Broad NIR and visible emission from rare earth doped SiO_2-Nb_2O_5 nanostructured materials prepared by an alternative sol-gel route

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Among the preparation methods, the Sol-Gel process has been successfully used for obtaining a wide range of rare earth doped materials. Ordinarily, the sol-gel route employs metal alkoxide precursors, such as niobium ethoxide.[1] Nevertheless; these precursors normally are very sensitive to moisture. In view of that, this study focuses on the preparation and structural and spectroscopic characterization of Er^{3+}-, Yb^{3+}-, and Eu^{3+}-doped and co-doped (100-x)SiO_2-xNb_2O_5, using optical grade Nb_2O_5 as an alternative precursor instead of niobium ethoxide. The Nb_2O_5 was dissolved in HCl, followed by drying with addition of anhydrous ethanol and rare earth ions. TEOS, anhydrous ethanol, and HCl were prepared in a separate container. The Nb_2O_5 and SiO_2 precursors were mixed and the resulting sols were maintained at room temperature for 60 days. Lastly, the xerogels were triturated to powder and annealed at 700 ºC, 900 ºC, and 1100 ºC. The Nb_2O_5 crystallization was depended on the annealing temperature and Nb content, with the lanthanide ions distributed in the Nb_2O_5-rich environment preferentially, which affected the luminescent properties. The effect of the annealing temperature on the Nb_2O_5 crystallization process was assessed for the Er^{3+}/Yb^{3+} co-doped 70Si:30Nb nanocomposites. An amorphous material emerged at 700 ºC, whereas the orthorhombic (T-phase) and monoclinic (M-phase) Nb_2O_5 phases arose at 900 ºC and 1100 ºC. The NIR emission spectra of the samples showed a broadband with a maximum around 1530 nm corresponding to $^4I_{13/2} \rightarrow {}^4I_{15/2}$ transition of Er^{3+} ions when excited at 980 nm radiation. Full width at half maximum (FWHM) of 52 and 67 nm and $^4I_{13/2}$ lifetime values of 5.6 and 5.4 ms were verified at 1.5 µm for 700 ºC and 900 ºC, respectively.[2] For the Er^{3+}/Yb^{3+} co-doped (100-x)SiO_2-xNb_2O_5 nanocomposites annealed at 900 ºC the FWHM and the $^4I_{13/2}$ lifetime values were as high as 70 nm and 5.2 ms. The visible emission from upconversion processes also depended on the Nb content. For lower Nb concentrations, emission occurred mostly in the green region, whereas cross-relaxation enhanced the red emission for higher Nb concentrations. For the Eu^{3+}-doped nanocomposites annealed at 900 ºC a quantum efficiency values up to 71 % was calculated, where the Eu^{3+} are found distributed in different symmetry sites. In conclusion, photonic materials with excellent optical properties were developed, which paves the way for the applications such as optical amplifiers at 1.5 µm, solid-state lasers, energy converters and phosphors.

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