NANO-FABRICATION WITH FOCUSED ION BEAMS - WHERE ARE THE RESOLUTION LIMITS?

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The interactions between energetic ions and solids lead to well-known processes that are widely used to modify the topography, crystallography or electronic properties of the irradiated target. These effects are widely exploited in microelectronics like ion etching and doping applications. Focused Ion Beam (FIB) is a technology that is extending these capabilities. Nowadays FIB instruments combining etching and deposition have become indispensable in such fields as failure analysis, transmission electron microscope (TEM) sample preparation.

We will describe our specific iterative effort started under the Nano-FIB EC project combining developments in liquid metal ion source geometries and research in ion optics specifically for high-resolution applications, together with ion induced damage fine characterisation. Our objective was to demonstrate that the Focused Ion Beam technique could be a challenging technique for nanotechnology. We were anticipating that lateral patterning of structures having one nanometre-sized dimension (thickness) with FIB would no longer rely on sputtering effects with high local incident dose (> 10^{16} ions/cm²), but rather on local defect injection and surface modifications of high crystallinity substrates [**1**].

We will present our work aiming to explore the nano-structuring potential of a highly focussed pencil of ions. We will show that Focused Ion Beam technology (FIB) is capable of overcoming some basic limitations of current nano-fabrication techniques and to allow innovative patterning schemes for nanoscience. In this work, we will first detail the very high resolution FIB instrument we have developed specifically to meet nano-fabrication requirements. Then we will introduce and illustrate some new patterning schemes we have proposed for next generation FIB processing. These patterning schemes are ranging from Nano-engraving to local defect injection via the functionalisation of substrates to selective epitaxy of semiconductors. Thus demonstrating that FIB patterning is fully compatible with "bottom-up" or "organisation" processes [1].

Finally we will present the potential of our instrument now capable to fabricate **directly** nano-pores with diameters below **5 nm**. To our knowledge this performance is defining a new state of the art in direct removal of particles using a focused charged particle beam.

[**1**] Exploration of the ultimate patterning potential achievable with high resolution focused ion beams, J. Gierak , D. Mailly, P. Hawkes, R. Jede, L. Bruchhaus, L. Bardotti, B. Prével, P. Mélinon, A. Perez, R. Hyndman, J.-P. Jamet, J. Ferré, A. Mougin, C. Chappert, V. Mathet, P. Warin, J. Chapman: Appl. Phys. A, 10.1007/s00339-004-2551-z (2004)