nGauge AFM

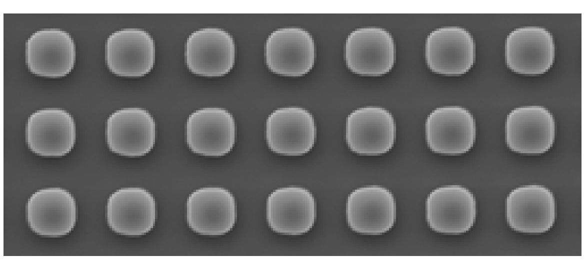
Microfabrication

The nGauge Atomic Force Microscope (AFM) can be used to look at a variety of microfabricated devices ranging from microfluidics and photonics crystals to semiconductor devices.

One common way to inspect microfabricated features is scanning electron microscopy (SEM). However, SEM only gives a two-dimensional image, which does not provide much quantitative information about the feature size, especially height of the structures. In contrast, with the nGauge AFM, it is possible to easily obtain a three-dimensional image of the sample in just a few minutes.

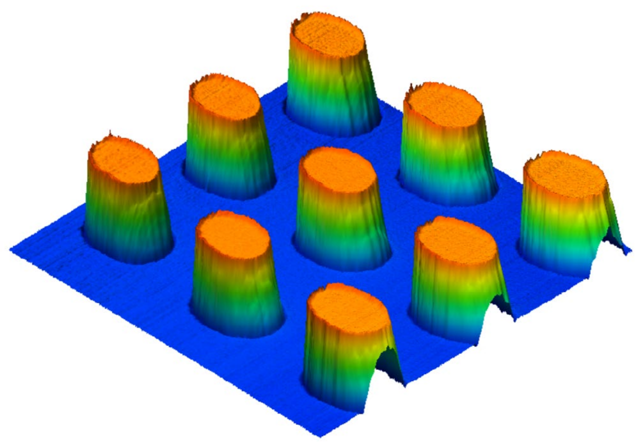
Furthermore, nGauge scans are performed in ambient conditions on a benchtop without necessitating any complex sample preparation steps. The nGauge can image samples whether they are conductive, semiconducting, or dielectric—whereas SEMs can only image conductive samples reliably. Dielectric samples must be coated with a thin layer of metal to image with SEM. Furthermore, the extra expense and time required by the vacuum operation requirement of electron imaging is avoided. By not needing these two sample preparation steps, the nGauge can save users about an hour per sample, enabling much higher throughput.

Here, the nGauge is used to inspect an etched silicon device which is expected to have 520 nm tall features in the shape of rounded squares on the XY plane with a 3 micron pitch. The SEM image effectively only shows the lateral shape and size of the posts, but gives no data about their height other than that they are likely protruding from the surface.

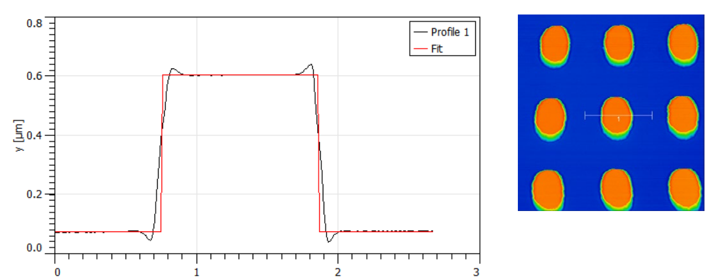


2D image of the sample using SEM

In contrast, not only does the nGauge AFM have similar or better lateral resolution, it can be seen from a scan of the same sample that the nGauge can quantitatively measure the height of the structures with nanometer accuracy. This can easily be derived from the data by drawing a line profile over the data and reading off the difference in plateau heights.



3D image of the sample using the nGauge AFM



Line profile over AFM data

By modifying the position of our line profile, measurements of the width and pitch of the features can be obtained to see if they match their expected values. The measurements from the nGauge also show that the features are not actually perfectly rounded squares, and tend to be more rectangular—which is also evident just from looking at the 2D representation of the AFM data.

In fact, the wrong lateral profile of the posts from the SEM image is an artifact stemming from its non-quantitative qualities. This is as SEM imaging is analogous to taking a photograph—the angle in which the image is taken will dramatically impact the observed shape of the feature, while AFM in contrast gives precise measurements of each feature.

The nGauge also allows users to gather highly accurate surface roughness measurements, as well as many other statistical quantities. This is useful for a large number of applications in the semiconductor industry such as verifying the roughness of a wafer post-chemical mechanical polish (CMP), or whether photoresist complies with the ever increasing flatness requirements for photolithography.

Moment-Based	
Average value:	185.7 nm
RMS roughness (Sq):	209.4 nm
RMS (grain-wise):	209.4 nm
Mean roughness (Sa):	172.0 nm
Skew (Ssk):	1.386
Excess kurtosis:	0.04349
Order-Based	
Minimum:	0.0 nm
Maximum:	682.2 nm
Median:	74.7 nm
Maximum peak height (Sp):	496.5 nm
Maximum pit depth (Sv):	185.7 nm
Maximum height (Sz):	682.2 nm
Hybrid	
Projected area:	58.68 μm^2
Surface area:	81.97 μm^2
Volume:	10.89 μm^3
Surface slope (Sdq):	1.897
Variation:	44.38 μm^2
Inclination θ:	1.89 deg
Other	
Inclination φ:	-77.46 deg
Scan line discrepancy:	0.04460

Statistical quantities

Overall, the nGauge allows users to see if a given process creates the desired features and enables quantitative analysis of microfabricated devices. This allows tighter control over microfabrication processes and provides highly accurate information about microfabricated devices.