Characterization of surfaces nanostructured with swift gold clusters

Elodie, Emilie CALVIE

Introduction

Nanomaterials are the object of numerous research studies, due to a growing interest in micro- and optoelectronics. There are several methods for processing nanostructures: (i) electron beam lithography, which presents a limitation of size around 20 nm, (ii) high-energy ion irradiation, followed by track etching, which leads to a random distribution of nano-objects and (iii) focussed ion beam treatment (FIB), which allows for construction of a regular array of impacts, but is time consuming when the target area is large.
The aim of this work was to test a new method of nanostructuration, using irradiation with gold clusters Aun+ accelerated in the MeV range. Such projectiles induced very large sputtering effects and were well suited for opening nanopores with a controlable density (via the fluence) at the target surface.
Two materials, deposited as thin films, were used: gold, previously studied in close conditions by M. Fallavier et al [1] and SiO2, which has not yet been covered by any study. Atomic Force Microscopy (AFM) observations allowed for precise observation of the morphology of the bombarded surface, as well estimation of its sputtering rate.

Experimental conditions

The gold targets were produced by depositing 10 nm gold onto a doped P-type silicon substrate by electronic bombardment within a vacuum. The SiO_2 targets, of 50 nm thickness, were obtained by thermal oxidizing a Si wafer in dry oxygen at 1000°C for 1 h.
The samples were irradiated in the 10^{10}-10^{12} cm^{-2} fluence range, at the Institut de Physique Nucléaire de Lyon (IPNL) with clusters of Au_9^+ of 1.35 MeV total energy. These projectiles were delivered by a 2 MV Van de Graaff accelerator equipped with a liquid metal source. The irradiated surfaces were then observed by AFM in tapping mode, using a "Nanoscope V" instrument available at INL laboratory. The raw images were processed with "WSxM" and "Nanoscope" software.

Results and discussion

The AFM image processing (Figure 1) allowed for observation and measurement of the geometrical parameters of the holes created by each projectile impact. In gold, the openings displayed a roughly conical shape (Figure 1a), with an average diameter of 16 nm and an average depth of 7 nm. Based on these results, it was possible to determine a sputtering yield per incident cluster of $Y \approx 14000$. This value was comparable with previous values [1] obtained from mass loss measurements utilizing a quartz microbalance. The target response was different in the case of SiO2. The crater shape suggested an inflation process, in agreement with a thermal spike description (figure 1b). The average diameter of these holes was about 4 nm. Their depth could not be measured precisely, due to the convolution effect of the AFM tip, but they were estimated to not exceed 2 nm. Therefore, in the case of a SiO_2 target, only a rough estimate of the sputtering yield could be given ($100 < Y < 400$).
In both cases, the pores did not reach the interface. Future experiments are planned, using thinner layers (5 nm of gold or 2 nm of silica), in order to open regions of very small size on the underlying substrate.

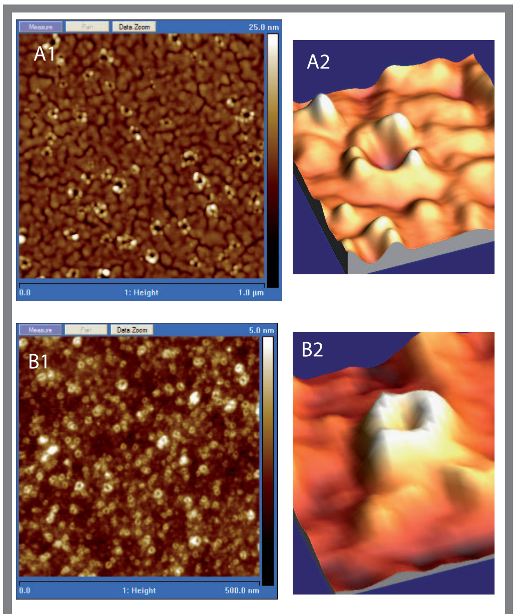

Figure 1 : AFM images of irradiated surfaces
A1: Gold target, irradiation dose: 1010 cm-2
A2: One impact (3D), diam.: 30 nm, depth: 9nm
B1: Silica target, irradiation dose: 1012 cm-2
B2: One impact (3D), diameter: 6nm

Conclusion

Irradiation with swift gold clusters, seems a promising way to create, through a metallic or an insulating deposit, openings of a few nanometers reaching the interface. Such a treatment, followed by epitaxy or electrochemical steps, could allow for processing of nanodots or nanowires with original electrical properties, on a silicon substrate.

Institut des Nanotechnologies de Lyon

Institut des Nanotechnologies de Lyon I.N.L
CNRS U.M.R. 5270
Site INSA de Lyon
BAT. Blaise Pascal
7 avenue Jean Capelle
69621 Villeurbanne cedex