Integration, Automation and Performance at the Nano scale

Fast scanning technology in the SmartSPM™

Developing a Scanning Probe Microscope capable of **high quality imaging at high scanning speeds** is a complex task requiring novel approaches in mechanical engineering, electronics and instrument control software design. First of all, a scanner of such an SPM should provide adequately fast response to input signals. Second, a controller should meet the following requirements: fast low-noise high voltage amplifiers and probe/positioning sensors electronics; high speed DSP or microcontroller, implementing flexible and effective control algorithms. And finally "Smart" software control algorithms are required. The last point to be considered is a probe capable to react fast enough to surface interaction during the scanning process.

AIST-NT is intensively developing the technology in all above directions. Some essential characteristics of the AIST-NT's Scanning Probe Microscopes are superior compared to any other commercially available SPM. Especially regarding the fast scanning, AIST-NT has **two key advantages:**

First, it is our **unique fast scanner** which has a wide scanning range and high resonance frequencies. In the same time the scanner features very low drifts, low nonlinearity and the cross-talk between the axes;

Second, it is a **"MagicScan" technology** including a set of feedback and scanning process control software algorithms.

AIST-NT scanner

AIST-NT has developed and currently produces **the fastest in the industry 100 micron scan range flexure-guided scanner** with monolithic piezo-stacks. The position of the scanner is measured by highly sensitive capacitance sensors.

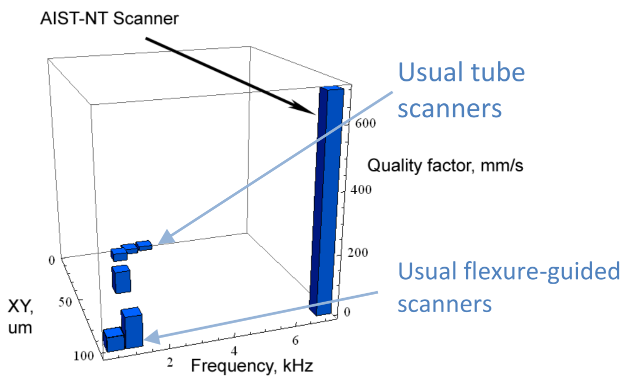

Figure 1a

Uniqueness of our scanner is that it has the highest XY and Z resonant frequencies among all commercially available SPM scanners with wide range of positioning: **100×100x15 um, up to 7kHz in XY & 15kHz in Z**. These high resonant frequencies along with large scanning range allow extending the feedback bandwidth, providing short response time and decreasing image acquisition time.

Depending on what problem you are solving using our SmartSPM™ you can always optimize the SPM mode. If you scan your sample with the speed normal to commonly used scanners, you can dramatically decrease the feedback error and consequently interaction forces between your probe tip and sample surface **keeping your probe in a good working condition during a long period of time** as well as providing non-destructive measurements. During high speed scanning you can keep the same feedback error and image quality, but with significantly **decreased data acquisition time**.

During any scanner development, its range and resonance frequencies appear to be mutually contradictory parameters, i.e. the wider the range is, the lower the resonance frequencies are.

In general, for scanners with any scanning range and any design type the product of resonance frequency and scanning range (in each axis) can be used as the main quality factor of scanner dynamical properties [1].

In AIST-NT we have developed the unique scanner, the quality factor of which is many times higher than any other commercially available scanners. The comparison of scanners with different scanning ranges and three axes based on the above quality factor is shown in fig. 1a, b.

It's important to say that there is no compromise between such high quality factor and other critical scanner properties. The AIST-NT scanner provides excellent metrological parameters (non-linearity in XYZ is less than 0.05%) comparable with the best commercial scanning probe microscopes. The scanner design guarantees plane-parallel motion of the sample without a parasitic slope of an image for any XY probe position relatively to the sample.

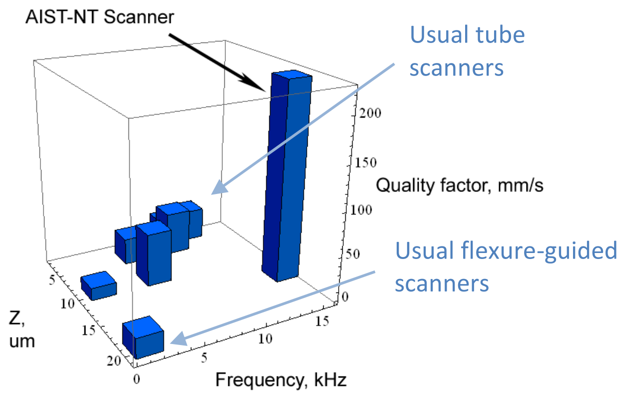

Figure 1b

The SmartSPM's system-level mechanical design is thermo compensated in order to minimize the XY scanner drift. This makes it possible to obtain high quality and high resolution images, e.g. HOPG with atomic resolution or lamellar structures of organic polymer monolayers.

AIST-NT, 359 Bel Marin Keys Blvd., Suite 20, Novato, CA 94949, USA
tel. +1-415-884-9500 fax. +1-415-884-2775 | www.aist-nt.com

MagicScan technology

The “MagicScan” technology is the set of feedback and scanning process control algorithms. These algorithms allow eliminating different dynamical errors such as overshooting, ringing and phase lag. The MagicScan key feature is the **absence or some negligible level of image distortions** while the scan rate is altered over the wide range.

To demonstrate our new technology, we have chosen a sample with some complex topography. The sample is a silicon test grating with 3 microns pitch and 25 nm height. The imaging of such samples is a hard job for any SPM. First, it’s due to several or many (on scan areas of tens of microns) sharp steps along scan line. Second, the surface is rather smooth that makes it possible to clearly see any ringing and overshooting of the scanner. In addition, the imaging of small steps (few nanometers) among the high steps (25 nm) shows no loss of resolution while accelerating the scan rate.

The semicontact AFM mode and a probe with a resonant frequency about 500 kHz was used to acquire images of 12x12 and 30x30 microns scan areas [2] with 300×300 and 400x400 points XY image resolution respectively.

The advantage of the “MagicScan” technology is illustrated in fig. 2 – 4 and video clips on our web site www.aist-nt.com [2]. Each image contains parts of two successive scans - one is the scan from the bottom to the top and another is from the top to the bottom. First of all, it’s seen that there is **no phase lag.** In other words, during changing of scan rate the image does not shift along scan line, which is very important for further positioning inside the scanned area. Moreover, there is no ringing after sharp turn at the beginning of each scan line, which is very usual for scanning at high rates (such ringing can be found as one or several vertical lines along the whole scan area).

On the 12×12 microns scan area the rate is increased from **3 to 30 lines per second**, while on the 30×30 microns area it’s increased from **2 to 20 lines/sec**. The actual value of the current scan rate is shown near the “rate ” field in the scan window (since we use the Z-error adaptive scanning algorithm, the actual rate is slightly different from the setting value).

To demonstrate the **fast scanning of small features on small areas**, we have done the local anodic oxidation of Ti film using the vector SPM-nanolithography technique (fig. 4). The image size is 3 µm, the scan rate has been changed **from 30 Hz down to 5 Hz**. The image was obtained in the semicontact AFM mode (tip resonance frequency is about 400 kHz).

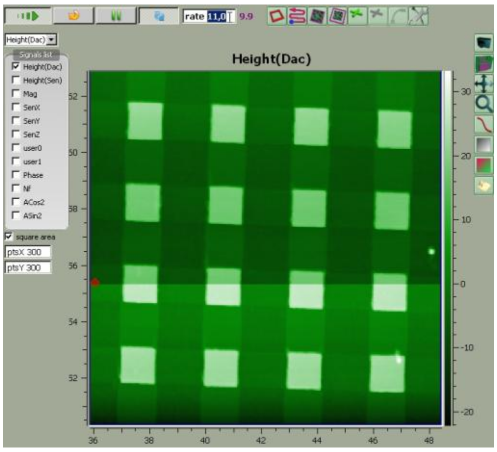

Figure 2. Si test grating, 3 µm pitch, height - 25 nm. Image size - 12x12 µm. Below red marker the scan rate is 3 Hz, above red marker - 10 Hz.

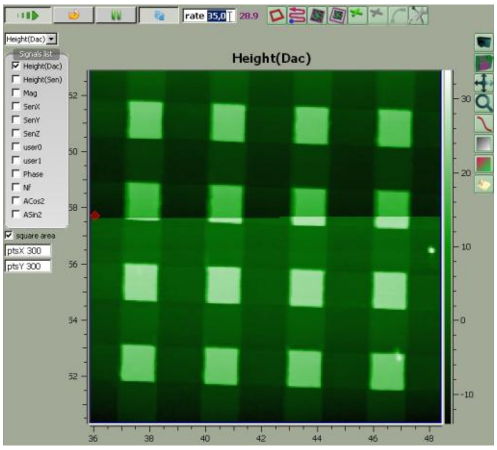

Figure 3. Si test grating, 3 µm pitch, height - 25 nm. Image size - 12x12 µm. Below red marker the scan rate is 20 Hz, above red marker – 30 Hz.

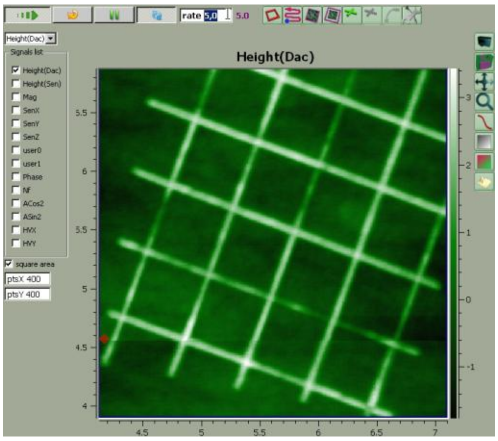

Figure 4. Local anodic oxidation on Ti film using the vector SPM nanolithography technique. Image size – 3x3 µm, line height – 3 nm. Below red marker the scan rate is 30 Hz, above red marker – 20, 10 and 5 Hz.

1. *Some design criteria in scanning tunneling microscopy. Dieter W. Pohl. IBM J. Res. Develop. Vol. 30 No. 4, July 1986.*
2. *Watch video clips of fast scanning (12 µm and 30 µm scan areas) at our web site www.aist-nt.com*