Organized porous alumina membranes for high density silicon nanowires growth

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The future use of nanostructures (carbon nanotubes, quantum dots, nanowires…) in devices will only occur if the growth of these nanostructures is self-organized, with a high density and a good control in terms of dimensions and localization in space. Currently, many nano-objects are made and studied for their fundamental physical properties but these studies are in general done on one or few nano-objects which are rather uncontrolled in terms of direction and localization.
In this paper, we present results on the development of generic high-density (10^{10} cm^{-2}) and self-organized matrix of nanoporous alumina. This matrix will locate and guide nanowires during their growth. Furthermore, the good mechanical, thermal and chemical stability of the matrix should also facilitate their integration in devices. An example of a porous alumina membrane fabricated using a double anodization procedure is shown in Figure 1 (hole period around 92 nm). The corresponding growth of silicon nanowires in this matrix using gold nanoparticles as precursors is presented in the inset of Figure 1 (10 to 50 nm diameter wires) [1]. The use of a porous alumina membrane enables to grow wires on non-aligned substrates (effective growth direction different from the preferential growth direction), with a good regularity and at low cost (compared to top-down lithography approaches). Nevertheless, no long distance order is possible and the double anodization procedure is long.
An alternative is to use nanoimprint lithography (NIL) to localize each pore. NIL is a low cost lithography technique especially suitable for large-area sub-50 nm regular patterning. Here, we use a silicon mold presenting a triangular array of pillars (92 nm period) to imprint a thermoplastic polymer deposited onto an aluminium layer. This polymer layer is then used as a mask to dry etch holes in the top of the aluminium layer. When the anodization voltage is adjusted to the holes period, these holes will initiate the formation of pores in the alumina matrix and give rise, in a single anodization step, to a well organized array of pores. As shown in Figure 2, this method increases significantly the quality of the porous structure and is expected to have a direct impact on the quality (dimension regularity and crystal quality) of the wires obtained by catalytic growth. Additional advantages of this method are the possibility of a very low initial aluminum layer thickness and a perfect control of the positioning and density of the wires.
At the moment, investigations are under progress to analyse the regularity of the super-network of pores, the walls roughness and quality of the silicon nanowires fabricated in such a matrix. Potential direct applications of these regularly grown nanowires include photovoltaic's and optical, X-rays and gamma detectors at very high resolution. In microelectronics, it is also possible to make vertical nanowire transistors with very good control of the quantity, quality and position of nanowires into each device, allowing a very good reproducibility of electrical properties between each transistor.

[1] D. Buttard, T. David P. Gentile, F. Dhalluin, T. Baron, Phys. Stat. Sol. RRL 1, 19 (2009).

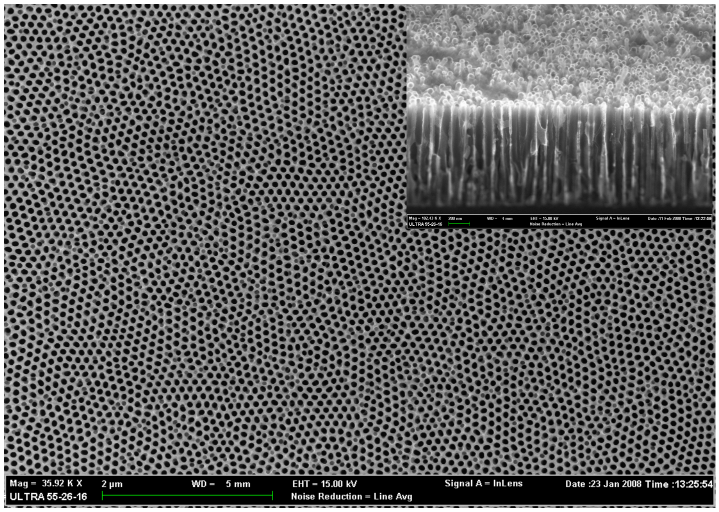

Figure 1: Nanoporous alumina membrane on silicon after a double anodization procedure (inset: catalytic growth of silicon nanowires in the porous membrane)

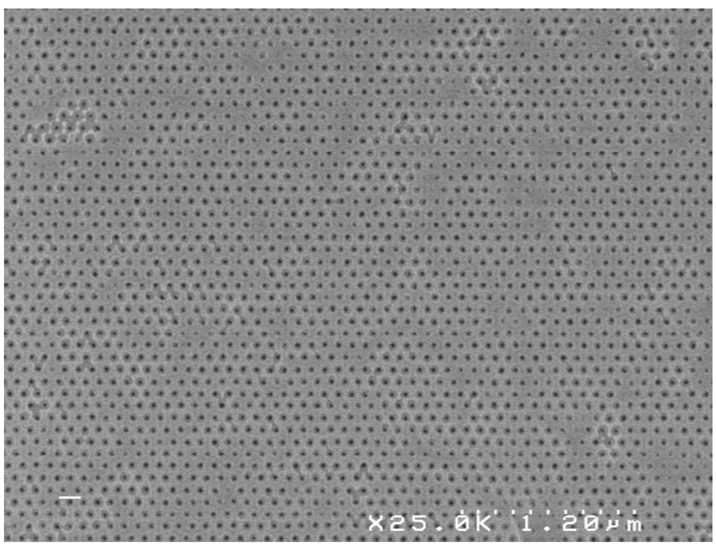

Figure 2: Nanoporous alumina membrane on silicon fabricated using a single anodization procedure and organized by nanoimprint lithography