High precision FIB fabrication of customizable AFM probes

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Nanobits are exchangeable and customizable tips for atomic force microscopy (AFM) that are transferred by a micromanipulator to a standard AFM cantilever. They are intended to be used for inspection of high aspect ratio structures or 3D scanning. Such high precision AFM tips are important for characterization of devices in semiconductor and photonics industry, and the tip morphology can be accurately shaped to match the individual application. In previous work, enhanced Nanobits have been prepared by electron beam lithography (EBL) and standard silicon processing[1]. In the present work we use focused ion beam (FIB) milling instead of EBL for rapid fabrication custom made prototype AFM tips. These tips are milled in a thin silicon membrane (130 nm thick) using a Helios FIB station.

Tolerance of fabrication is going to be obtained much better than 10 nanometers by implementing of further considered methods. We observed that the resulting shape of the structure depends significantly on the sequence of go-round of ion beam milling. The most simple raster scanning occurs to be very sensitive to drift and redeposition of sputtered material that results in shape distortion. It is originated from thermal drift of the construction, residual movement of the stage, charging effect of the sample. We try to get rid of them by using different patterning strategies, such as circular milling toward important points, back scan of contour and etc. This provides more uniform and exact shape of the structures. Also a fine drift of focus was observed, apparently because of the electronics instability. Objective lens voltage correction on 20 V per hour is required (the full value is about 19 kV), that is comparable to 20 nm defocusing of beam spot at 28 pA FIB current. This had to be corrected manually and regularly.

Sharpening of tips is one of the challenging problems. Tip diameter 30-40 nm easily obtained by FIB, but AFM needs less than 10 nm. TEM imaging helps to evaluate the acquired shape, precisely measure the size, observe changes in the crystal structure and formation of amorphous layer, also to understand mechanism of tip formation. While sharpening of the tip it is necessary to escape “melting“ (overheating) of silicon and bending of needle end by beam impact. It is preferable to conduct sharpening by FIB etching on a tangent from the base toward the end of needle. Also usage of two-layered membrane, stronger material and other sharpening methods are of interest. Further investigations will be carried out within Nanobits FP7 project (www.nanobits-project.eu).

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[1] R.T. Rajendra Kumar, S.U. Hassan, O. Sardan Sukas, V. Eichhorn, F. Krohs, S. Fatikow, P. Boggild. Nanobits: customizable scanning probe tips. Nanotechnology, 20:395703, 2009.