Annular Milling FeatureMill functionality for Atom Probe Tip preparation

Product Information

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SEM/FIB technology is extensively used for fabrication of nanometer-scale structures by direct ion beam writing. With its high resolution SEM live imaging capabilities the instruments of the CrossBeam® series allow full control over the complete ion beam milling process and thus enable very precise site specific sample preparation. Therefore the entire sample preparation process is greatly simplified. By the availability of both SEM- and FIB-image that provide different views from different view points the precise position of the sample or a micro-manipulator tip in the three dimensional space is known. Hence in-situ sample micro-manipulation is made much easier using a combined SEM/FIB microscope.

Due to these capabilities CrossBeam® systems are highly interesting for the site-specific preparation of atom probe tips (APT). Live SEM imaging of the annular milling process is essential in order to ensure that the regions of interest like grain boundaries or micro-cracks are ideally located within the atom probe tip to be prepared.

In general, Annular Milling provides the ideal beam scanning strategy for any kind of circular structure down to the nanometer scale: the ion beam follows the circular shape of the nanostructure to be generated.

The application tailored annular milling software solution provides a quick and easy way for the preparation of any kind of tips or annular structures on a nanometer scale without the need for an additional complex and high-priced lithography system solution.

The Annular Milling functionality is completely embedded into the well-known FeatureMill option of the SmartSEM® software.

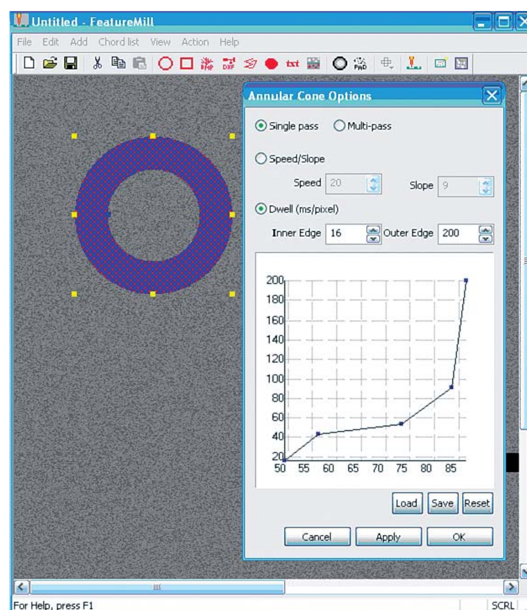

Figure 1: Screenshot of the user interface of the Annular Milling application embedded into FeatureMill.

Figure 1 shows the GUI of FeatureMill with the icon for adding an Annular Milling object and the corresponding options window opened.

The slope profile of circular structure can be defined by varying the dwell time between the inner and the outer circle by a linear function or by editing a look up table (LUT). Speed is directly related to dwell time. Typically a dwell time between 20 msec and 1 sec is used. The milling always starts at the outer diameter and sequentially moves to smaller diameters. The parameter External radius defines the diameter of the start circle. Its value

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may range from one pixel to half of the y-height pixel resolution (192 to 2304 pixels). The parameter internal radius defines the diameter of the final milled circle and may range from one pixel to external diameter minus one pixel.

By choosing the ion probe current the milling resolution is automatically adjusted ensuring an exposure overlap between adjacent pixel positions and the calculated milling time is displayed. Multiple Annular Milling objects with different parameter settings can be milled sequentially and the milling mode can be single or multi-pass. In single mode each circle is milled once. In multi-pass mode the number of passes is the number of individual circles to be milled. In the first pass only the outer circle is milled and in the last pass all circles from the outer to the inner circle are milled. The different milling strategies are depicted graphically in figure 2.

Figures 3 and 4 show an application of the Annular milling software for the generation of sharp tips (tip radius < 20 nm) on large aspect ratio Si pillars.

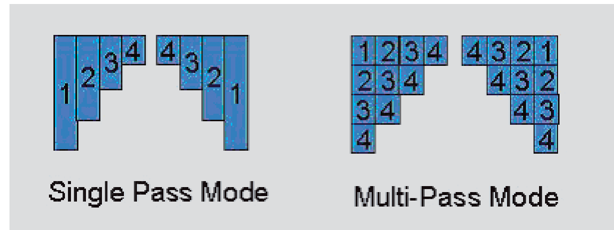

Figure 2: The Single and Multi-Pass Milling Mode.

Figure 4:
Very sharp Si tips (tip radius < 20 nm) fabricated by Annular Milling (Sample Courtesy of E. Cadel, University of Rouen, France).

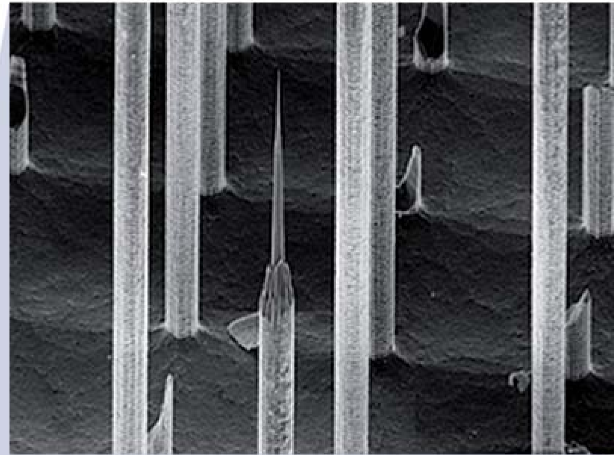

Figure 3:
Overview of large aspect ratio Si Posts fabricated by Reactive Ion Etching.
The Si post in the front was trimmed by Annular Milling (Sample courtesy of E. Cadel, University of Rouen, France).

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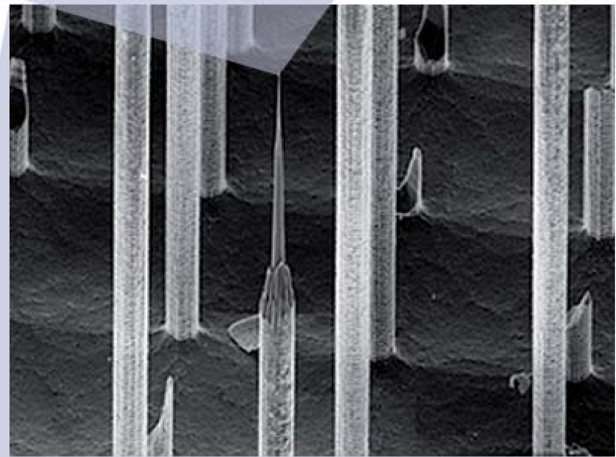
Figure 5:
Zoomed view of Si tip fabricated by Annular Milling with tip radius of less than 20 nm
(Sample courtesy of E. Cadel, University of Rouen, France).



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