Si nanoclusters coupled to Er^{3+} ions in a SiO_2 matrix for optical amplification

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One of the scientific and technological challenges of silicon–based photonics consists in making silicon an efficient light emitter that can also provide amplification. This will allow combining both the functionality of silicon microelectronics with ultra-fast optical data generation, processing and transmission on a single silicon-based device.

Low dimensional silicon in the form of silicon nanoclusters (Si-nc) is a material with extremely interesting optoelectronic properties that differ strongly from those of bulk Si. In particular, the capacity of Si-nc to act as sensitizers of rare earth ions, specifically erbium ions (Er^{3+}) [1], has opened the route towards an all-optical or electrically pumped Si based light amplifiers operating in the third telecommunication window. However, during the last years, several reports have shown what seems to be an intrinsic limit of the material itself, which is the low content of Er^{3+} taking advantage of an efficient indirect transfer mechanism [2-4].

We will focus our presentation on two studies that are crucial for the understanding and optimization of the performances of this material, in particular for samples produced by reactive magnetron co-sputtering:

i) An experimental characterization of the interaction mechanism process between excited Si-nc and Er^{3+} ions by means of fast time-resolved photoluminescence measurements. This study has revealed a Dexter type fast (less than 100ns) transfer mechanism. The energy released through a carrier intraband transition within the conduction band of the Si-nc excites the Er^{3+} ions nearby to the Si-nc surface mainly to the $^4I_{11/2}$ level [5], as it can be understood from the scheme shown in figure 1.

ii) A study on the quantification of the different concentrations that determine the potentiality of the material for light amplification, which are: the total content of erbium present in the material; the concentration of ions that are optically active; the concentration of ions that are optically active and emit light; and the concentration of ions that are efficiently coupled to the Si-nc and emit light efficiently. We demonstrate the highest to date fraction of optically active Er ions coupled to Si-nc (» 52%), which produces an internal gain in waveguide samples of about 1dB/cm at 1.55μm.

References

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Figures

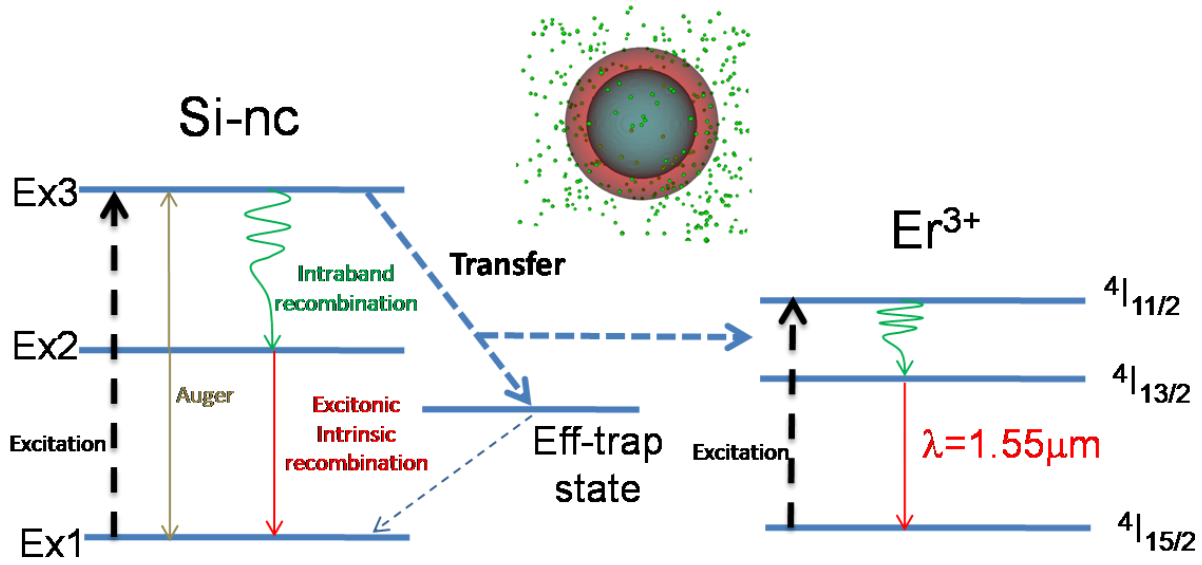

Figure 1. Scheme of the levels and transitions involved in the transfer mechanism