Adding 3D to conventional SEM or FIB surface imaging information - In situ Surface Sensing and Nanoprofilometry for Focused Electron and Ion Beam Induced Processes Verification

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Well-established, standard electron and ion beam nanolithography instruments are regarded as a must-have in modern research labs to enable state-of-the-art nanofabrication. Nanopatterning processes and corresponding parameters are typically well understood for standard applications such as resist based electron beam lithography (EBL) or FIB milling processes like circuit editing or TEM lamella preparation.

In the recent past however, the bandwidth of nanofabrication applications for dedicated nanopatterning tools has significantly broadened and is no more limited to standard resist based EBL and mere, standard FIB milling tasks. Some few latest generation professional and multi-purpose electron and ion beam nanolithography tools even facilitate additional *in situ* processes such as resistless focused electron or ion beam induced processes, like e.g. material deposition or gas enhanced etching. The number of variable parameters for such complex processes involving e.g. new gas chemistry or ion species is nearly “infinite”, so that an efficient in situ characterization of e.g. material deposition, milling or etching rates becomes crucial for most effective understanding and subsequent optimization of such processes. Smart patterning strategies e.g. by using loops in conjunction with flexible multi-directional patterning modes can significantly improve the final nanostructure´s definition and performance.

In contrast to using additional analytical equipment outside the vacuum and subsequently re-introducing the sample for further processing, we have implemented a distance sensitive nanomanipulator with nanoprofilometric capabilities, which allows *in situ* characterization of nanostructures in 3D with a sharp W-tip (see *Figure 1*) by collecting topographic sample surface information via line scans well below 20nm height resolution (see *Figure 2* and *Figure 3*).

First results of direct *in situ* growth rate determination of focused electron beam induced material deposition (FEBID) for process calibration (see *Figure 4* to *Figure 6*) as well as 3D surface topographic information of challenging milling applications will be presented.

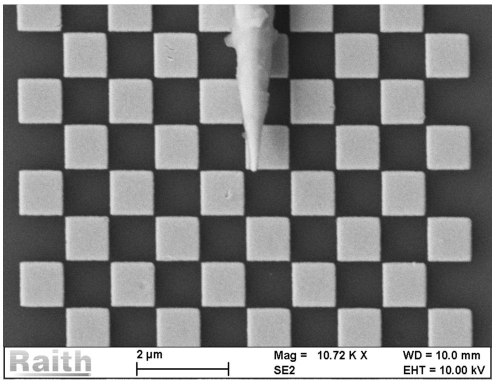

Figure 1: Distance sensitive W-tip for nanoprofilometric *in situ* characterization above a checkerboard test pattern.

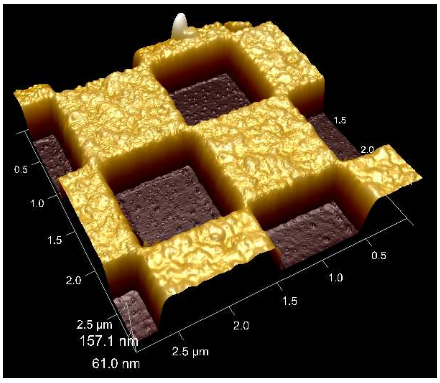

Figure 2: Nanoprofilometric 3D scan of a checkerboard test pattern.

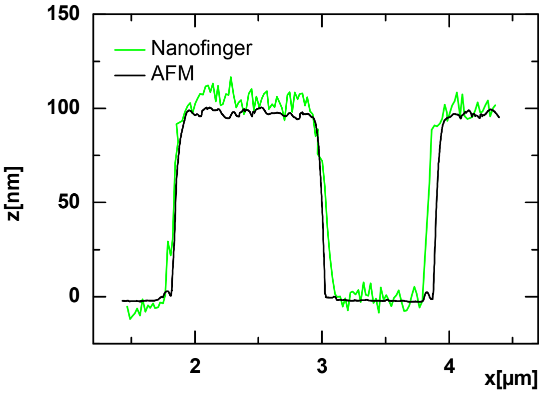

Figure 3: Comparison of topographic sample surface information acquired by an external AFM and the *in situ* nanoprofilometer.

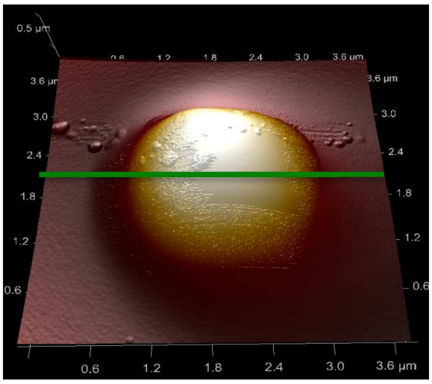

Figure 4: FEBID test structure for growth rate determination (the green line is indicating the placement of the line scan, see *Figure 5*).

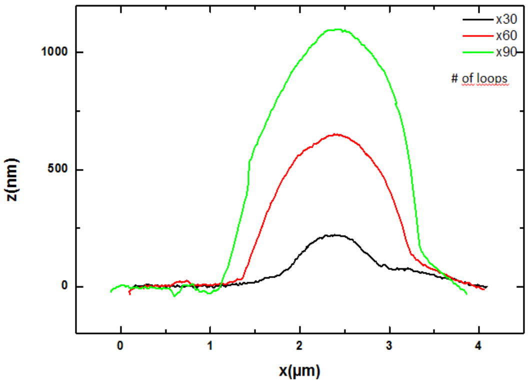

Figure 5: Nanoprofilometric line scan showing the cross section of the deposit as a function of the number of loops.

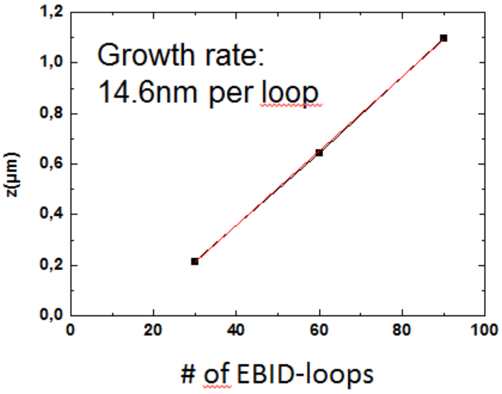

Figure 6: Height of the deposit plotted against the number of loops reveals a growth rate of 14.6 nm per loop.