Rare Earth Sensitization in Si-based Structures for Photonic Applications

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The discovery of the quantum confinement effect of carriers in nanometer sized Si clusters (Si-ncls) and their efficient sensitization of Rare earth ions (RE) have paved the way of a wide range of application in microelectronics, photonics and more recently, in photovoltaics. Intense efforts have been focused on the study of the coupling Si-ncls:RE such as Er^{3+} because of a promising solution to gather electrical and optical efficient components on the same wafer compatible with the CMOS technologies. However, the most commonly addressed Si-based nanostructure such as Silicon-rich Silicon Oxide doped with Er^{3+} ions does not show till now a relevant net optical gain allowed the possible transfer of the technology to the industry. This can partially be attributed to numerous losses processes (cross relaxation processes, the confined career absorption, reabsorption process etc…,) occurring in such optical devices. It is worth to note also that the sensitizing of RE ions can be achieved not only via Si-ncls, but also via other radiative channels that can open potential solar cell applications.
The aim of this talk is to give an overview of our recent results achieved on rare earth doped Si-rich based matrices produced by reactive magnetron sputtering for Si-based light emitting materials or frequency converter layers. To overcome the losses problem of "Er^{3+}-SiO_x layers, our team has focused its research on Nd^{3+}-doped Si-based matrices. The feasibility of an optical Nd-doped amplifier has been analyzed through the modelling of the excited structure by an Auxiliary Differential Equation (ADE) and a Finite Difference Time Domain (FDTD) method. Two pumping configurations have been investigated: i) top-pumping and ii) co-propagation of pump and probe. The results show that the co-propagation configuration does not allow to the pump to propagate along the waveguides while the top-pumping one leads to more homogenous repartition of power in active layer (Figure 1). Gain of about 3 $dB.cm^{-1}$ at 1064 nm can be expected in Nd- doped systems. Pump and probe experiments have been carried out and will be detailed.

Concerning solar applications, we focused our interest on the development of down converting layers compatible with the solar cell industry process. Based on the efficient sensitization of rare earth ions in Si-based host matrices, we have developed Tb^{3+}-Yb^{3+} co-doped SiN_x thin films to overcome the low absorption cross-section of the lanthanide ions in glasses. After achieving a strong emission of Tb^{3+} ions by optimizing the deposition parameters to enhance the coupling between RE ions and Sensitizers, Yb^{3+} ions have been incorporated to this system. Its optical properties have been investigated by time resolved- and excitation- photoluminescence experiments as a function of the Tb^{3+} and Yb^{3+} contents. Typical photoluminescence spectrum obtained is presented on Figure 2. The excitation mechanisms of the different RE ions will be discussed and the demonstration of the achievement of an internal quantum efficiency as high as ~190% will be given.

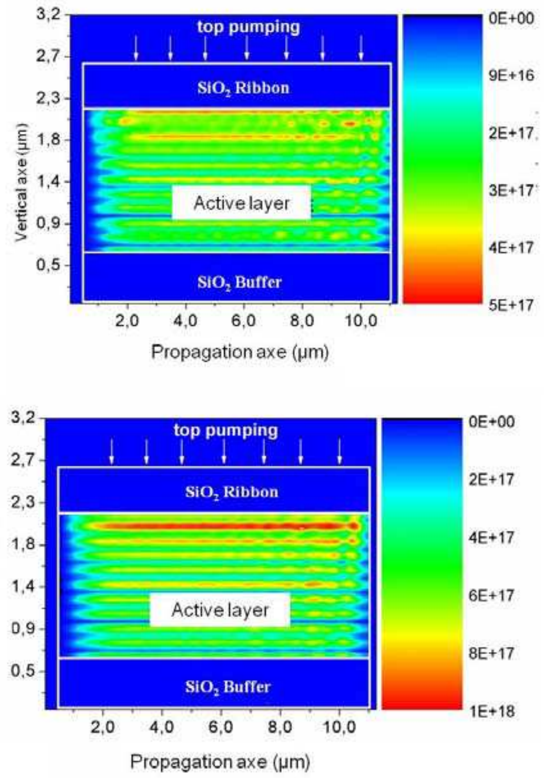

Figure 1 : Exciton population (cm^{-3}) (up) and Nd^{3+} population in the $^4F_{3/2}$ level (down) along the propagation axe of the waveguide.

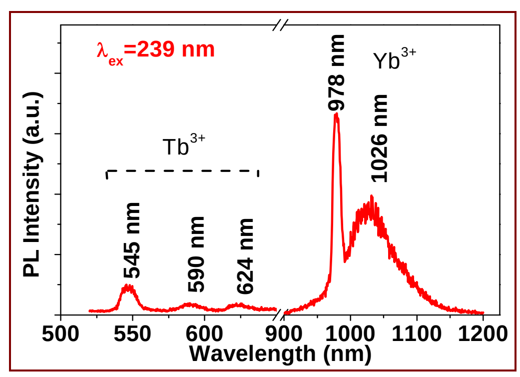

Figure 2 : Photoluminescence spectrum of the Tb-Yb system.

This work is supported by French National Agency (ANR) through Nanoscience and Nanotechnology Program (Project DAPHNES n°ANR-08-NANO-005), and by the DSM (Material Science Department) through Energy Program (Project HOFELI).