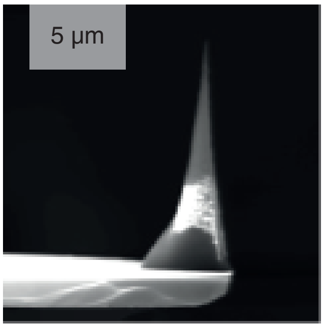
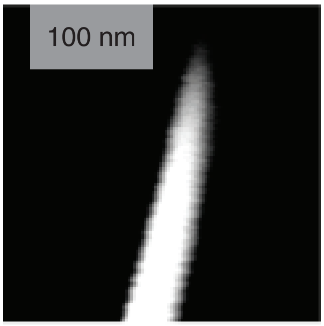
Sharp Diamond AFM Tip for Force Nano Lithography

SPM can be used not only for imaging but also for lithography providing small sizes of details. The main limitations of SPM lithography relate to the probe tip that degrades when using both force lithography and anodic oxidation techniques. When applying force lithography, the desired modification on surface can be obtained either directly by the tip or by etching through a pattern drawn by the tip on a relatively soft layer of resist, but even in the latter case the degradation of the tip is very likely as it has to cut the resist down to the substrate and even deeper to ensure the resulting line is solid.

Sharp diamond AFM (SCD) tips provide new opportunities for force lithography because of their durability and reliability. As diamond is harder than most of the materials, the tip tend to induce the necessary deformations on almost any surface.



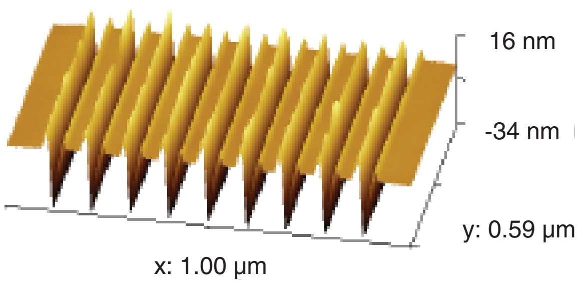
SEM image of the SCD probe tip.



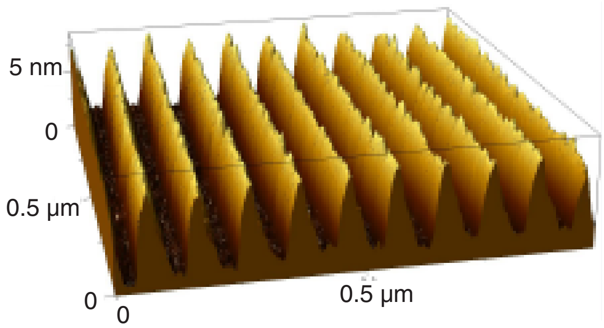
SEM image of the SCD tip end.

The tip can be used for force lithography both on rigid surfaces or soft layers applied on hard substrates. Among the materials that can me easily treated by the diamond tip are silicon, glass, metals and alloys.

Some of the results obtained by means of force lithography are presented below. The grating on the left was obtained in pulse force mode, i.e. point-by-point indentation. The grating on the right is made by scratching in contact mode. Both images are obtained by the same tips that ware used to cut the gratings. See next page for larger scans and details.

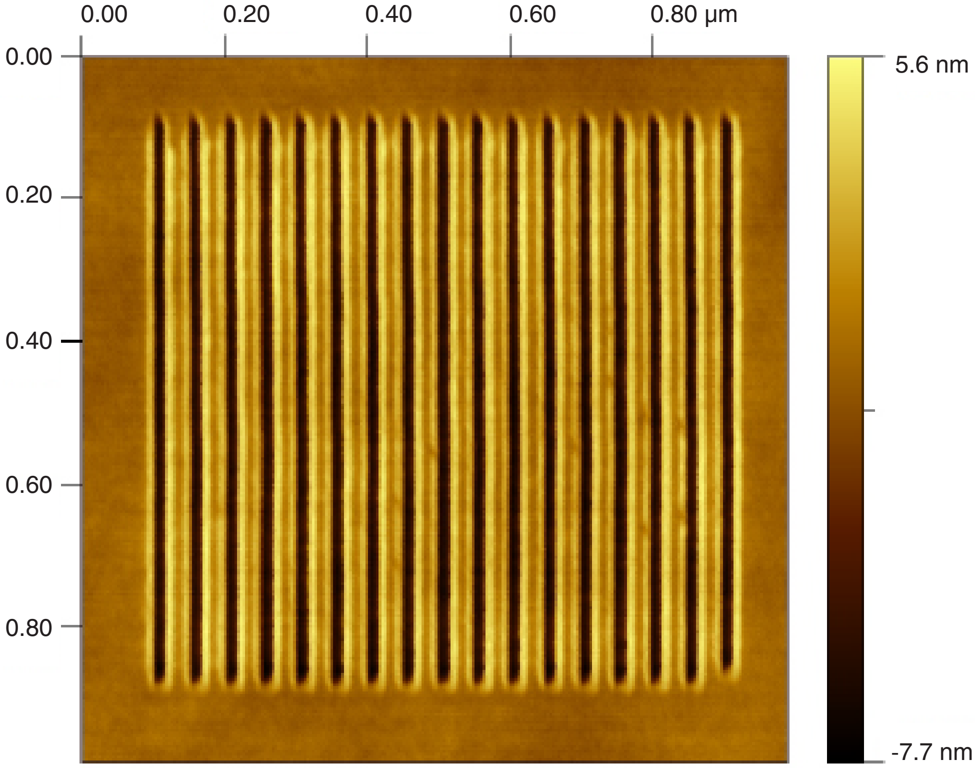


Grating cut on Si in pulse force lithography. Period 100 nm, depth 31-32 nm. Courtesy of A. Temiriazev, IRE RAS. AIST-NT SmartSPM.

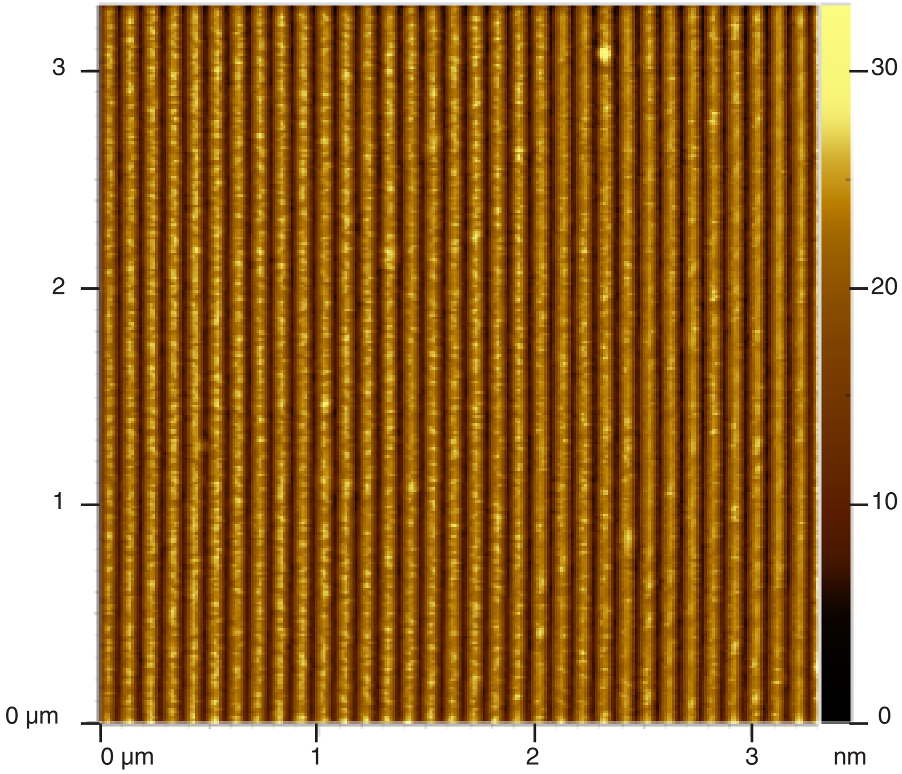


Grating cut in alloy film by scratching, material hardness about 500 GPa. Period 100 nm, depth 5-6 nm. Courtesy of E. Huseynov, T. Mekhtiyev, Institute of Physics of ANAS.

In terms of the attainable feature sizes, FIB technique is the only alternative to SPM. FIB is widely used in industry because of its speed. Still the costs of using FIB in research and prototyping are high because of a long and complex setup procedure, while SPM lithography with diamond tips is simple and advantageous for a lab.



AFM scan of a grating made by sharp diamond tip using raster force lithography. Period 50 nm, depth 6 nm. Courtesy of A. Temiriazev, IRE RAS. The use of SCD tips for pulse force nanolithography is described in detail in [1].



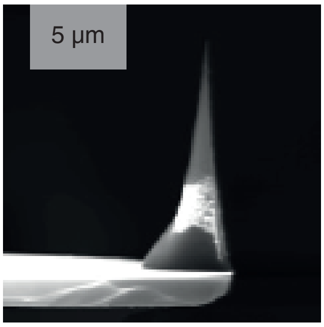
AFM scan of a grating made by scratching by sharp diamond tip. Period 100 nm, depth more than 20 nm. Courtesy of E. Huseynov, T. Mekhtiyev, Institute of Physics of ANAS.

1. Alexei Temiryazev, Pulse force nanolithography on hard surfaces using atomic force microscopy with a sharp single-crystal diamond tip. Diamond & Related Materials 48 (2014) 60–64.

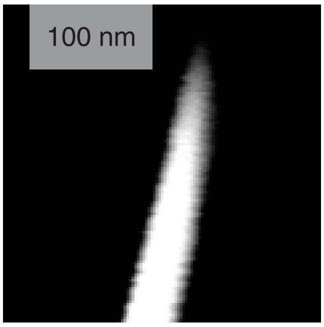
SCD Probe

ART™ tips are specially grown in CVD process and attached to silicon cantilevers for use in AFM. The probes have high aspect ratio and small tip radius.

The probe is highly resistant to wear, which is useful when fast scanning speed is needed, or when the surface contains sharp and rigid edges. Other applications are nanoindention, scratching and nanolithography experiments.



SEM image of the SCD probe tip.

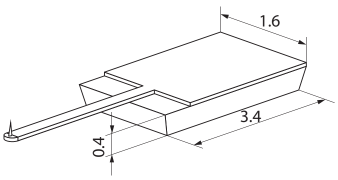


SEM image of the SCD tip end.

Tip material	Single Crystal Diamond (SCD)
Tip radius	5-10 nm
Tip aspect ratio*	about 5:1
Tip full cone angle*	about 10°
SCD orientation	<100> along the tip axis
Glue type	Non-conducting
Glue temperature stability	70°C (160°F)

*When measured at least on the last 200 nm of the tip end.

Cantilevers



ART™ diamond probes are glued onto rectangular (diving-board) silicon etched cantilevers. The range of spring constants and resonant frequencies of cantilevers available covers the Contact mode, Force Modulation, Non-Contact and Tapping mode. Cantilever backside is coated by Aluminium.

The chip holder size is 1.6 mm x 3.4 mm x 0.4 mm.

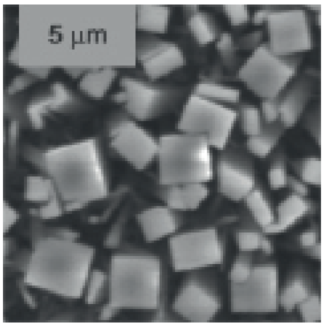
Part Number	Resonant Frequency, kHz	Spring Constant, N/m	AFM mode
D10	**10**	0.15	Contact mode
D80	**80**	3.5	Tapping mode. Force modulation. Contact mode.
D160	**160**	5	Tapping mode. Contact mode on hard surfaces.
D300	**300**	40	Tapping mode. Non-contact mode. Contact mode on hard surfaces. Nanoindentation. Force nanolithography.

Note: The glue used to attach the tip to the cantilever is not conducting, so the probe is not applicable for conductive AFM measurements. Values for resonant frequencies and spring constants are typical.

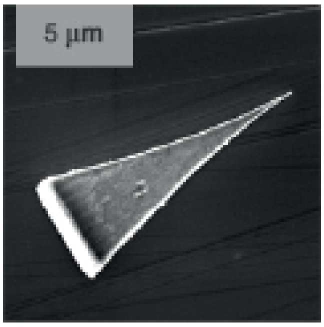
bAtch™ gRowth & aTtachment

ART™ stands for bAtch gRowth and aTtachment technology. ART™ probe for AFM consists of two parts that are manufactured separately: a cantilever on a chip-holder and a tip. The tips grow in batch in a specially designed process and then glued onto cantilevers using micromanipulation equipment and procedure.

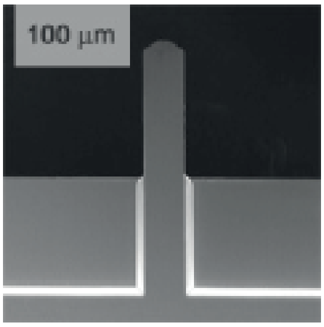
ART™ technique provides highly reproducible production at reasonable costs. Images below illustrate some of the key stages of the technology.



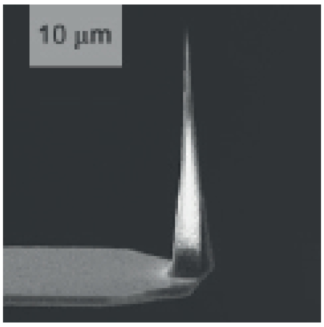
Film of diamond crystals. SEM image.



Single crystal diamond tip of the needed size and shape separated from others. SEM image.



Tipless silicon cantilever. SEM image.



SCD tip mounted on silicon cantilever. SEM image.

Diamond Tips

Diamond is a very promising material for making AFM tips because of its durability, hardness, outstanding chemical stability, high temperature conductivity and potential ability to conduct electric current. Besides application in AFM as a probes or indentors, the diamond tips can also be used as nanosized temperature sensors and X-ray detectors.

The tips are monocrystal diamond pyramids with the {001} facet in the basis having a controllable shape along the <001> axis.

Attachment

Attachment consists in positioning and gluing a the micro-sized object on a cantilever with high precision. This manipulation technique can be used to attach not only diamond tips and not only on silicon cantilevers. Our experience shows that other objects like carbon fibers or micro-sized particles can be handled the same way. For AFM, the objects can also be glued to silicon nitride cantilevers, piezo cantilevers or tuning forks.

Contact us if you have an idea how the diamond tips or micromanipulation technique can be used for your research. We also offer a service of cutting a pattern of your design on your substrate by SPM nanolithography methods.

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