ELECTRONIC SUPPLEMENTARY INFORMATION

# Non-aqueous sol-gel synthesis of hybrid rare-earth-doped γ-$Ga_2O_3$ nanoparticles with multiple organic-inorganic-ionic light-emission features

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**Materials & Methods:**

All chemicals were purchased from Sigma-Aldrich (benzyl alcohol anhydrous 99.8%, gallium(III) acetylacetonate 99.99%) and ABCR (europium(III) acetate hydrate 99.99%) and used as received without further purification. Powder preparation were performed in a glove box with $O_2$ < 0.1 ppm and $H_2O$ < 0.1 ppm.

TEM measurements were made on a Philips FEI Tecnai F30 microscope operated at 300 kV on samples prepared by depositing onto carbon coated Cu grids 10 µL of ethanol (Aldrich) suspension of washed NPs. X-ray diffraction (XRD) measurements were performed in reflection mode (Cu Ka radiation at 45 kV and 40 mA) either on a X'Pert Pro diffractometer or on an Empyrean diffractometer (equipped with a high temperature chamber model HTK 1200 from Anton Paar), both from PANalytical (The Netherlands). Differential scanning calorimetry and thermogravimetry analysis were performed on a Netzsch DSC 449F3 thermoanalyzer; samples were prepared by placing nanopowders in Pt crucibles with a lid, and measured in Ar flux against empty Pt crucibles as a reference with a heating rate of 10 °C/min$^{-1}$. Raman spectra were collected in backscattering configuration using an inVia Renishaw spectrometer and a 785 nm laser line as light source. Steady-state photoluminescence has been measured using a FP-8500 by Jasco. The data were corrected for the spectral response of the detection system and the spectral shape of the light source. Time-resolved photoluminescence has been carried out with a FLS 980 spectrofluorometer and using an EPLED by Edinburgh Photonics operating at 340 nm with pulse duration of about 900 ps as light source. Slow component of time-resolved (i.e. intrinsic lifetime of Eu ions) photoluminescence measurements were performed at RT using a Varian Eclipse spectrofluorometer and a pulsed Xenon lamp as light source.

**XRD patterns:**

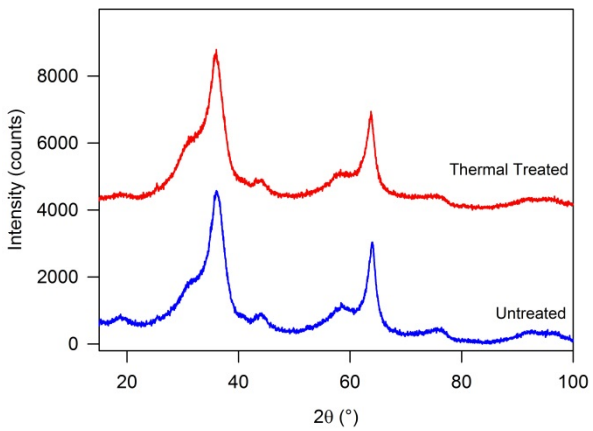


Fig. S1: XRD patterns of $Ga_2O_3$ nanopowder before (blue line) and after (red line) thermal treatment at 420 °C for 1 h.

**Fitting results on lifetime measurements:**

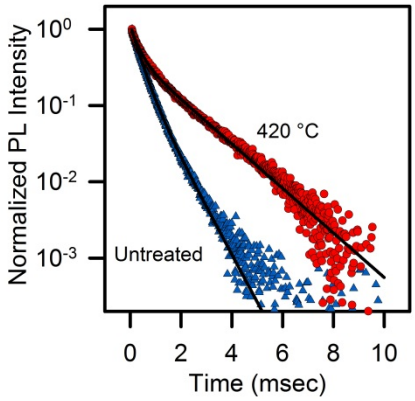


Fig. S2: lifetime measurements and relative fitting curves (black lines) of as-synthesized (blue triangles) and heat treated at 420 °C for 1 h (red circles) samples exciting at 290 nm and monitoring the luminescence at 620 nm.

| | a | b | $\tau_1$ (μs) | $\tau_2$ (μs) |
|---|---|---|---|---|
| Untreated sample | 0.810 | 0.346 | 320 | 697 |
| 420 °C, 1 h | 0.615 | 0.463 | 312 | 1160 |

Table S1: fitting results of lifetime measurements reported in Fig. S2, data have been fitted using the following biexponential formula:

$$f(t) = a\exp\left(-\frac{t}{\tau_1}\right) + b\exp\left(-\frac{t}{\tau_2}\right)$$