Nanostructured silicon surfaces by self-assembled nanoporous anodic alumina for photonic applications

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Nanoporous anodic alumina (NPAA)[1] has become a very interesting material in nanotechnology because of its cost-effective production and its geometrical properties that can be tuned in a wide range. The main application of NPAA is in templating to achieve different nanostructures with different functionalities: [2-4]. Furthermore, the structure of nanoporous anodic alumina is a two-dimensional self-assembled structure with a triangular arrangement of the pores. If no pre-patterning techniques are used, the triangular pore arrangement is broken into domains, giving rise to a quasi-random structure. By adequately tuning the fabrication conditions, the size of the domains can be increased. Such triangular pattern reminds that of a triangular Photonic Crystal [5], although it lacks the perfect periodicity. However, it can be demonstrated [6] that the NPAA pattern can show photonic stop bands in the same way it happens with photonic quasicrystals [7] or even in random structures [8].

Silicon is a good candidate to obtain two-dimensional photonic crystals [9] for different applications, mainly because its compatibility with the wide-spread silicon technology. In order to obtain such photonic crystals, a lithography-based pre-patterning technique and further wet- or dry-etching techniques are required. This makes the cost relatively high, especially if the lattice constants have to be reduced to a few hundreds of nanometers. However, some applications may only need to benefit from the existence of a stop band, and thus, in this case, the NPAA pattern could be adequate.

In this work we focus on the transfer of the NPAA pattern to the silicon surface for further electrochemical etching. Such nanostructured silicon substrate will enable a great variety of applications that take benefit from the existence of a photonic band gap onto a conductive substrate that provides electrical contact: efficient light emitters (both diode or lasers), solar cells with more efficient light harvesting, sensors with enhanced sensitivity. With this aim, the process parameters concerning aluminum deposition, etching conditions and processing steps are optimized. We present results on fabrication and characterization of the structures fabricated. One of the main issues is the optical characterization of the resulting Si nanostructure by angular-dependent reflectance spectroscopy and polarimetry[10,11]. Such measurements require a good surface finish between the pores on the silicon. Consequently the process will be optimized to obtain such a surface quality.

The figures show some of the achievements up to date. Figure 1 shows the current transients and the SEM pictures of the surface and of the cross-section of a NPAA layer grown onto p-Si by a two-step electrochemical etching process with a 0.3 M oxalic acid electrolyte and under potentiostatic conditions with an applied voltage of 40 V. Figure 1a shows the current-time curve for the first and the second steps of the anodization processes, Figure 1b shows an ESEM picture of the sample surface and finally, Figure 1c shows the cross section of the sample, showing the alumina and the silicon regions. Figure 2 shows the same information but for a sample obtained with a 0.3 M phosphoric acid electrolyte and an applied voltage of 160 V.

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Figures

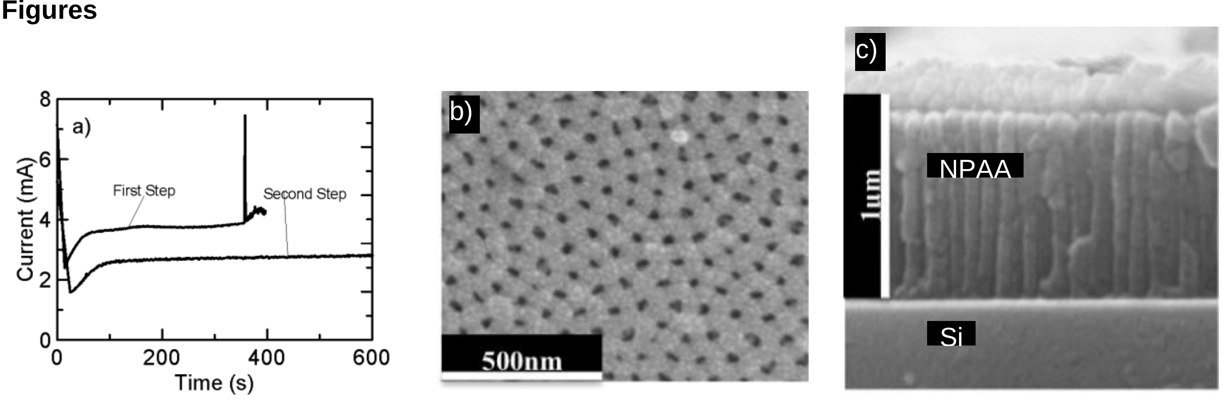

Figure 1 : NPAA template on Si obtained with an 0.3 M oxalic acid electrolyte, under potentiostatic conditions with an applied voltage of 40V. a) current-time curve for the first and the second anodization. b) ESEM picture of the sample surface. c) ESEM picture of the sample cross-section.

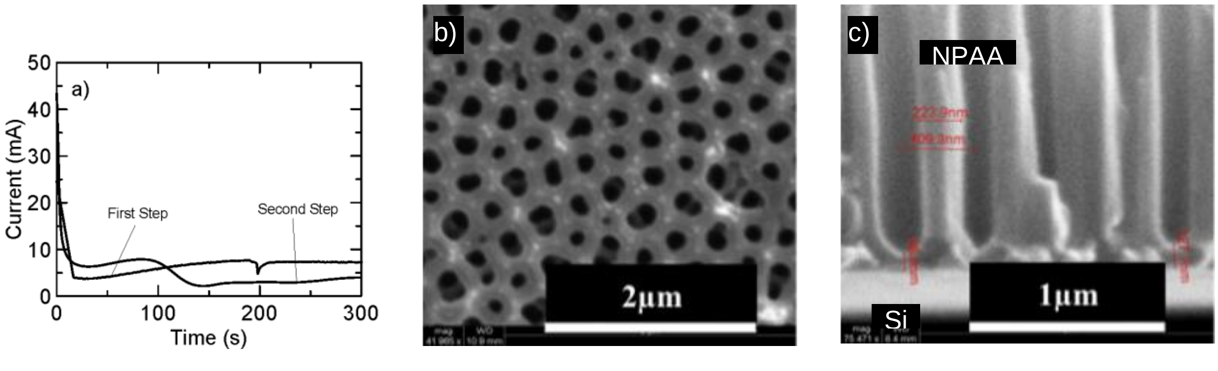

Figure 2 : NPAA template on Si obtained with an 0.3 M phosphoric acid electrolyte, under potentiostatic conditions with an applied voltage of 160V. a) current-time curve for the first and the second anodization. b) ESEM picture of the sample surface. c) ESEM picture of the sample cross-section.