AFM of High-Profile Surfaces

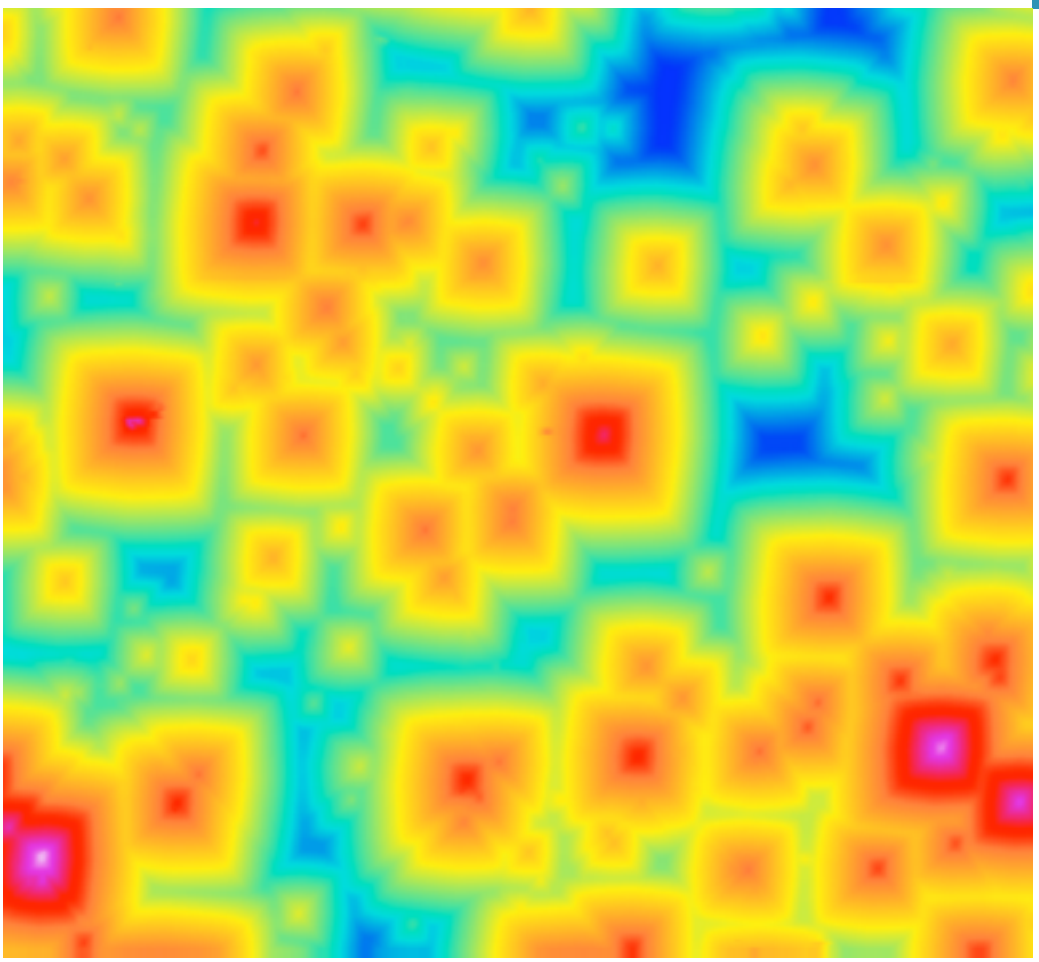
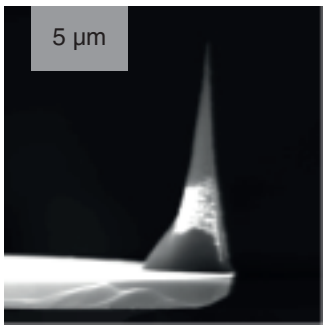


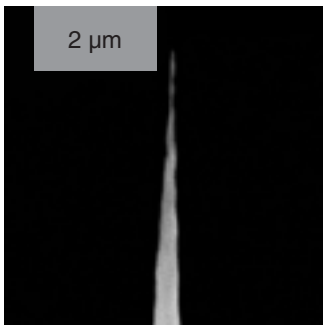
Fig. 1. AFM topograpgy image of black Si made using SCD probe tip. Scan size 40 µm. Profile height is more than 8 µm. See details and other application examples below.

High Aspect Ratio SCD Probe

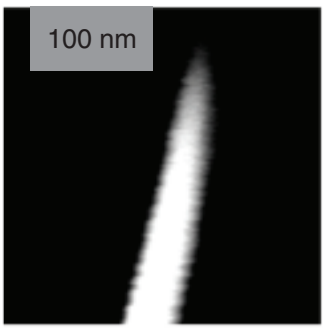
AFM imaging pores, deep trenches, high projections and other corrugations on surface requires high aspect ratio tips, i.e. tips having as small opening angle as possible. There are a number of known techniques how to manufacture this kind of AFM probes. Is SCD just another way of doing the same things? Not exactly.



SEM image of the SCD probe tip.



SEM image of the tip aspect ratio over 2 microns from the end.



SEM image of the SCD tip end.

Sharp single crystal diamond (SCD) AFM tip, full cone angle from 5° to 10°, tip radius less than 10 nm.

The first distinction of SCD is that it is not a structure on top of traditional AFM tip having large opening angle. The high aspect ratio is kept on several microns from the tip end, so that the tip is able to penetrate deeper than others. And when compared to tips of the same good shape, the difference is in the manufacturing costs and the end-user price.

Black Si Morphology

The height of the black Si profile used in solar panel applications in the images below made using SCD probe tip is about 6-8 µm. The precise evaluation of the sample topography of these black Si samples and its correlation with light trapping is important for improving the solar cell efficiency. Images are courtesy of Marko Surtchev and Sergei Magonov, obtained with Titanium scanning probe microscope (NT-MDT). Sample courtesy of Salman Manzoor (Holman Lab, ASU).

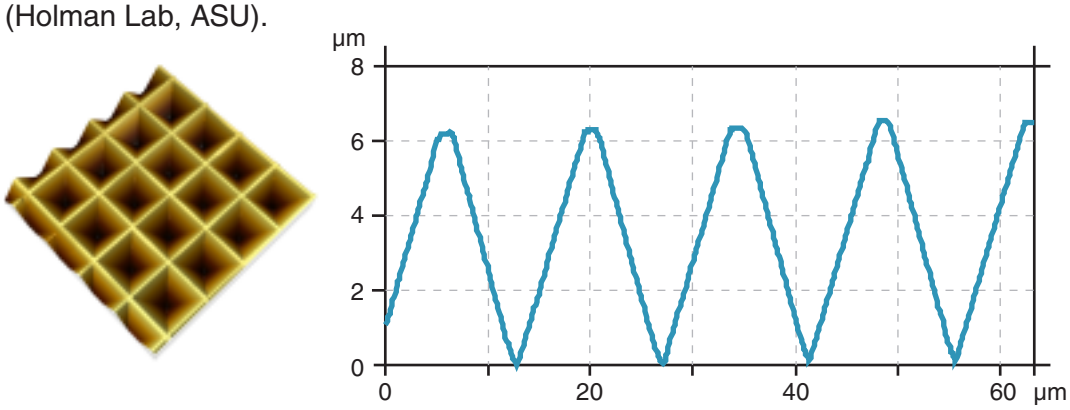


Fig.2. 3D height image of a black Si sample constructed of inverted pyramids and a cross-section profile along the horizontal diagonal. Scan size 40 µm.

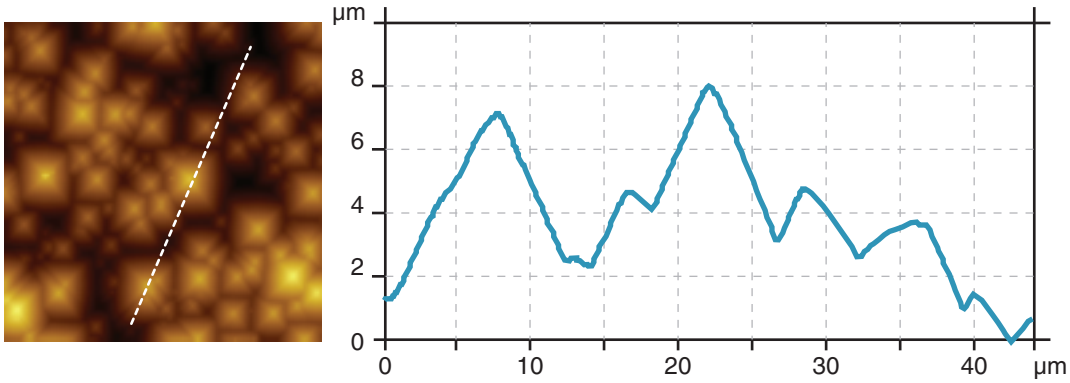


Fig. 3. Height image of black Si sample and a cross-section profile along the white dashed line. Scan size 40 µm.

Honeycomb Polymer Structure

SCD tip allows visualizing the sharp edges of the honeycomb polymer structure. Image courtesy of Sergei Magonov, NT-MDT.

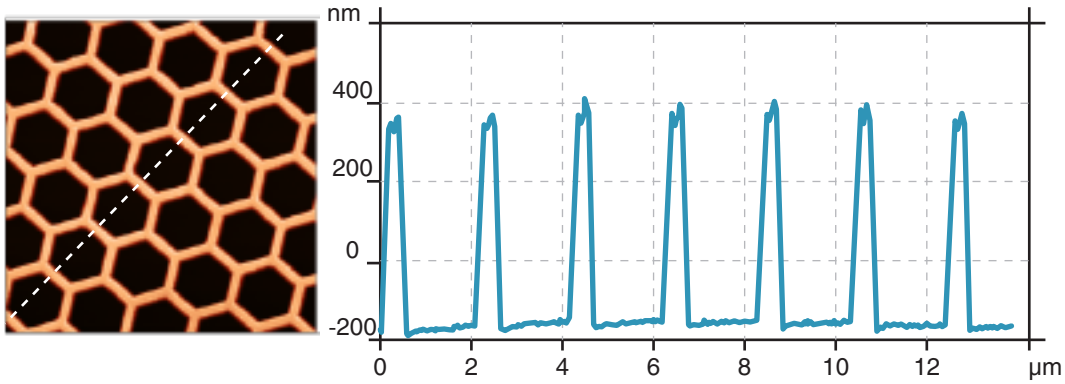


Fig.5. AFM topography of a honeycomb polymer structure and a cross-section made using SCD probe. Scan size 10 µm, height more than 500 nm.

Nitrocellulose membranes

AFM images of nitrocellulose membranes with different morphologies are presented below. Profile height is 1-3 µm. Images are made using SCD tips, courtesy of Sergei Magonov, NT-MDT.

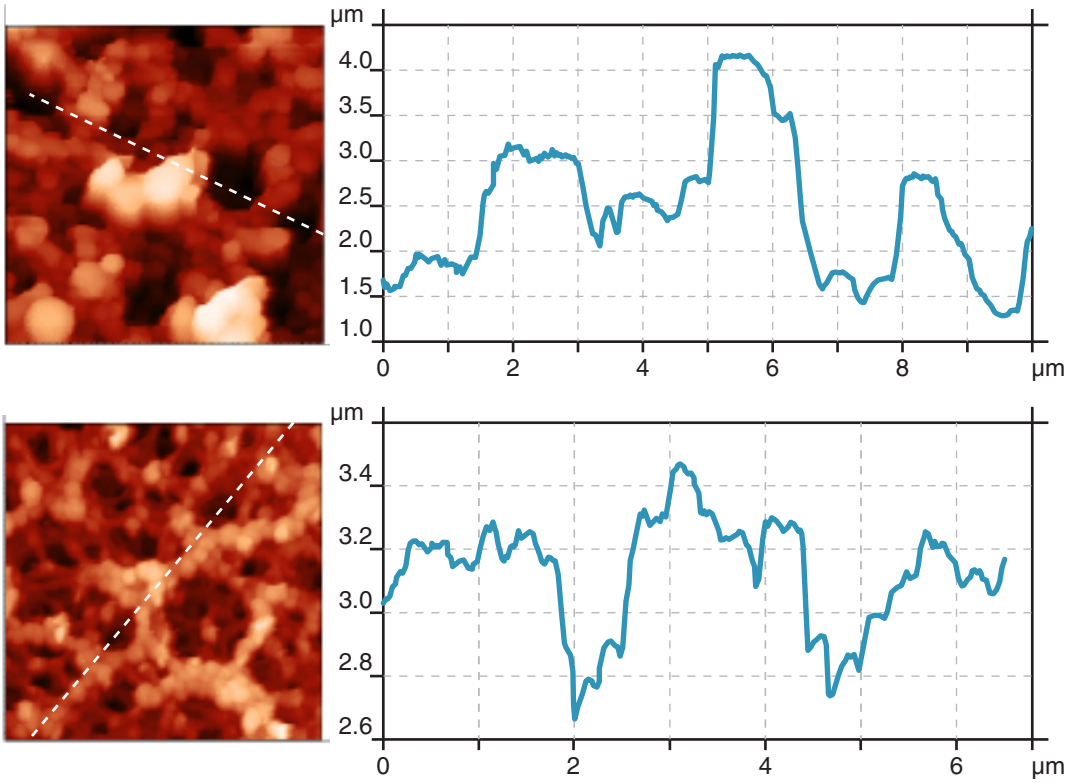


Fig. 4. AFM images of nitrocellulose membranes of different morphologies and corresponding cross-section profiles along the dashed lines.

Microporous polypropylene membrane

SCD probe allows visualizing both the large-scale corrugations and tiny details on AFM topography of microporous polypropylene membrane Celgard™ 2400. Image courtesy of Sergei Magonov, NT-MDT.

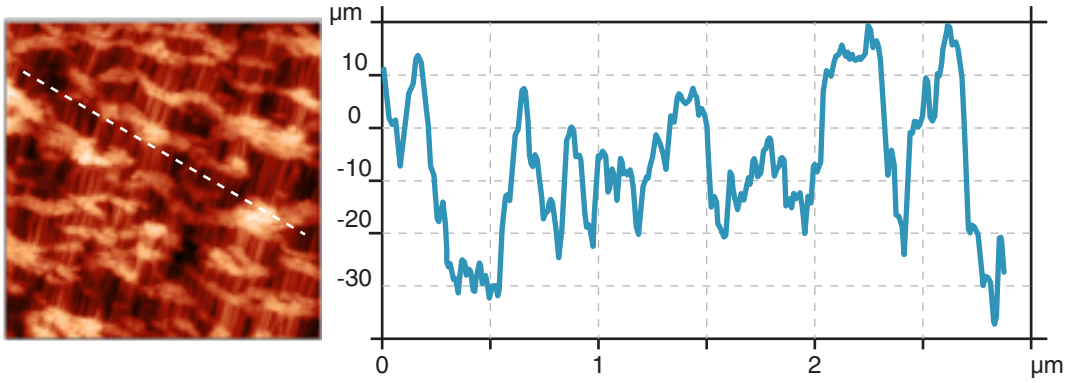
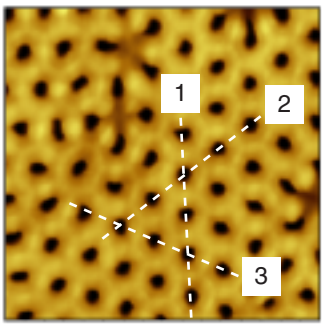
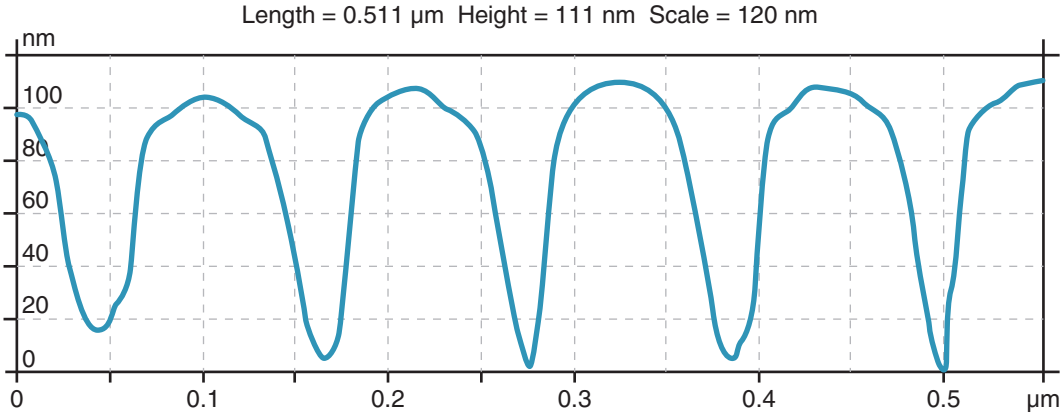


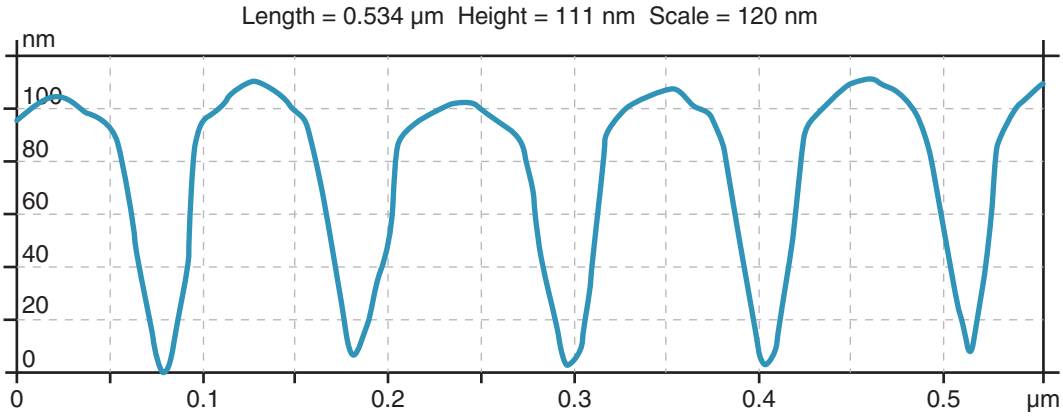
Fig.6. AFM topography of a microporous polypropylene membrane and a cross-section made using SCD probe. Scan size 10 µm, height more than 500 nm.

Porous Alumina

AFM topography of porous alumina sample exhibits pores more than 100 nm deep, the pitch of the hexagonal structure is also about 100 nm. Images are courtesy of Sergei Magonov, Agilent (2008). Sample courtesy of K. Napolski, MSU.







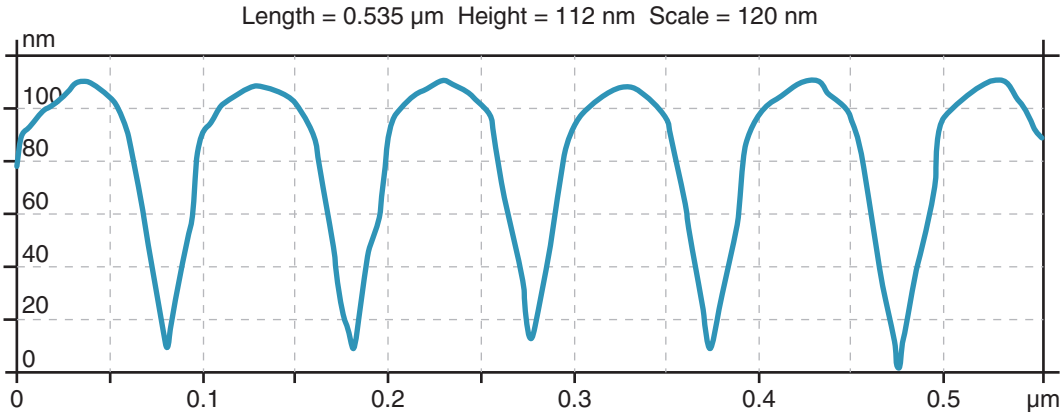
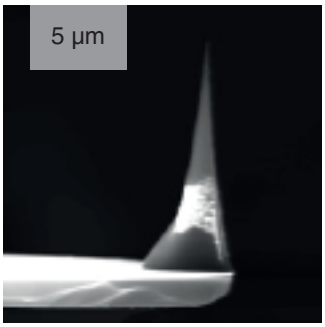


Fig.7. Topography AFM Image of porous alumina and corresponding cross sections. Scan size 800 nm.

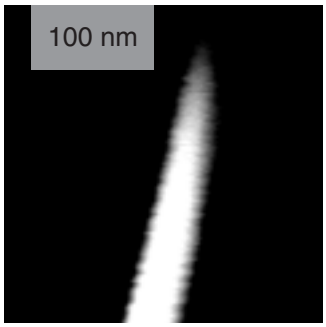
SCD Probe

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.

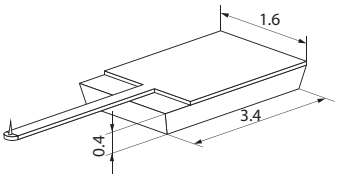


SEM image of the SCD tip end.

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.

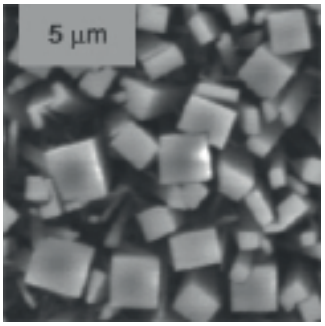
Part Number	Resonant Frequency, kHz	Spring Constant, N/m	AFM mode
D10	**10**	0.15	Contact mode
D80	**80**	3.5	Tapping mode. Force modulation. Contact mode.
D160	**160**	5	Tapping mode. Contact mode on hard surfaces.
D300	**300**	40	Tapping mode. Non-contact mode. Contact mode on hard surfaces. Nanoindentation.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

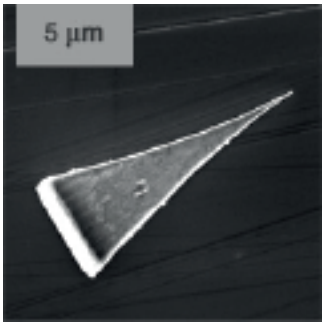
bAtch™ gRowth & aTtachment

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.

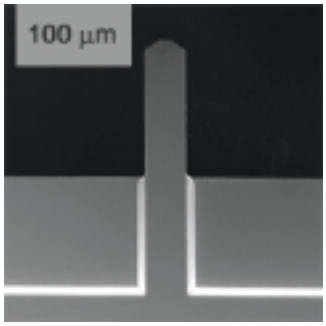
ART™ technique provides highly reproducible production at reasonable costs. Images below illustrate some of the key stages of the technology.



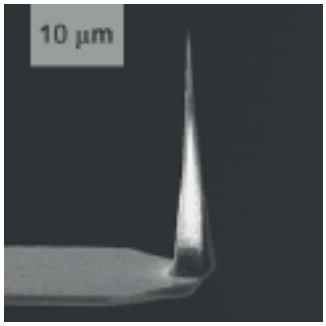
Film of diamond crystals. SEM image.



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.

Artech Carbon OÜ

Jõe 5, 10151 Tallinn, Estonia
Tel: +372 630 77 00
Fax: +372 630 77 99
Mobile: +7 926 295 68 32
e-mail: info@scdprobes.com