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Photoluminescence in silicon based multilayers grown by PECVD technique

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Abstract – In order to study the photoluminescence (PL) in silicon based nanostructured films two different silicon based multilayers systems were produced by PECVD, alternating a-Si:H layers with either SiO_2 or Si_3N_4,layers, and characterized by RBS, Raman, FTIR, XANES, PL and HRTEM. The multilayers present intense PL in the visible region in counterpart to bulk amorphous silicon, SiO_2 and Si_3N_4. The observed PL results are compatible with quantum confinement in the amorphous silicon layer combined with interface effects. After heat treatment at 1000°C, the PL is centered at 1.8 eV for both systems, result attributed to Si nanocrystals observed by HRTEM.

Since the observation of intense visible photoluminescence (PL) at room temperature in porous silicon by Canham [1], silicon-based nanostructured materials with PL in the visible spectra have being intensively studied. Nowadays, research in optoelectronics demonstrates challenging problems of materials compatibility since optoelectronic applications are based on group III-V materials.. In this way, fabrication of light emitting devices utilizing materials compatible with current silicon technology is a way to permit the integration of microelectronics and optical devices in a same chip [2]. High optical efficiency has been demonstrated in low dimensional silicon system such as porous silicon, silicon nanocrystals embedded in high gap dielectric matrix and silicon/insulator superlattices. Even though numerous research studies have succeeded in reaching this goal, there remains considerable uncertainty on the mechanism responsible for the PL in these materials. Some authors attribute the PL to quantum confinement effects others to interfacial effects at nanocrystal surfaces. In previous work we demonstrated intense PL in silicon rich SiO_xN_y with energy emission related to the silicon excess [3]. The results were consistent with confinement effects in the amorphous silicon clusters dispersed in the oxynitride matrix however interface effects were not discarded. In order to analyze separately the interface and confinement contributions in the photoluminescence two types of silicon multilayer, one of a-Si:H/SiO_2 and the other of a-Si:H/Si_3N_4 were produced by the PECVD technique. The amorphous silicon layer thickness was controlled in 2nm, 5nm, 10nm and 15nm while the dielectric layer thickness was kept constant in 15nm for both multilayer systems, as can be appreciated in the HRTEM image for the 2nm a-Si:H/SiO_2 sample shown in fig. (a).

The PL was measured in the samples as deposited and after annealing. Both multilayer systems present intense PL as deposited for silicon layer thickness lower than 15 nm. This behavior enforces the confinement effect in the multilayer. The energy emission in the a-Si:H/SiO_2 is centered at 1.9 eV and shifts to 1.8 eV for increasing silicon layer thickness as observed in fig (c), for the a-Si:H/Si_3N_4 the emission is centered at 1.9 eV and does not change with the silicon layer thickness. The different behavior in these two systems indicates that it might be related to the different interface utilized in each system. After heat treatment, as observed by Raman and confirmed by HRTEM (fig (b)), silicon nanocrystals formation occurs, the PL in the multilayers remains fixed at the same energy value. The hypothesis for this result, supposing individual silicon nanocrystals in the layer, is that the PL could be related to quantum confinement in the nanocrystals. Also the results demonstrate that through the deposition process is possible to control the PL emission, which is attractive for optical applications.

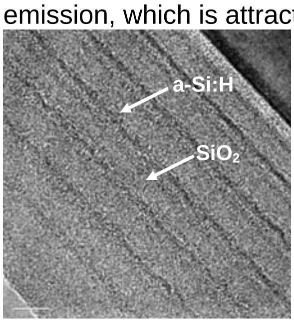

Fig. (a) HRTEM image of the as deposited 2nm a-Si:H/SiO_2 multilayer.

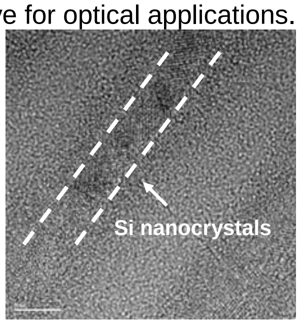

Fig. (b) HRTEM image of the multilayer with crystallized areas as indicated by the lines.

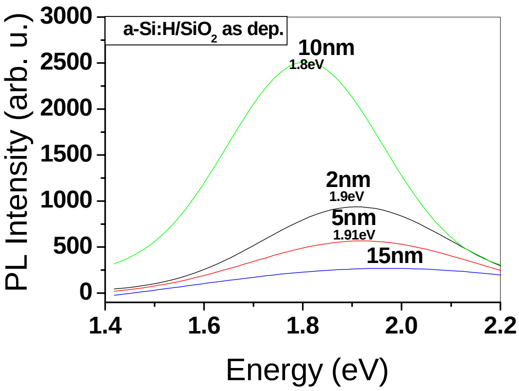

Figure (c) PL of as deposited a-Si:H/SiO_2 multilayer

[1] L.T.Canham. Appl. Phys. Lett. 57 (1990) 1046.
[2] J. Faist , Nature 433 (2005) 691.
[3] M. Ribeiro, I. Pereyra and M.I. Alayo. Thin Solid Films 426 (2003) 200.