NenoVision

Application Note

In-situ AFM analysis of FIB etched nanostructures

FIB-SEM system combines SEM imaging with surface modification by a focused ion beam.
Such a device allows the implementation of a wide range of high-performance nanofabrication applications and precise characterization techniques for visualization and analysis of manufactured nano-objects.

LiteScope™ is a compact and modular atomic force microscope (AFM) specially designed for integration into FIB-SEM systems.

By combining all the aforementioned techniques, a researcher gains enhanced possibilities of surface characterization and control over FIB milling processes as well as benefits from detailed 3D information about fabricated structures.

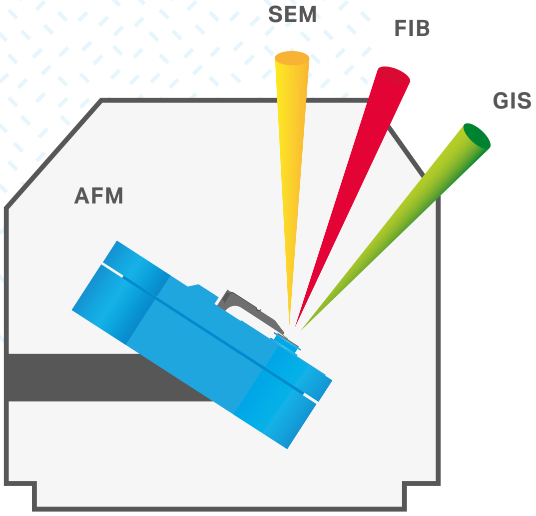


Figure 1: AFM LiteScope can operate in a tilted position up to 60°, therefore, it is compatible with FIB/GIS SEM systems.

LiteScope key advantages for FIB applications

- Depth and height profiling
- Roughness estimation
- FIB milling process optimization
- In-situ imaging:
  - Precise AFM tip navigation to the region of interest
  - Time-efficient analysis
  - Simultaneous measurement of AFM and SEM signals – in time correlative imaging CPEM technique (Correlative Probe and Electron Microscopy)
  - Vacuum preservation and minimal sample handling

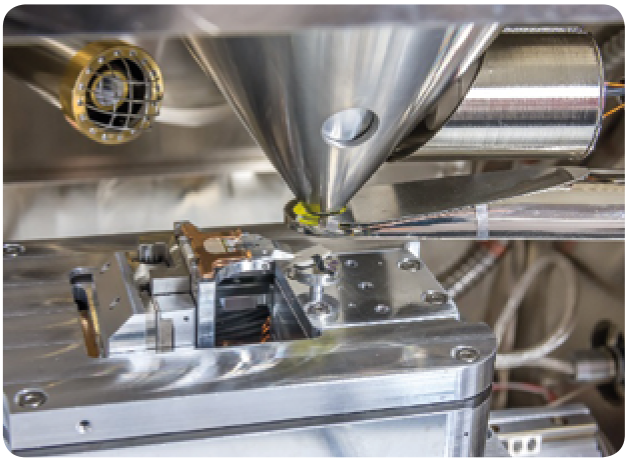
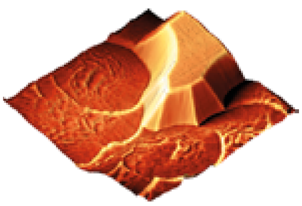
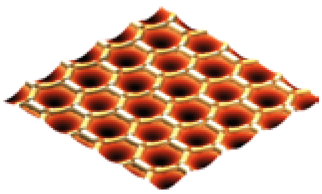


Figure 2: AFM LiteScope inside the SEM chamber.

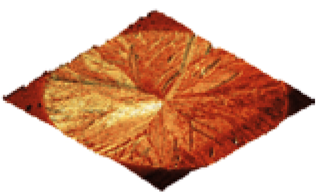
Application examples



CPEM of FIB etched CdTe



AFM analysis of FIB etched structure



CPEM of FCC to BCC FIB modification of $Fe_{78}Ni_{22}$

CPEM of FIB etched NenoVision logo into Au

Optimization of FIB milling process

LiteScope allows in-situ measurement of the real depth of the milled structures and precise time-efficient optimization of the milling process, including ion beam current, dwell time, acceleration voltage, or depth to minimize shape artifacts and to obtain a smooth surface.
A gradient spiral phase plate (SPP) was prepared by FIB on a silicon substrate. It is difficult to determine how the milled structure looks based solely on the SEM image. AFM measurement adds the third dimension and reveals the true topography of the structure. In this case, a smooth spiral gradient, as shown in **Figure 3**.

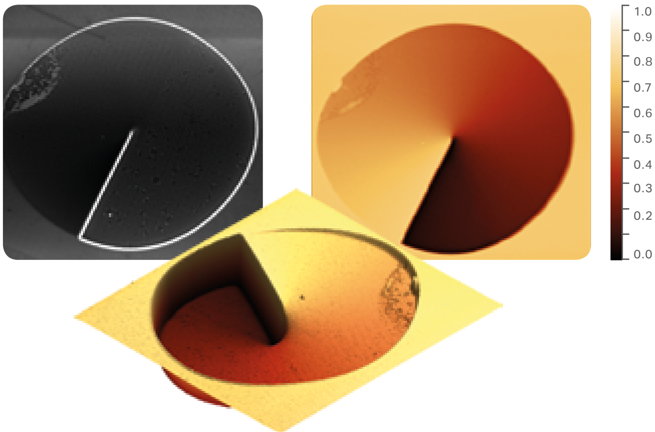


Figure 3: Simultaneously acquired images of phase SEM and AFM and 3D CPEM view of milled gradient spiral phlase plate.

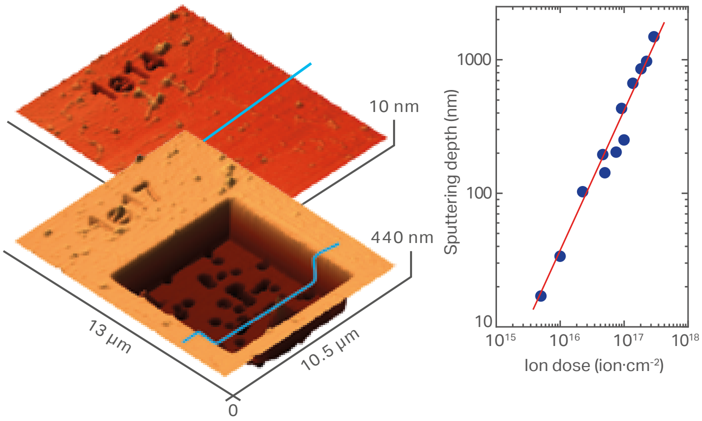


Figure 4: High-resolution 3D surface view by CPEM with height profile of irradiated areas with different ion doses. The sputtering rate of CdTe was estimated to be $2.6 \cdot 10^{14}$ ion·cm^{-2}·nm^{-1}.

Sputtering rate optimization

FIB milling is usually followed by ex-situ AFM analysis to establish a specific sputtering rate of the material and to check the quality of the structure.
AFM LiteScope integrated into an SEM allows direct in-situ measurement of surface properties (depth, roughness, etc.), which is not only time-efficient but also eliminates exposure of the sample to atmospheric conditions preventing surface contamination and oxidation.
LiteScope can be operated in a tilted position, thus the sample surface can be modified and immediately measured by AFM. The sputtering rate of Cadmium Telluride was estimated in this case, see **Figure 4.**

Sample surface analysis after FIB modification

LiteScope integrated into FIB-SEM offers instant analysis of fabricated structures. Interesting features can be selected using SEM and immediately analyzed by AFM.
Magnetic properties of the metastable iron thin film grown on Cu(100) substrate can be selectively changed when irradiated by an ion beam.
Using LiteScope with CPEM technology, it was found that the material transformation from paramagnetic (fcc) to magnetic (bcc) is accompanied by surface changes in the range of a few hundred picometers. In this case, the step between high and low magnetic moment was 470 pm high, as depicted in **Figure 5**.

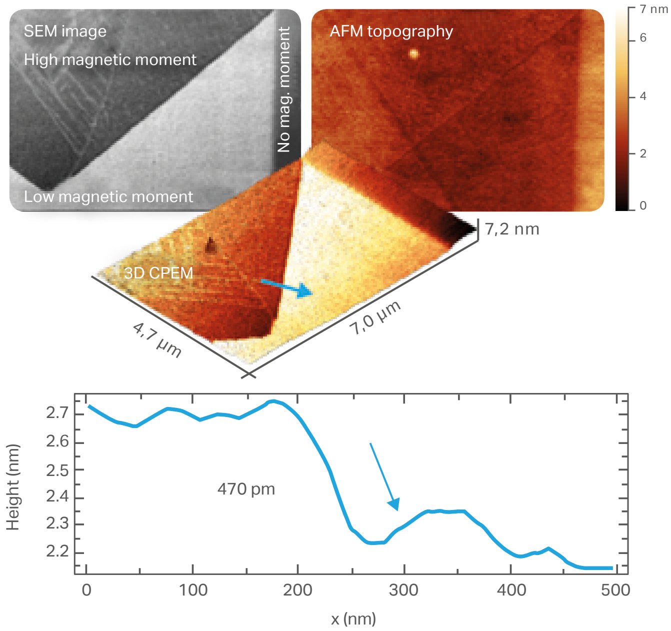


Figure 5: Simultaneously acquired images of SEM and AFM and 3D CPEM view of the modified surface of metastable iron. Profile of the high magnetic moment iron.