Luminescence of SRSO and SRSN gradient thin films

V. Donzella[1,2], P. R. J. Wilson[2], K.A. Dunn[2], J. Wojcik[2], and P. Mascher[2]

[1]*Scuola Superiore Sant'Anna, piazza Martiri della Liberta' 33, 56100 Pisa, Italy*
[2]*Department of Engineering Physics, McMaster University, Hamilton, ON, Canada L8S 4L7*

So far the feasibility of monolithically integrated Si optoelectronics has been hindered by the lack of practical Si light emission. However, recently several efforts have converged in fabricating silicon based materials that are able to emit light. One of the more promising approaches is to reduce Si's dimensionality to nanometer scales, where both quantum confinement and surface chemistry effects improve the efficiency of light generation. This approach has focused the attention on silicon nanocrystals (Si-ncs) and nanonclusters (Si-ncls), providing interesting results in terms of efficient light emission. There is, however, still a variety of open issues. In particular an active material, useful to build active devices, such as amplifiers and lasers, has still to be chosen and likely optimized.

In this study silicon rich silicon nitride (SRSN) and silicon rich silicon oxide (SRSO) thin films were deposited by Inductively Coupled Plasma Chemical Vapour Deposition (ICP-CVD). In particular during the depositions the concentration of N_2 or O_2 have been varied, by gradually changing the deposition atmosphere, in order to achieve films with composition gradients, meaning that the composition of the films varies along their thickness. Three different kinds of gradient film were achieved. In one case the concentration of nitrogen or oxygen is a maximum at the bottom of the films and decreases going towards the top of the films, in another case it is a maximum at the top and decreases going towards the bottom, and in the last case the concentration is a maximum at the bottom and at the top and is a minimum in the middle of the films, and decreases and increases consequently. Post-deposition the films were thermally annealed for two hours in a quartz tube furnace, under the flow of different gases (i.e. Ar, Ar+5%H_2, N_2+5%H_2) and at various temperatures (from 600 to 1200˚C with steps of 100˚C). The final properties of the thin films, as determined by RBS measurements, strongly depend on the processing conditions.

The emission properties of the annealed films were characterized through ultraviolet photoluminescence (PL) measurements with a 17 mW HeCd laser (at 325 nm) excitation source, and compared with the emission of as deposited (AD) samples, which showed almost no luminescence. The annealed films showed various PL spectra, and in some cases the luminescence is due to defects, in other cases it is likely due to the formation of nanostructures of silicon. The SRSN and SRSO films behave very differently, and their PL has a different dependence on the annealing temperature. On the other hand films based on the same material but with different composition gradients act likewise with respect to the wavelength emitted, but in some films the emission is brighter. These findings suggest the exciting possibility of realizing optimized films, on the basis of specific performance criteria: bright photoluminescence, electroluminescence, wavelength of interest, or transmission of excitation to rare earths.

E-mail: v.donzella@sssup.it