In situ Height Measurement with a 4Q-BSE Detector of FIB Produced Structures

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FIB/SEM microscopes are designed for deposition and milling of materials on the sub-micron range, however control and measurements of produced heights and depths is still challenging. For both FIB/SEM applications, the specimen is modified in the z-direction and may be readily imaged with SE or BSE signals, however these techniques cannot provide height or depth measurements. Dose-rate calibration has therefore become the standard approach for the control of these processes, which require additional preparation of cross-sections, followed by analysis of heights and depths as a function of dose. The dose-rate approach is therefore inherently time consuming and prone to errors in dose and injection variations. This work proposes and demonstrates the use of *in situ* height reconstruction for measurements of typical FIB produced structures.

In situ height measurements in FIB/SEM require a standard segmented BSE detector to be inserted below the SEM pole piece, which may then be retracted for further FIB deposition or milling. Surface height, e.g. 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 is very computationally efficient and thus allows for live *in situ* topographic view of the produced structure. A dedicated calibration standard has been used for this study to ensure height accuracy.

Pt layers are commonly deposited for protection during milling, and thus provide an ideal example of a 'height structure'. Figure 1a shows a deposited Pt structure on Si, illustrating the shadowing present in the four BSE images acquired by the four quadrants (4Q) of the segmented BSE detector. In the next step, a line profile (fig. 1c) is extracted from the calculated height model (fig. 1b). Already after a few minutes the Pt layers is determined to be 25.8 um long and 660 nm thick in this case.

Similarly, milling of Si is very common, in particular for cross-section or TEM-lamella preparation, and provide an ideal example of 'depth structure'. A typical Si cross section cut was prepared and imaged with the 4Q-BSE detector. The specimen is tilted by 15 degrees to image the cross section surface also, which is intended to be perpendicular to the specimen's surface. The extracted line profile (fig. 2a) does not only show the depth of the cross section preparation but also the size of the cross section surface which is level and flat. The typical but unwanted broadening of the cross section shows up at the bottom of the cross section surface. Future work will concentrate on a further improved reconstruction of the height model from a 4Q-imaging of an untilted specimen by considering the fixed geometry of the FIB applications.

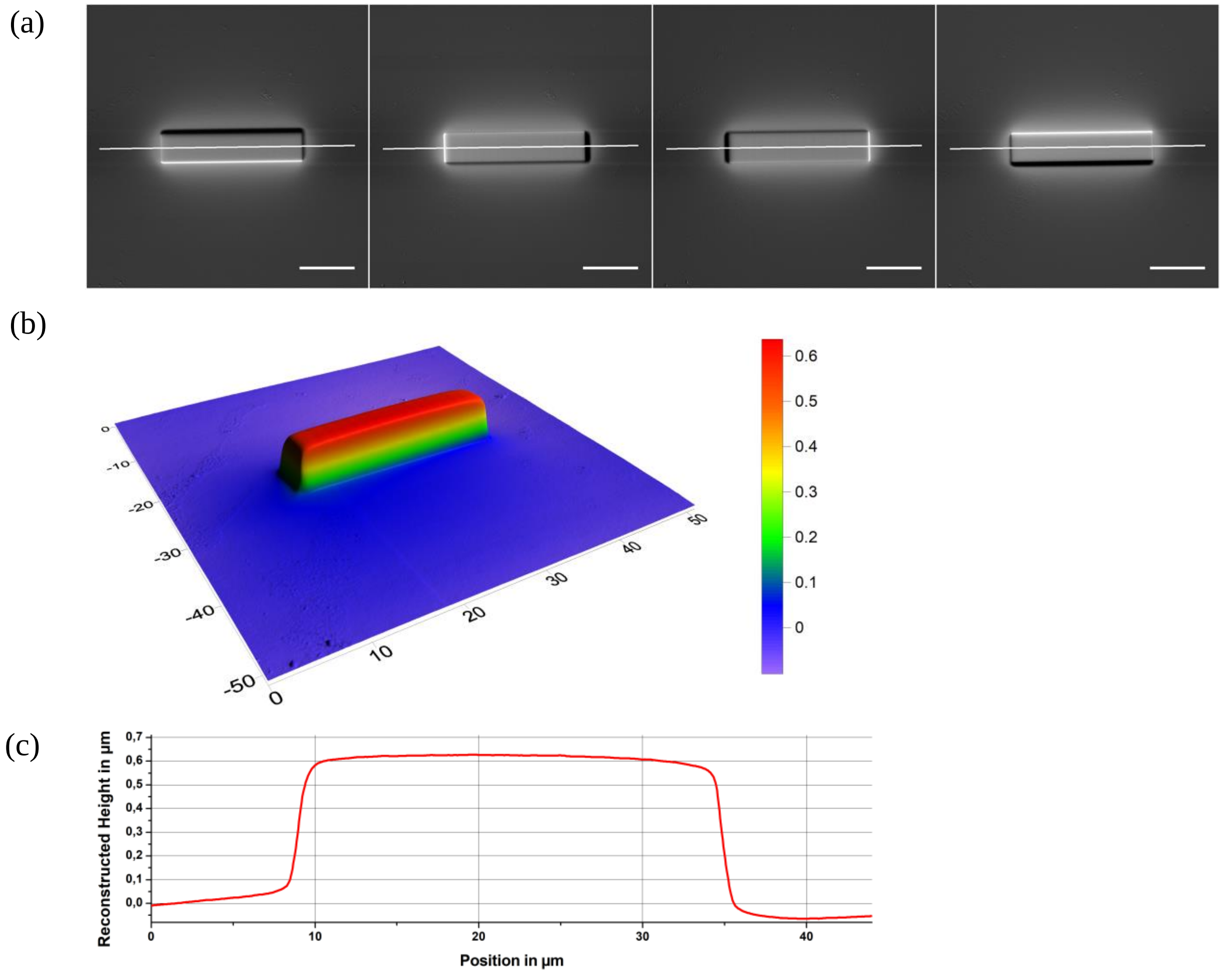

Figure 1: 4Q BSE images with 10 um scale bar (a), height map with scale in m (b) and extracted line profile (c) of deposited Pt structure

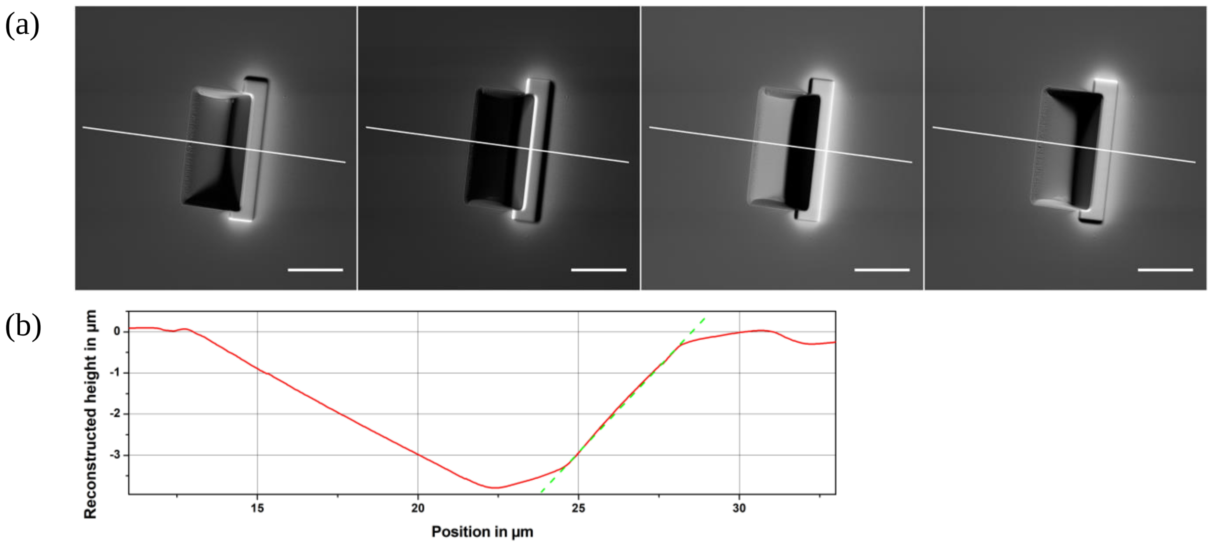

Figure 2: 4Q BSE images with 10 um scale bar (a) and line profile (b) across milled Si structure, note that the cross section surface is not vertical since the specimen is tilted by 15° during 4Q-imaging