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SiO_2/Si interface nanostructuration by co-diffusion of Pb and Se

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Abstract – We have recently developed a method to produce high densities of metallic nanoislands along SiO_2/Si interfaces. The method comprises the ion implantation of metallic species within the oxide layer followed by high temperature annealing. The diffusion of the host atoms towards the SiO_2/Si interface result in islands-like nanostructuration. In this work we extend this technique to produce compound semiconductor nanoislands of PbSe via Diffusion Trough Oxide (DTO) and solid state chemical reactions.

Our group has recently developed a method to nanostructurate SiO_2/Si interfaces via room temperature ion implantation followed by high temperature thermal annealing [1,2]. According to this process, the ions are implanted within the SiO_2 film. Upon annealing, a fraction of the implanted atoms migrates toward the SiO_2/Si interface that works as a diffusion barrier. The accumulation of the atomic species along a single plane results in the precipitation of nanoislands. In the present work we extend our investigations by studying the synthesis of compound nanoislands of PbSe. This semiconductor material presents potential characteristics for photovoltaic, photonic and sensors applications.

In our experiment, Pb + Se co-implantations were performed sequentially in a thermally growth 190 nm thick SiO_2 layer in (001) Si substrates. The samples were then submitted to thermal treatments at 1100 ^oC for 1 h. Rutherford Backscattering Spectrometry (RBS) was used to study the thermal diffusion and depth concentration of the atomic species. Transmission Electron Microscopy in image and Electron Dispersive Spectroscopy (EDS) modes was performed to characterize the microstructure. The RBS results show that the thermal treatment causes a redistribution of the co-implanted elements with evident accumulation at the interface. The TEM investigation revealed the formation of discrete depth distributions of spherical precipitates within the SiO_2 layer and nanoislands at the interface with Si. By EDS analysis we have detected Pb and Se in single precipitates and islands thus evidencing the formation of the PbSe compound. Fig. 1 illustrates the results by showing the RBS spectra of the annealed samples superimposed to a TEM image. The accumulation of Pb and Se at the interface (peaked at ~190 nm depth) is strongly correlated to the formation of the islands. Fig. 2 shows a diameter versus height graph superimposed to a high resolution TEM image of a single island. Notice the exceptionally regular aspect ratio of the structures. X-ray diffractometry, plan-view TEM imaging and electron diffraction are currently undergoing to further characterize the structures.

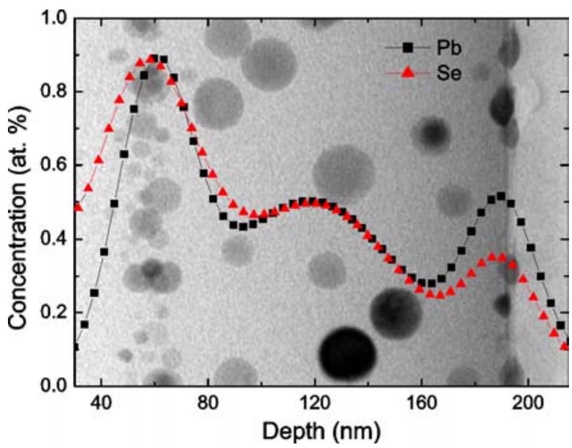

Figure 1: RBS spectra superimposed to a TEM image. It provides an overview of the microstructure and atomic concentration distribution. The peak at ~190 nm refers to the Si/SiO2 interface where the nanoislands are formed.

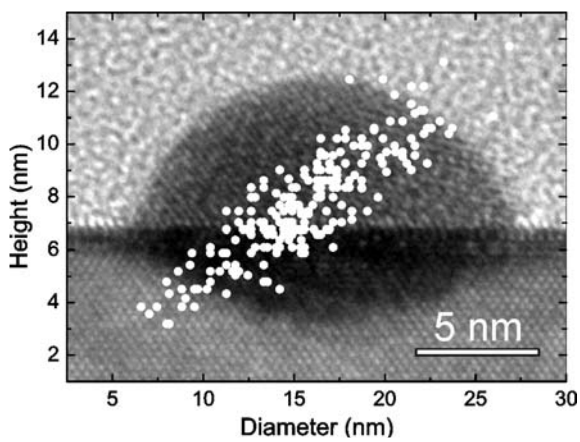

Figure 2. Diameter versus height of the nanoislands superimposed to a HRTEM image. Notice the regular aspect ratio of the structures with medium diameters close to 15 nm.

[1] J. M. J. Lopes, F. C. Zawislak, P. F. P. Fichtner, R. M. Papaléo, F. C. Lovey, A. M. Condó,A. J. Tolley. *Appl. Phys. Lett.* **86**, 191914 (2005).
[2] F. Kremer, J. M. J. Lopes, P. F. P. Fichtner, F. C. Zawislak. *Appl. Phys. Lett.* **91**, 083102 (2007).