The low temperature effects on up-conversion emission of Er^{3+}/Yb^{3+} co-doped Y_2O_3

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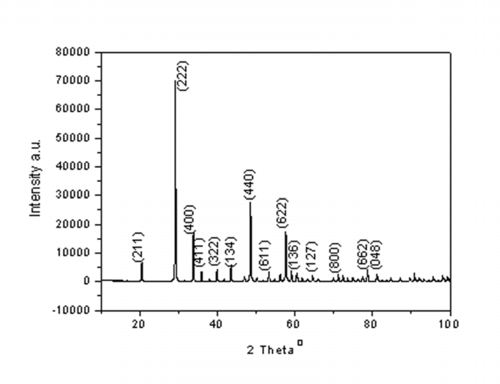
Abstract Rare Earth (RE^{3+}) ions doped materials have been attracted a great deal of interest due to the potential application as optical temperature sensors. Luminescence properties of these materials are sensitive and changeable with the temperature. Here, we have investigated yttrium oxide co-doped with Yb^{3+} and Er^{3+} that was synthesized through spray pyrolysis method at 900 °C and afterwards additionally thermally treated at 1100 °C for 24h. Structural and morphological characterizations were done through X-ray powder diffraction (XRPD) and scanning electron microscopy (SEM). The obtained particles are spherical in shape and crystallized in cubic bixbyte structure with the space group Ia-3. Photoluminescent measurements (PL) were recorded in the temperature range from 10 K to 300 K using the 978 nm exciting wavelength. Emission spectra are assigned to the following trivalent erbium f-f electronic transitions: $^2H_{9/2} \rightarrow {}^4I_{15/2}$ (blue: 407-420 nm), ($^2H_{11/2}$, $^4S_{3/2}$) → $^4I_{15/2}$ (green: 510-590 nm), and $^4F_{9/2} \rightarrow {}^4I_{15/2}$ (red: 640-720 nm). The fluorescent intensity ratios of the blue, green and red areas under emission bands show significant temperature sensitivity, with the largest value of 2.3 K^{-1}.

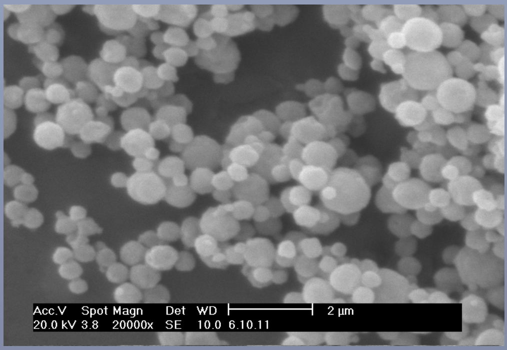
Structural and morphological characteristics



The X-ray diffraction pattern of $Y_{1.97}Yb_{0.02}Er_{0.01}O_3$ powder thermally treated at 1100 ^{0}C for 24h

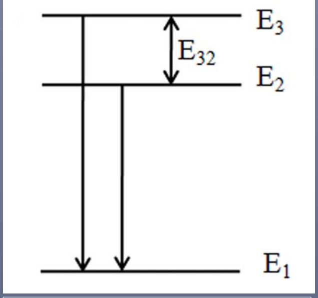
The sample exhibits a cubic bixbyte crystal structure with the space group *Ia-3*. Peaks positions correspond well to the reported ones of $Y_{1.88}Yb_{0.12}O_3$ (PDF 87-2368).

Particles are spherical, sub-micronic and un-agglomerated. After they being thermally treated for 24h, spherical shape has been preserved although at several places formation of "necks" were detected but it's not typical for the sample.



SEM image of $Y_{1.97}Yb_{0.02}Er_{0.01}O_3$ particles obtained through spray pyrolysis

Thermografic properties

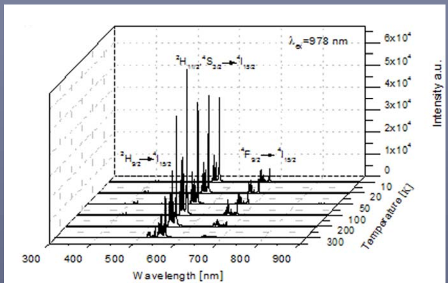


Simplified three energy level diagram

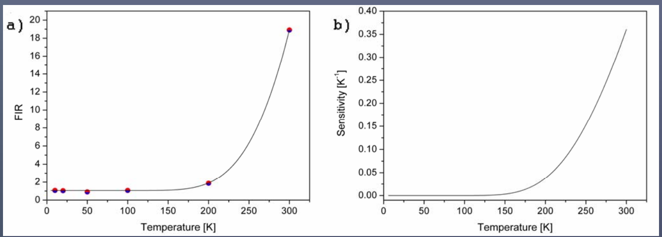
$$R = \frac{I_{31}}{I_{21}} = C \exp\left(-\frac{E_{32}}{kT}\right)$$

$$S = \left|\frac{dR}{dT}\right| = R\left(\frac{E_{32}}{kT^2}\right)$$

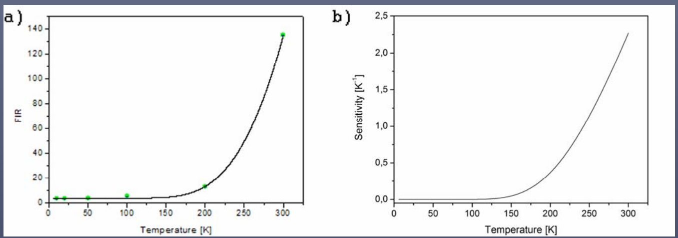
The fluorescence intensity ratio (FIR) method is based on comparison of two emission lines or the ratio between the intensities of the areas that shows temperature dependence in observed temperature range. The FIR measurement technique involves using the fluorescence intensities from energy levels with a small separation of order i.e. "thermally coupled" ones, since they are of particular interest in the low temperature sensing.



Up-conversion emission spectra for $Y_{1.97}Yb_{0.02}Er_{0.01}O_3$ sample over a temperature range 10-300 K (λ_{ex}=978 nm)



Intensity ratio of $Y_{1.97}Yb_{0.02}Er_{0.01}O_3$ for red/blue (a) temperature dependence sensitivity for red/blue ratio (b)



Intensity ratio of $Y_{1.97}Yb_{0.02}Er_{0.01}O_3$ for green/blue (a) temperature dependence sensitivity for red/blue ratio (b)

Conclusion Observed temperature dependence exposed through comparison of red/blue and green/blue emission ratios implies impressive sensitivity: **0.35 K^{-1}** for red/blue and **2.3 K^{-1}** for green/blue ratio.

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