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Automatic FIB-SEM Preparation of Straight Pillars for Micro-Compression Testing

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In this work the automatic preparation of micro-pillars by focused ion beam (FIB) milling in a bulk sample is described. Compression tests on such FIB fabricated pillars allow to characterize the mechanical deformation properties of the sample at the micron scale [1,2]. Depending on the specific scientific question the preparation of a large number of pillars at different sample locations might be required for a statistically meaningful experiment. Therefore, an automatic fabrication approach becomes necessary.

Today, state-of-the-art Ga FIBs feature currents up to 100 nA allowing to fabricate a typical pillar – 5 µm in diameter, 15 µm tall, for which a surrounding area of 40 µm across has been freed up – easily within half an hour. Thus, during an overnight run several tens of pillars can be machined.

In an additional preparation step the geometry of the pillar can be improved further to achieve perfectly perpendicular pillar side walls using a technique commonly known as lathe milling [3]. The ideal cylindrical geometry facilitates an accurate determination of material parameters from the stress-strain experiments. Two different lathe milling workflows were implemented. They both involve many FIB milling steps each performed at a different sample rotation to shape the pillar walls along its whole circumference. After each sample rotation the pillar needs to be repositioned accurately. This is done by means of SEM and FIB image recognition of fiducial marks.

In a first approach, #1, the walls of the pillar are shaped from the side by FIB milling at zero degree stage tilt as shown in Figure 1(a). In this experiment FIB beam and pillar axis form an angle of 54°. For sample repositioning a single fiducial is used which is placed – for symmetry reasons – exactly in the center of the pillar (see Figs. 1(b) and (c)). Approach #1 was automated using the application programming interface (API) of the FIB-SEM instrument. Including lathe milling the total preparation time per typical pillar adds up to about an hour. Because of the space needed for the fiducial mark only pillars with diameters, d >5 µm, can be fabricated automatically in this way.

For pillars with d <5 µm an alternative automatic lathe milling workflow, #2, was implemented and evaluated. The schematics in Figure 2 illustrate the new experiment. Here, the walls of the pillar are shaped at FIB normal incidence to the sample from the pillar top. By slightly under-tilting the sample a few degrees an edge of the pillar is exposed to the FIB for machining (Fig 2(a)). The sample is then rotated and repositioned for the next milling step. This process is iterated to cover the full circumference of the pillar. In order to reduce the number of iterations the milling is done following the green boomerang type of shape depicted in Figure 2(b). As few as eight such iterations are needed to obtain an almost perfectly circular pillar cross section (see Fig. 2(c)).

The two different lathe milling methods, their implementation, limitations, advantages and possible improvements will be discussed in this conference contribution.

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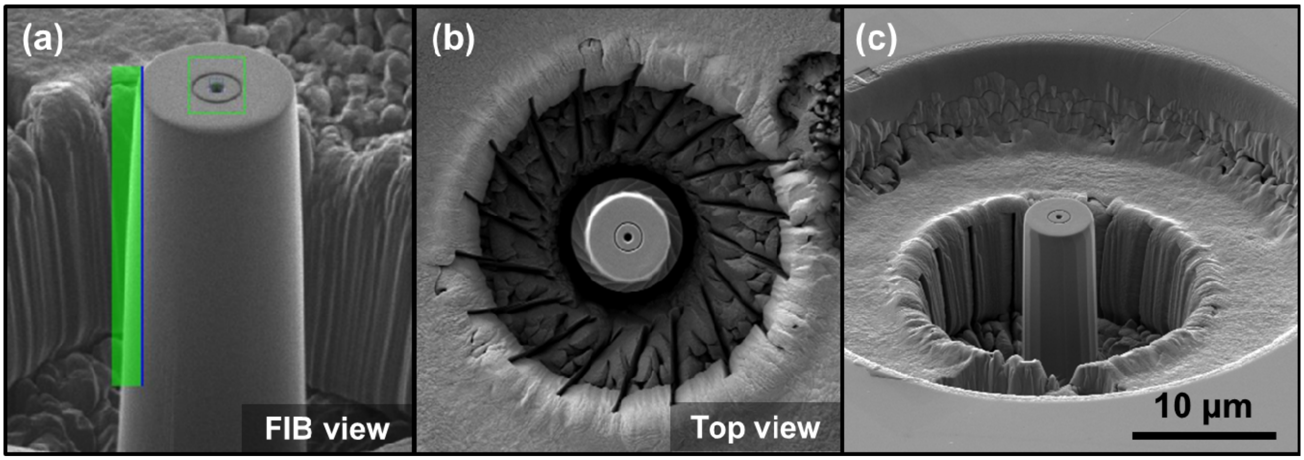

Figure 1. (a) Pillar imaged from the FIB perspective prior to lathe milling following workflow #1. (b) Top view and (c) tilted view of the pillar after lathe milling using method #1 (see text).

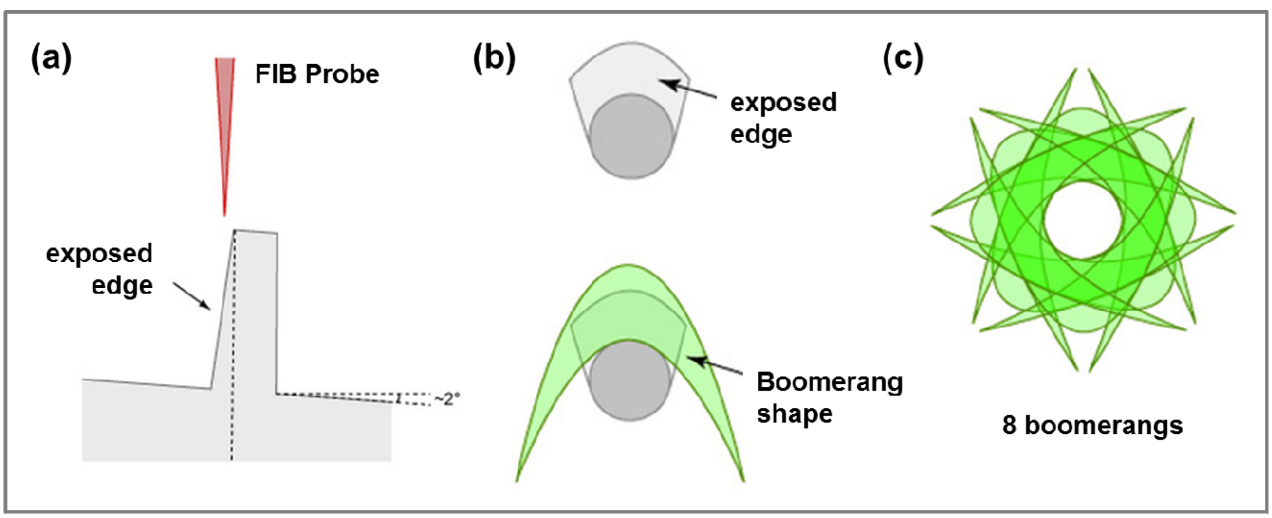

Figure 2. Schematic illustrating the automatic lathe milling approach #2 in which the pillar is machined from the top (see text).

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