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Synthesis and characterization of Pb nanoislands at the SiO_2/Si interfaces via ion implantation and high temperature annealing

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Abstract –High density of Pb nanoislands at SiO_2/Si (001) interfaces has been produced via ion implantation followed by high temperature annealing (T = 1100 ^oC). The formation and morphological evolution of the islands was studied by Transmission Electron Microscopy (TEM). We show that by controlling the annealing time and implantation fluence we are able to manipulate the shape, size and density of the nanostructures.

Techniques to construct and manipulate nanostructures are among the major issues in materials science. In this work, we report on the formation of Pb islands at SiO_2/Si interfaces via Diffusion Through Oxide (DTO) technique. The method is based in the ion implantation of atoms within an oxide layer grown in (001) Si followed by high temperature thermal treatments. The annealing step causes a strong accumulation effect along the SiO_2/Si interface [1, 2] leading to the formation of a dense arrays of nanosized islands. Our technique provides a method to produce islands without the requirements of Ultra High Vacuum (UHV) conditions of depositions methods.

In this work, 150 nm SiO_2 layers thermally grown on a (001) Si substrate were implanted with 225 keV Pb ions from 1 to $2x10^{16}$ cm^{-2} fluence range. The samples were then annealed at T = 1100 ^oC at times ranging from 30 to 180 min. Rutherford Backscattering Spectrometry (RBS) and Transmission Electron Microscopy (TEM) were then used to characterize the specimens.

Figure 1 displays a TEM image of the low fluence sample ($\Phi = 1x10^{16}$ cm^{-2}). After 30 min annealing (Fig. 1a), very small dome-like Pb islands having diameters of ~ 4 nm were formed at the SiO_2/Si interface. The islands are epitaxially matched with the Si lattice and mainly growing within the SiO_2 layer. Increasing the annealing time to 180 min (Fig. 1b), the island presents a considerable penetration in the Si substrate producing a half octahedron with four {111} interfaces, while keeping the dome shape within the oxide. For higher fluences ($\Phi = 2x10^{16}$ cm^{-2} annealed for 180 min) the Pb islands are much larger and evaluated to half truncated-octahedron within the Si substrate. These results are discussed in terms of kinetic and thermodynamical arguments.

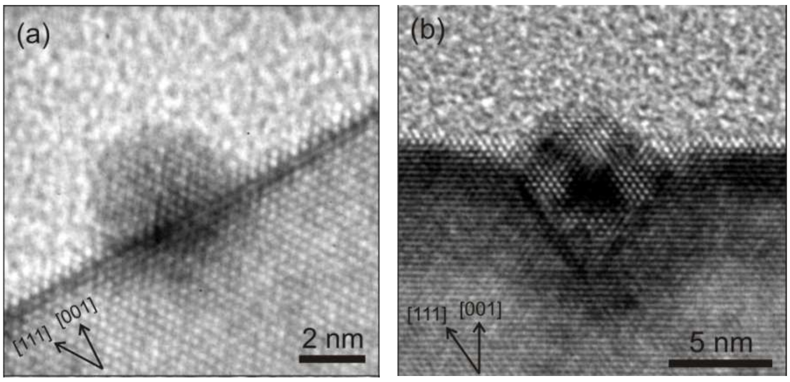

Figure 1: Cross-sectional HRTEM images islands formed after 1100 ℃ annealing (sample implanted to $\Phi = 1x10^{16}$ cm^{-2}). It shows the evolution of the islands from a dome-like shape within the SiO_2 layer after **(a)** 30 min annealing to half-octahedron half-dome morphology after **(b)** 180 min annealing.

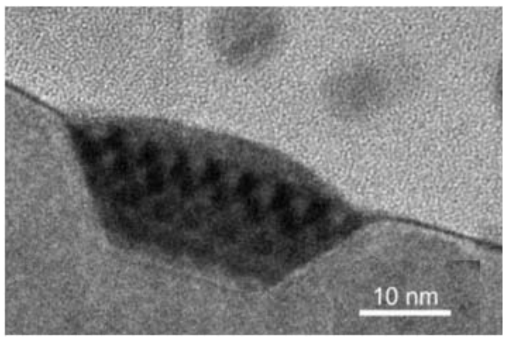

Figure 2: Cross-sectional HRTEM image of a Pb island formed after 1100 ℃ annealing (sample implanted to the fluence of $\Phi = 2x10^{16}$ cm^{-2} annealed at 1100 ℃ for 180 min). The islands have evolved to half-truncated-octahedron morphology.

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