Ion and Electron Beam Lithography in a Multifunctional Tool FIB/SEM with in-situ SPM

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Selective growth of metallic (Co, Au) nanostructures is important for several application fields such as microelectronics, magnetic data storage, plasmonics and biosensing. The use of focused ion beam (FIB) is a straightforward method for modifying the surface that can be further utilized for a selective growth of metallic particles. It is desirable to control and optimize resulting structures by both scanning electron and probe microscopes (SEM, SPM). Combined FIB/SEM/SPM[1,2,3] tool introduced recently by TESCAN as the first commercial tool of its kind allows ion and/or electron beam lithography (IBL, EBL) and consequent in-situ investigation by SPM. With this tool we can manufacture, investigate and optimize. An example is shown in Figure 1. The surface patterning is generated using TESCAN DrawBeam software that enables sketching of arbitrary geometrical shapes, arrays or bitmap pictures. Patterning is made by precise milling of the mono-crystalline silicon surface. The frames 40x40 μm^2 are useful for SEM navigation and serve as a playground for the arrays. They are optimized using both SEM and SPM. The resulting structures are then in the second step used as a diffusion barrier for Au atoms deposited by an effusion cell in UHV. Final patterns are again localized by SEM and investigated by SPM.
Plasmonic antennas in the second example are suitable for applications in the field of sensorics. Arrays of gold antennas for near and middle infrared (NIR-MIR) light were fabricated on substrates with a layer of nano-crystalline diamond (NCD) using EBL, see Figure 2. Arrays consist of dimer antennas: the lengths of rods range from 0.5 to 2.1 μm, the width is between 0.45 and 0.50 μm and the size of the gap between the rods is about 0.3 μm. Spacing between the dimer antennas is chosen from 3 to 5 μm. Optical properties of these antennas were further studied by infrared spectroscopy. Both examples show that a combination of FIB/SEM and SPM is extremely useful.

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[3] J. Jiruše *et al*, in *Proceedings of Microscopy and Microanalysis, Phoenix, 2012,* edited by J. Shields, S. McKernan, L. Brewer, T. Ruiz and D. Turnquist (Microscopy Society of America, 2012), p. 638-639.

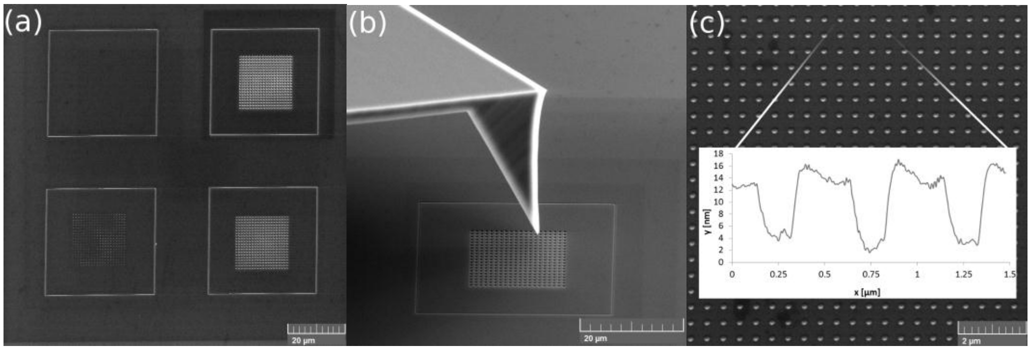

Figure 1:
(a) Arrays of different patterns made in mono-crystalline silicon.
(b) SEM view and navigation of SPM module to approach the area of interest.
(c) SEM image of the array of holes (200 nm diameter, 15 nm depth and 500 nm spacing) with SPM depth profile in the inset.

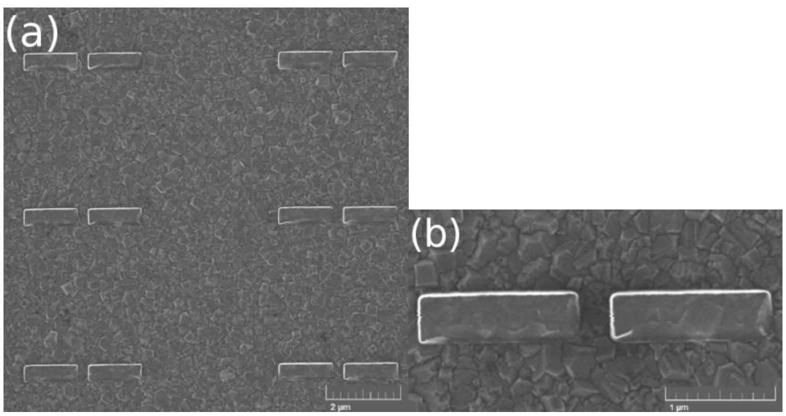

Figure 2:
(*a*) Gold dimer antennas (1500 x 500 nm, gap 300 nm) on 650 nm-thick nano-crystalline diamond (NCD) layer on silicon substrate fabricated by EBL with electron dose 300 – 350 $\mu C/cm^2$.
(b) Detail of (a) making the grains of NCD clearly visible.