EFFICIENT LUMINESCENCE RESPONSE FROM NANOSCALE CONTROLLED Er-Yb DISTRIBUTION IN Al_2O_3 WAVEGUIDES

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The development of photonic circuits for optical communications requires the fabrication of integrated waveguide amplifiers operating at the standard wavelength of 1.5 μm. Gain devices integrated on Si platforms with typical lateral dimensions in the micrometer range are desired, and significant response after only few centimetres is required. It is therefore necessary to develop waveguides with an efficient photoluminescence (PL) emission around 1.5 μm and low propagation losses.

Er^{3+} doped oxide waveguides are commonly used for this purpose because of the optical transition of Er^{3+} at 1.54 μm. Nevertheless the performance of only-Er doped materials is somehow limited by the small absorption cross-section of Er^{3+} ions. This limitation can be overcome by co-doping the oxide matrix with Yb^{3+} that has an absorption cross-section about one order of magnitude higher than that of Er^{3+} when excited around 975 nm and is able to tranfer resonantly energy to Er^{3+}. The rare-earth concentration and distribution within the waveguide become key factors in order to optimize the luminescent response, and ultimately to achieve gain.

The aim of this work is to show that an efficient PL response can be achieved in Er-Yb codoped Al_2O_3 waveguides by controlling the Er and Yb relative concentrations and at the same time controlling the rare-earth distribution in the nanoscale. Planar waveguides were prepared by pulsed laser deposition at room temperature onto Si substrates covered with a 10 μm-thick SiO_2 buffer layer. Three independent Al_2O_3, Er and Yb targets were ablated following the sequence [a-Al_2O_3/(Yb-doped layer/a-Al_2O_3/Er-doped layer/a-Al_2O_3/Yb-doped layer/a-Al_2O_3)$_{150}$]. The total thickness of the deposited films was of the order of 1μm. The amount of each deposited species was controlled by adjusting the number of laser pulses per deposited layer on the appropriate target. The separation between Er and Yb deposits has been chosen to be 1 nm in order to optimize energy transfer between Yb^{3+} and Er^{3+} ions, whereas the separation between subsequent Er deposits that was controlled through the last a-Al_2O_3 layer of the sequence has been set to 7 nm in order to minimize concentration quenching by Er-Er interactions. The content of Er per layer is constant and in the order of 10^{20} ions /cm^3, and samples with relative Yb/Er content of 2, 4 and 8 have been prepared. Channel waveguides with a width from 1 to 5 μm have been produced on those planar waveguides by reactive ion etching (RIE).

The results show that the 1.5 μm photoluminescence of Er-Yb co-doped waveguides is always higher than that of Er-only doped ones upon pumping at 975 nm. As prepared planar waveguides show low intensity and lifetime (~1 ms) values. Improvement of the photoluminescence intensity and lifetimes ≥ 4 ms have been achieved after annealing. The possibility to achieve net gain in these Er-Yb codoped and nanostructured waveguides will be finally discussed. This work was partially supported by EU project PI-OXIDE (IST-NMP-017501).