Toward the realization of an efficient Si-based light source emitting at 1.55 μm

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For several years, silicon-based photonic devices have been widely considered in order to develop integrated circuits allowing to overcome the microelectronic bottlenecks. The challenge for silicon photonics is to manufacture low-cost information processing components by using standard and mature CMOS technology. Numerous photonic devices have already been developed in the last years for light propagation, modulation or detection on silicon substrates. The ultimate goal for the photonic and electronic convergence would be to monolithically integrate powerful Si-based light sources into the CMOS photonic integrated circuits.

Some encouraging works have reported the possibility to obtain efficient Si-based light emitting diodes [1,2,3]. Even stimulated emission by optical pumping of an Er doped Si-based material has been reported [4], but some effort have still to be pursued in order to increase the emitted power, and achieve the realization of an injection Si-based laser.

In this work, we report a systematic study of the electroluminescence (EL) properties and mechanisms of Si-rich silicon oxides doped with Er ions, by correlating the study of transport mechanisms and electroluminescence spectra. Three different techniques have been used to fabricate the active layer: LPCVD, PECVD, and ion implantation. Different Si excess were introduced, and various annealing treatment were performed in order to form Si nanoclusters (Si-nc) from the SRSO layers. Those nanoclusters are known to have an enhanced radiative emission in the visible respect to bulk when they are crystalline due to quantum confinement (figure 1a), or act as efficient sensitizers for the luminescence of Er ions at 1.5 μm when they are amorphous (figure 1b). A total of about 20 different wafers have been processed.

The devices were excited in DC excitation. We find that the three techniques of deposition give different power efficiency that we attribute to the different matrix defect concentration induced by each technique. Two kinds of transport mechanisms could be observed in function of the annealing treatment. In one case, the transport is made by hopping from Si-nc to Si-nc and low EL power is obtained. In the other case, the injection of hot electrons is observed, as suggested by the I-V characteristics (see figure 2), leading to a higher EL power of some 0.1-1 μW at 1.5 μm, that we attribute to direct impact excitation of the Er ions by the injected electrons. In order to achieve optical gain for the realization of a Si-based laser, the number of inverted Er ions has been estimated. In the best case, it has been possible to invert about 10% of the Er population. Some improvement is finally proposed to increase the optical power by the use of AC excitation.

References

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Figures

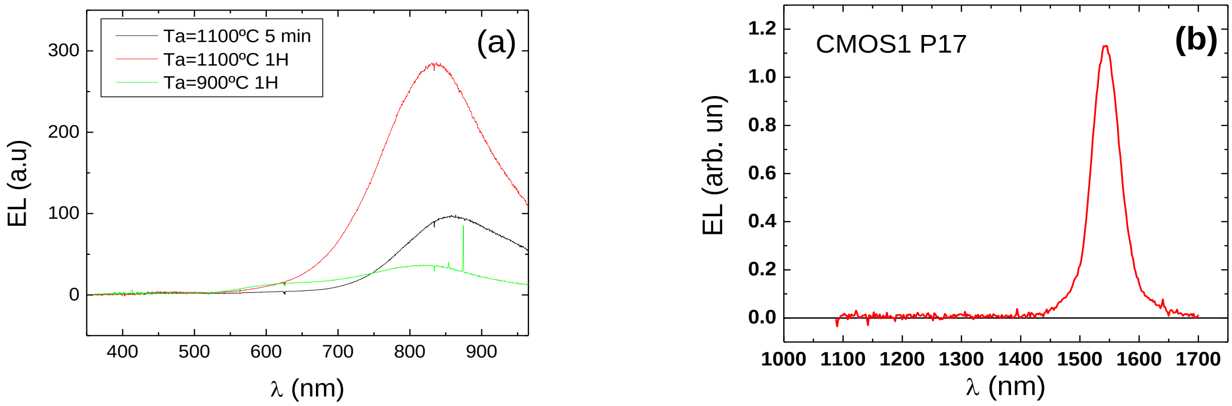

Figure 1 : Electroluminescence spectra of a) Si nanocrystals b) Er ions sensitized by Si nanoclusters.

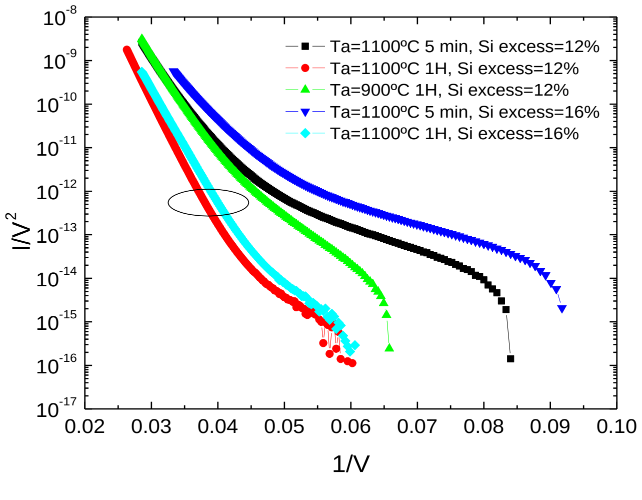

Figure 2 : Fowler-Nordheim representation of the I-V characteristics, suggesting direct impact excitation of the Er ions.