Fabrication and Spectral Investigation of Y_2O_3:Nd^{3+} Nano-Particles

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We have synthesized the Y_2O_3 (yttria) nanopowders with various Nd^{3+} concentrations (0.5, 1, 2, 5, and 10 %) by using thermal decomposition method and investigated the effect of annealing temperature on the particle size and the effect of particle sizes on the spectroscopic properties of these systems. The particle sizes were effectively controlled by synthesis and annealing temperatures; they were found to vary in the 15 – 290 nm range. The particle sizes and the cubic phase of the yttria were determined by using XRD patterns and confirmed by SEM and TEM measurements. A typical TEM image is shown in Figure 1. We noted that the particle size increases by increasing the synthesis and annealing temperatures.

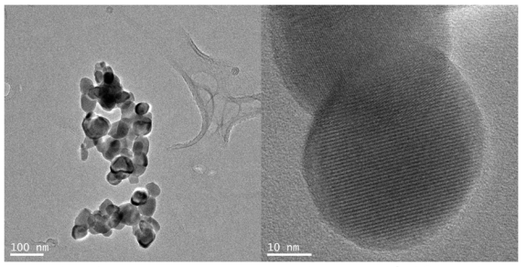

Figure 1: Representative TEM image of 1% Nd-doped Y_2O_3 naonparticles annealed at 1000 °C.

Continuous luminescence spectra were acquired under excitation with a laser diode operating at 803 nm. We observed the Nd emission in the spectral range between 850 and 1100 nm. The luminescence at room temperature is shown in Figure 2. All emission lines shown originate from the $4F_{3/2}$ manifold.

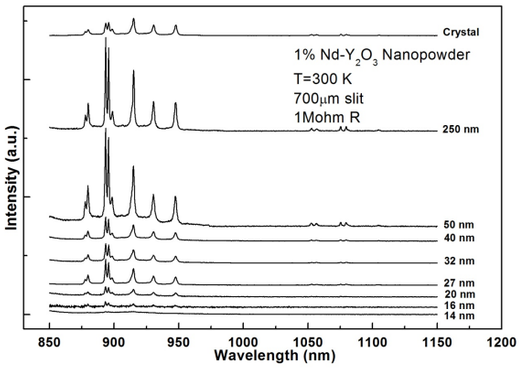

Figure 2. Room temperature emission sepctrum of Nd:Y_2O_3 under excitation at 803 nm.

In order to learn something about the sites at which the Nd atoms reside, we made a comprehensive line width and line shift investigation. For the linewidth study we chose the 893.5 nm line ($^4F_{3/2}$ (R_1) to $^4I_{9/2}$(Z_1) transition), and for the line shift study, we chose the 915 nm line ($^4F_{3/2}$ (R_1) to $^4I_{9/2}$(Z_1) transition). The temperature dependence of the width and position of a selected spectral line were successfully fit with the theoretical expressions. The linewidth results are shown in Figure 3.

The results show, as expected, that the linewidth increases as particle size decreases, presumably due to the increasing role of the surface as the size of the nanoparticles decrease.

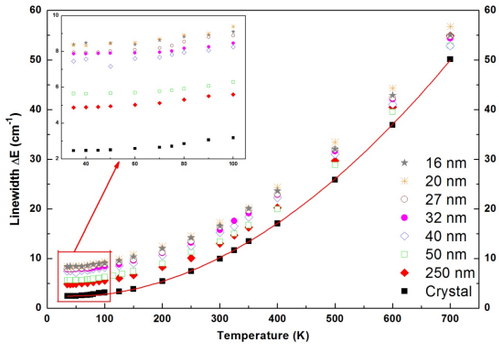

Figure 3. The temperature dependence of the linewidth of the $^4F_{3/2}$ (R_1) to $^4I_{9/2}$(Z_1) line for different particle sizes.

Finally, we studied thoroughly the response of the decay of the $^4F_{3/2}$ emission under pulsed excitation between 33K and 700K. The decay patterns at 600K for five different particle sizes, as well as for a sing crystal, are shown in Figure 4. As can be seen, the decay pattern in non-exponential for all the nanoparticles, and is a pure exponential for the single crystal. The decay patterns for the nanoparticles show an unusually long lifetimes at longer times, and some of their decay patterns even cross that of the single crystal. We will offer gave plausible explanations of the measured effects.

We also measured the lifetimes of the $^4F_{3/2}$ level of Nd at different concentrations (0.5, 1, 2, 5, 10 %). We observe that the lifetimes become shorter with the increasing concentration, evidence of the concentration quenching of luminescence. We also observe that the Nd-activated nanopowders are less prone to concentration quenching than their bulk counterparts.