CONCENTRATION DEPENDENT NEAR INFRARED-TO-VISIBLE UPCONVERSION IN NANOCRYSTALLINE AND BULK $Y_2O_3:Er^{3+}$

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Towards the end of the 20th century and into the new millenium, there has been a renaissance in the study of lanthanide-doped powder phosphors. Modern day scientists are investigating the luminescence properties of these crystalline materials in the nanometer scale, with particle sizes under the 100-nm threshold. These nanocrystals can be characterized by markedly different properties, compared to their bulk counterparts. The particle-size-dependant phenomena exhibited by these nanocrystals have attracted a considerable amount of interest, both from a fundamental and technological standpoint. In this paper, we investigate the luminescence, in particular the upconversion, by examining the emission following 980 nm excitation into the $^4I_{11/2}$ level of nanocrystalline $Y_2O_3:Er^{3+}$.

Nanocrystalline cubic Y_2O_3 doped with 1, 2, 5 and 10 mol% Er_2O_3 were prepared using a solution combustion (propellant) synthesis procedure starting from an aqueous solution containing glycine, $Y(NO_3)_3\ 6H_2O$ and $Er(NO_3)_3\ 6H_2O$, yielding nanoparticles with an average size of about 20 nm. For purposes of comparison, bulk samples doped with 1, 2, 5, 10, 25 and 35 mol% Er_2O_3 were prepared by mixing Y_2O_3 and Er_2O_3, pressing the powders into pellets under 10 tons of pressure and firing them in air at 1500 °C for 48 hours.

Continuous wave excitation (980 nm) into the $^4I_{11/2} \leftarrow {}^4I_{15/2}$ transition of the erbium ion, in Y_2O_3 (bulk and nanocrystal), produced intense upconversion luminescence spectra. Blue upconversion (Figure 1) was observed with bands centered at 460, 475 and 495 nm, which are assigned to the $^4F_{5/2} \rightarrow {}^4I_{15/2}$, $^2P_{3/2} \rightarrow {}^4I_{11/2}$ and $^4F_{7/2} \rightarrow {}^4I_{15/2}$ transitions, respectively. The observed bands in the green region (Figure 2) centered at 525 nm and 550 nm are assigned to the $^2H_{11/2} \rightarrow {}^4I_{15/2}$ and $^4S_{3/2} \rightarrow {}^4I_{15/2}$ transitions respectively, while the bands in the red region (Figure 2), centered at 660 nm, are assigned to the $^4F_{9/2} \rightarrow {}^4I_{15/2}$ transition. A pronounced concentration dependence of the upconverted emission signal was observed. The maximum in the fluorescence signal was obtained for the 10 mol% Er^{3+} doped sample indicating that concentration dependent processes, such as energy transfer, are responsible for the upconversion emission.

Possible mechanisms leading to the population and relaxation of several excited states are proposed and discussed.

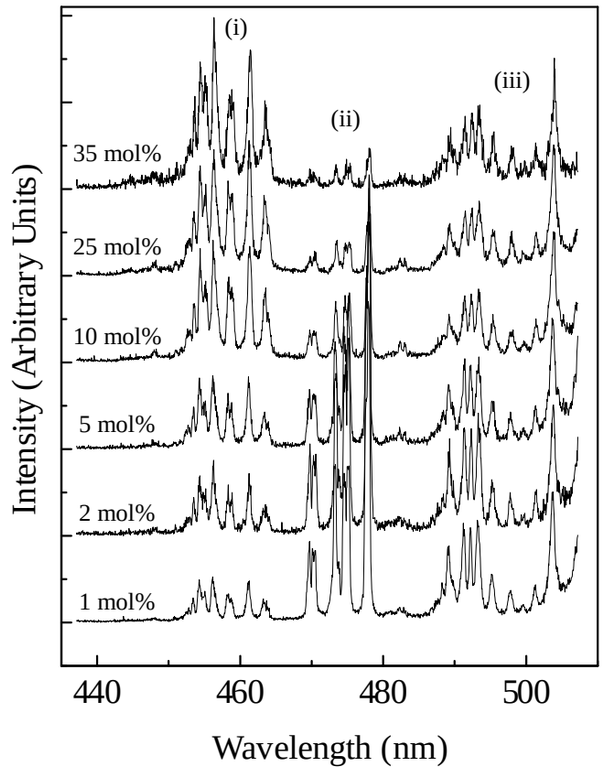

Figure 1: Upconverted emission of bulk $Y_2O_3:Er^{3+}$ at room temperature, showing (i) $^4F_{5/2} \rightarrow {}^4I_{15/2}$ (ii) $^2P_{3/2} \rightarrow {}^4I_{11/2}$ (iii) $^4F_{7/2} \rightarrow {}^4I_{15/2}$ transitions (λ_{exc} = 980 nm)

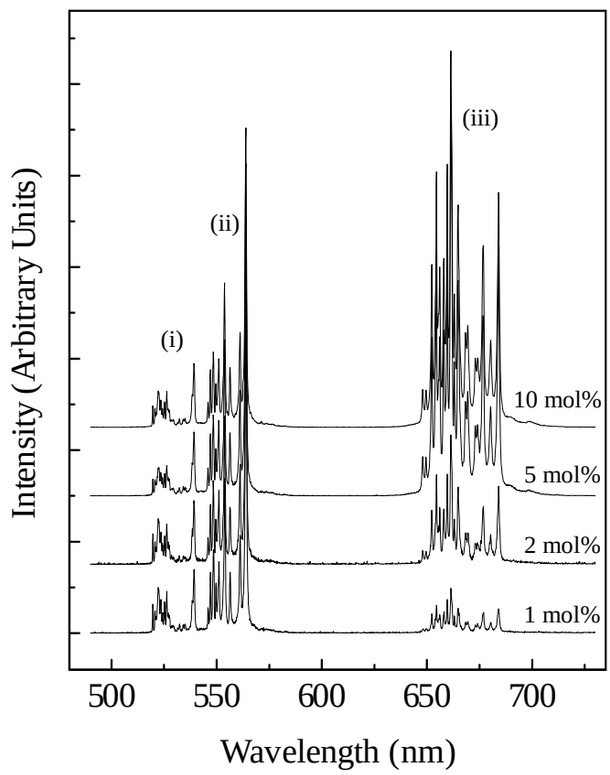

Figure 2: Upconverted emission of nanocrystalline Y_2O_3: Er^{3+} at room temperature, showing (i) $^2H_{11/2} \rightarrow {}^4I_{15/2}$ (ii) $^4S_{3/2} \rightarrow {}^4I_{15/2}$ (iii) $^4F_{9/2} \rightarrow {}^4I_{15/2}$ transitions (λ_{exc} = 980 nm)