spectra was explained by the energy transfer between chromium ions in sites with different local crystal field strength. Cr^{3+} ions in the low crystal field site have a higher probability of emitting photons rather than transferring the excitation energy to the nearby Cr^{3+} ions. The increase in concentration of Cr^{3+} ions caused an increase in the energy transfer between Cr^{3+} ions, thus increasing the ratio of emission intensity of Cr^{3+} ions in low crystal field to the total luminescence.

References

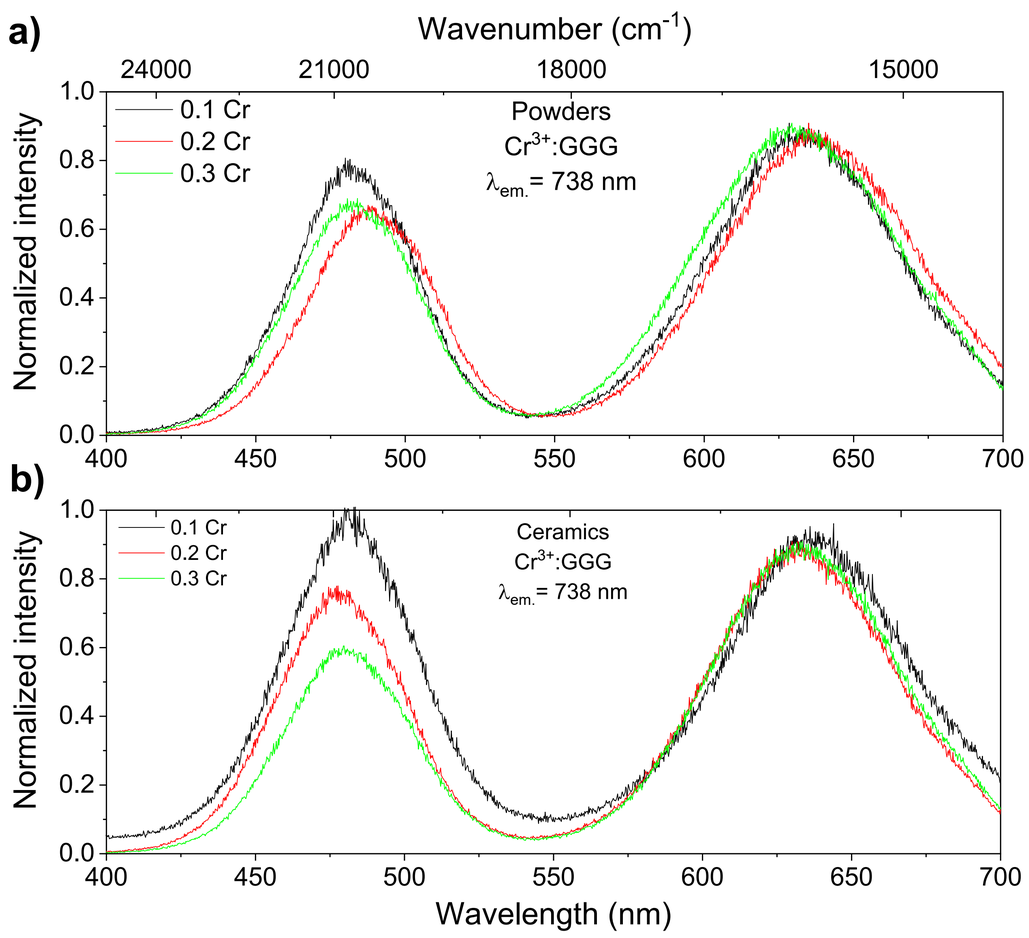
1. P. Gluchowski, & M. Chaika, J. Phys. Chem. C, 128(23), (2024) 9641-9651

Emission spectra



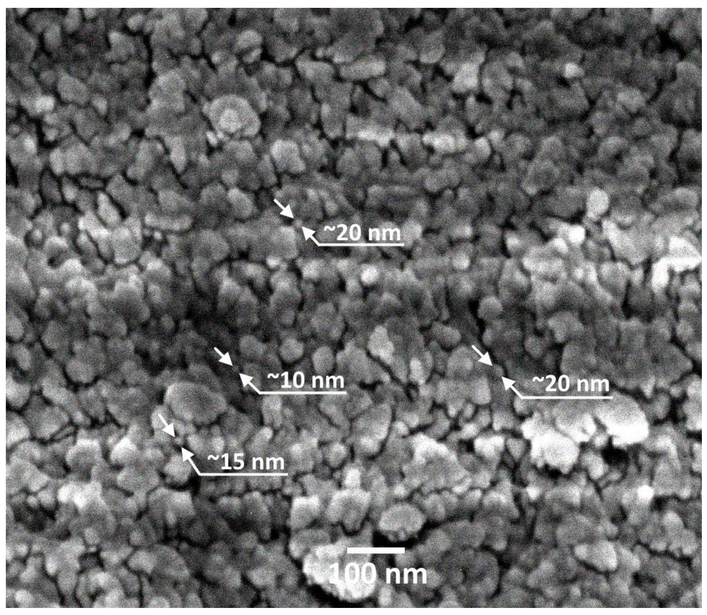
Low-temperature emission spectra of Cr^{3+}:GGG nanoceramics.

Emission spectra



Excitation spectra of the Cr^{3+}:GGG nanopowders (a) and nanoceramics (b)

Microstructure



SEM image of Cr^{3+}:GGG nanoceramics

Photo

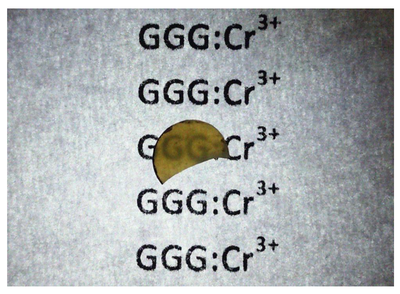


Photo of Cr^{3+}:GGG nanoceramics

Calculated Racah parameters

denote	Dq, cm^{-1}	B, cm^{-1}	C, cm^{-1}	Dq/B	Dq/B (^2E_g=$^4T_{2g}$)	C/B	Δ(Dq/B)
Cr0.1	1578	662	3181	2.38	2.17	4.8	0.21
Cr0.2	1582	677	3140	2.34	2.12	4.6	0.22
Cr0.3	1573	690	3122	2.28	2.08	4.5	0.20