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Helium-ion-beam-induced growth of 3-dimensional AFM probes

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In the past several years, AFM has been increasingly used for metrology, *i.e.* the measurement of roughness and width (or *critical dimension*) of trenches made in photoresist. However, measurements of undercut, sidewall roughness, and critical dimension have not yet been optimized in accordance to the International Technology Roadmap for Semiconductor (ITRS) recommendations. A limiting factor in the obtained accuracy is the extension of the probe-resist interaction region when the tip of an AFM probe is inserted into the trench. In order to improve the probe-surface interaction and, hence, to truly resolve 3D structures, a 3D-AFM tip needs to be developed.

The sub-nanometer resolution of the helium ion microscope enables fabrication of structures with almost nanometer precision. We utilize helium-ion-beam-induced deposition of Pt to develop an AFM probe with a hammer-head shape. For this purpose, we move the focused ion beam laterally (see Fig. 1a) to grow a thin nano-needle on top of a commercially available AFM probe (Fig. 1b and 1c). In the final growth stage, a perpendicular movement of the beam results in the required hammer-head shape (inset of Fig. 1c). The diameter of the needle depends on the ion beam current, dwell time, and speed of the beam movement. Diameters below 10 nm have been achieved. This fabrication process is highly reproducible and enables precise control over the 3-dimensions of the hammer-head of the AFM probe. Finally, we test the capabilities of the fabricated AFM probes on sidewall angle and line-edge roughness of resist trenches.

Keywords: 3D-AFM, ion beam induced deposition, helium ion microscope, metrology

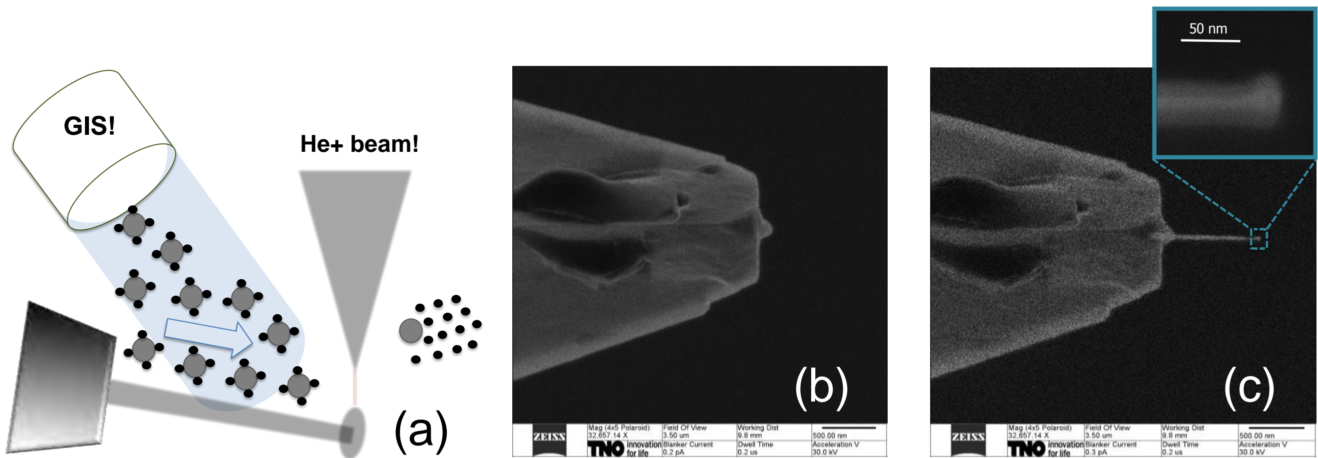

Fig. 1. Fabrication of an AFM probe with a hammer-head for 3D-metrology.

a: Sketch of the last step of the hammer-head growth. In the presence of a precursor gas, the beam is slowly moved from left to right; in the shown last step, the beam is moved in the perpendicular direction.

b: Conventional AFM probe before deposition.

c: AFM probe after growth of the nano-needle with a hammer-head shape (inset shows the hammer-head).