Three-dimensional measurement of tip shape geometry with SEM

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Objectives

For traceable measurements of complex structures, the characterization of the applied tactile tips is required (see fig. 1). Especially advanced measurement tasks, e.g. the recording of the geometry of silicon nanopillars with high aspect ratio, presumes knowledge about the three-dimensional shape. The complete coverage of the tip shape in a 3D measurement data set enables the extraction of 2D profiles in different spatial directions. These profiles can be used for the deconvolution of the data, which were measured with the applied tip.

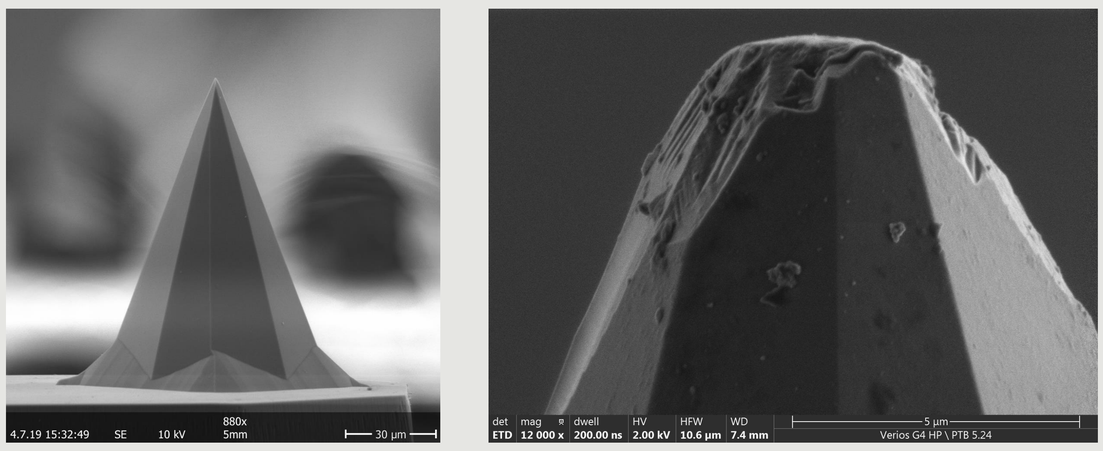

Figure 1: Si-tip (left, side view), wear effects on top of a Si-tip (right)

Applied Technique

For the characterization of the tip shape, a fast and reliable high-resolution measurement technique is required. SEM imaging fulfils these preconditions very well, but requires some extensions, if height measurements are required. Therefore, we applied a high-resolution SEM (Thermo Fisher Verios G4), which is equipped with a retractable four quadrant (4Q) BSE detector (PNDetector) and an active scanning system for topographic measurements (point electronic).

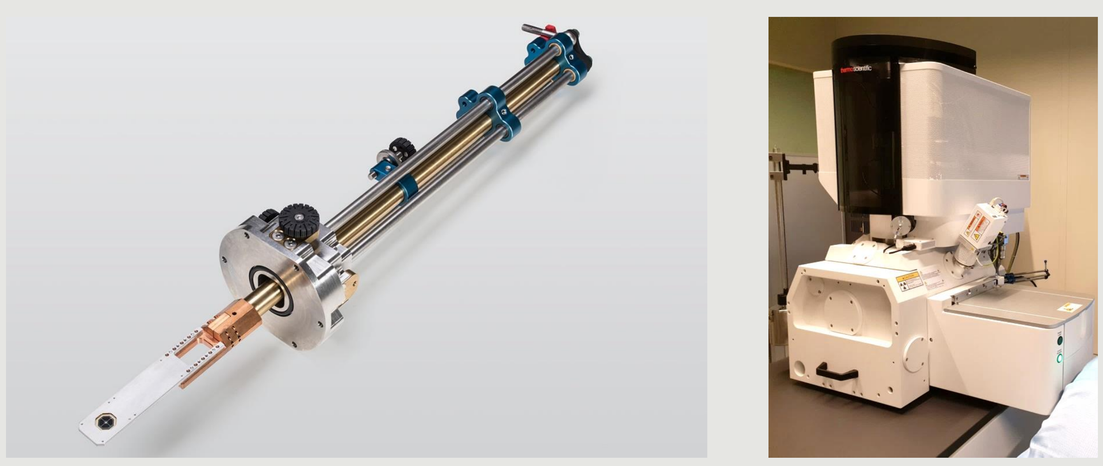

Figure 2: 4Q-BSE detector with retractable arm (left), SEM equipped with retractable 4Q-BSE detector (right)

BSE-Topography

The applied topographic measurement system utilizes the segmented BSE detector, which is inserted below the SEM pole piece. Surface height, i.e. topography, is obtained with a shape-from-shading algorithm that uses the subtle differences in simultaneous BSE signals, as described by the known angular distribution of backscattered electrons. This approach needs no sample tilting and is very computationally efficient and thus allows for live in situ topographic view of the investigated sample. A dedicated calibration standard has been used for this study to ensure height accuracy.

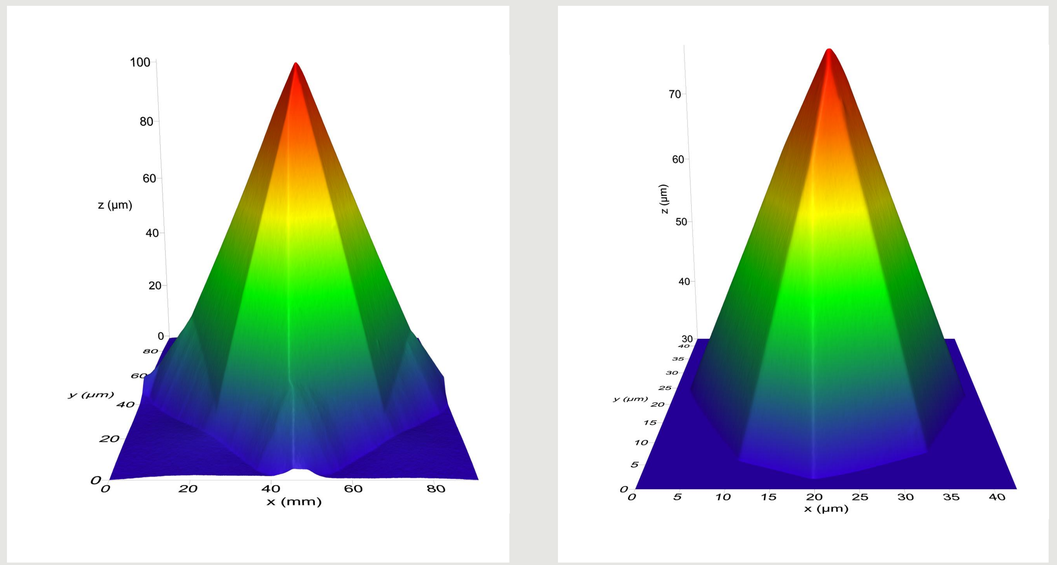

Figure 3: Reconstructed tip shape geometry. Left: complete tip, right: upper part of the tip.

Results

The results show the 3D reconstructed shape of a tactile tip (fig. 3). With high aspect ratio of the sample heights, z-scaling errors occur because of shadowing effects. Thus, the height of the tip was also measured with the 90-degree tilted sample and afterward used for the determination of the correct height scale. As a result, the measurement data of the tip shape were used to extract 2D profiles which are ready for the deconvolution of the tactile measurements (fig. 4).

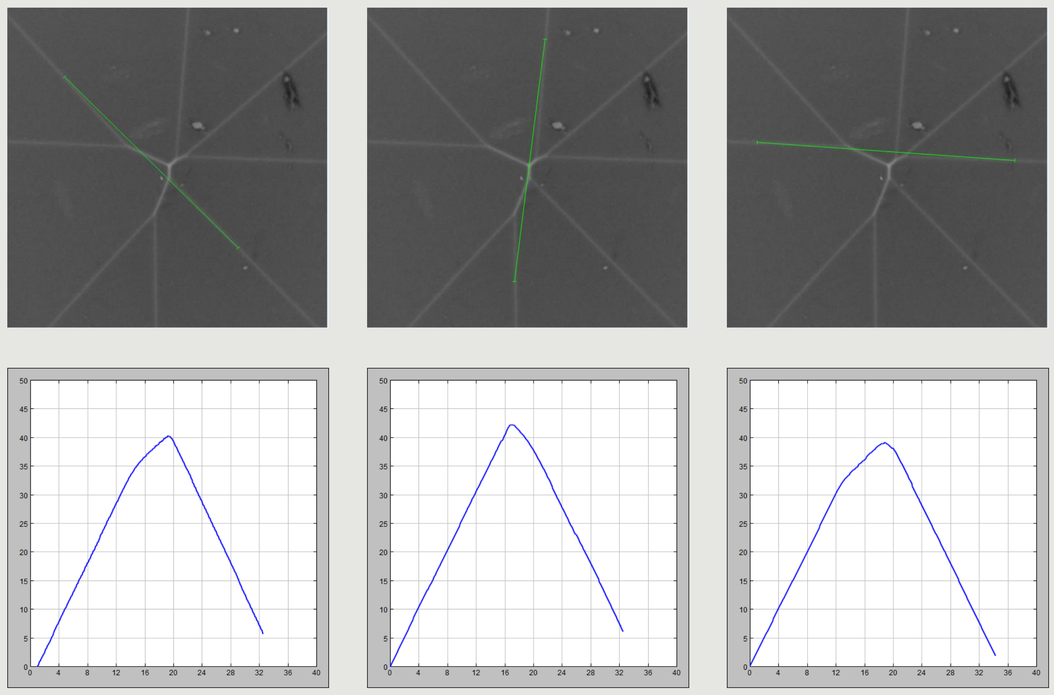

Figure 4: Three exemplarily extracted profiles, showing the asymmetric shape geometry of the investigated tip. Upper row: definition of the profile lines in the BSE image. Lower row: related profiles (in µm).

Summary

In summary, the application of topographic SEM measurements is a fast and reliable high-resolution method to determine the shape of tactile tips. Special attention is to pay on the system setup, BSE detector adjustment and the geometric calibration of the scanning system. Especially the measurement of samples with high aspect ratio requires an overall control of the z-scale. If these requirements are fulfilled, the quantitative measurement of the tip shape, and derived measures, like profiles, tip angle and diameter is possible in an easy way.

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More information and detailed technical specifications can be found at www.pointelectronic.de