Arrays of SiO_2 Nanoislands Grown Electrochemically on Silicon Through Nanoporous Anodic Alumina Template

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Nanopatterning of thin silicon dioxide layers is interesting in many applications, e.g. in self-assembly of semiconductor nanostructures on silicon [1]. A simple and low-cost technique for the creation of arrays of SiO_2 nanoislands on silicon is anodic oxidation through the pores of an alumina template [2]. In this work, regular arrays of SiO_2 nanoislands were fabricated and characterized by atomic force microscopy (AFM) and Transmission Electron Microscopy combined with Electron Energy Loss Spectroscopy (EELS).

Porous alumina films were fabricated on silicon by anodization of an aluminum film in sulfuric acid aqueous solution [3]. The obtained alumina shows cylindrical vertical pores with diameter of the order of 16 nm, arranged in hexagonal close packed arrays. The density of the pores is of the order of 6-8x10^{10} cm^{-2}. The anodization voltage is kept constant and the anodization current is monitored during the process, so as to determine the end of aluminum consumption (see Fig. 1, dotted line). If then the anodization is not stopped at the exact time when Al is fully consumed, oxidation of the silicon substrate starts at the bottom of each pore, thus creating SiO_2 nanoislands.

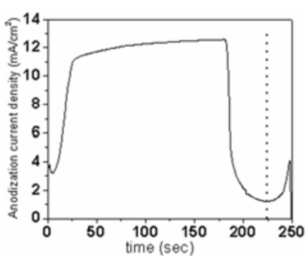

Fig. 1 Anodization current density versus time. The vertical dotted line shows the point where the Al is fully converted into alumina and the oxidation of the silicon substrate starts at the bottom of each pore, creating SiO_2 nanoislands.

The diameter, height and spacing of these nanoislands depend not only on pore diameter of the alumina template but also on the anodization time used. By dissolving the alumina template at the end of the anodization process in phosphoric acid, a structure of well separated SiO_2 nanoislands following the hexagonal distribution of the pores is obtained. An AFM image of such a structure is shown in Fig. 2a, where we distinguish the SiO_2 nanoislands in dense arrays. By using EELS within the TEM, the oxygen 1s peak was mapped and results are shown in Fig. 2b. We see in this figure that the nanoislands were separated from each other. We also used XPS to characterize the stoichiometry of the patterned SiO_2 film.

The SiO_2 layer of nanoislands was used in this work to deposit selectively silicon nanocrystals on areas outside the SiO_2 dots. An example of silicon dots grown on such a substrate is shown in the TEM image of Fig. 3. The density of silicon dots was high. Work is on-going to apply this process in silicon nanocrystals memories.

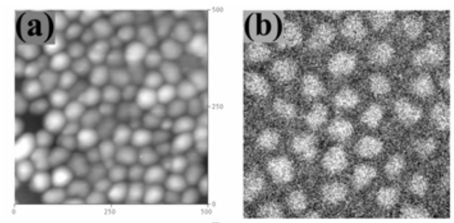

Fig. 2 Stoichiometric SiO_2 nanoislands normally distributed in hexagonal close packed arrays, following the pore distribution of the nanoporous alumina template. In (a) we observe an AFM tapping mode image while in (b) an oxygen mapping image.

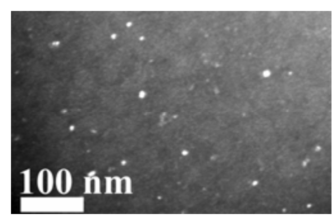

Fig. 3 Dark field TEM image of Si quantum dots grown selectively between the SiO_2 nanoislands.

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