SCD AFM Tip Nanolithography Applications

One of the challenging problems for force nanolithography AFM is cutting metal films in a way that provides electrical isolation between the separated parts. Diamond tips are most prominent candidates for this job because diamond is the hardest known material that is able to scratch any other. But tip material is not the only necessary condition as the tip shape is also important. The sharper the tip, the less force is required for cutting, the less deformation the sample as a whole is subjected to, and the neater the cut.

Single crystal diamond (SCD) tips are sharp (tip radius less than 10 nm) and have high aspect ratio, and still they are durable and reliable in force lithography applications. Images below show an example of electrical separation of parts of a thick (more than 60 nm) metal stripe after a number of passes.

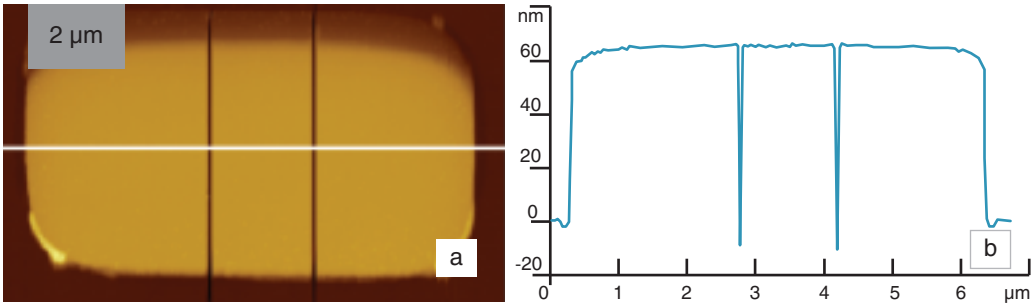


Fig.1. Co-Cr strip cutting experiment, AFM topography of the cut strip (a) and scan cross-section (b). The depth of the cut is 63 nm.

Images in Fig.1 represent a cut strip of CoCr 63-nm thick. The cut is made using SCD tip in Pulse Force AFM technique1, and it goes notably deeper into the Si substrate. The three parts of the strip became electrically isolated due to the cut (see Fig.2). Thus the Pulse Force technique allows producing less than 100-nm wide electrically isolated conducting paths in metal coatings.

Images courtesy of Alexei Temiryazev, IRE RAS.

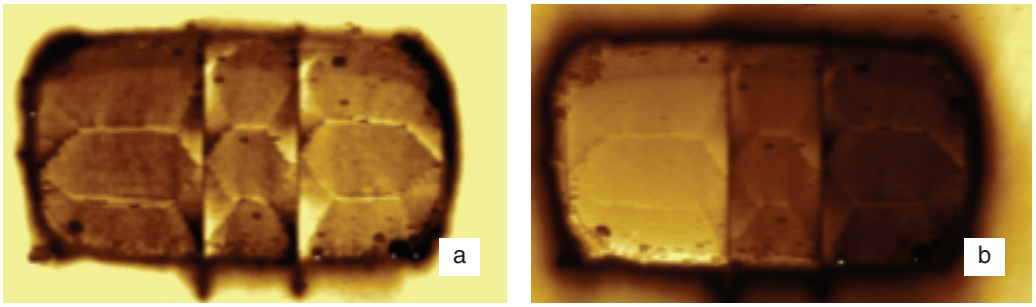


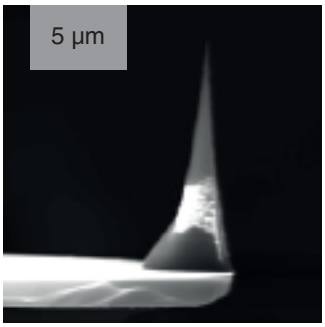
Fig.2. Lift mode AFM images of the cut strip made by Co-Cr-coated tip before (a) and after (b) charging one of the strip parts. Image contrast relate to the distribution of magnetic field of domains formed by the cut and electric field distribution caused by charging. Image (b) shows that the parts are electrically isolated. After a while, the charge starts leaking presumably because of air moisture absorbed on the sample.

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.

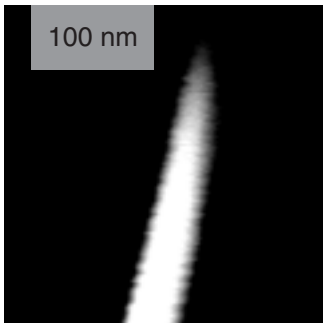
SCD Probe

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.

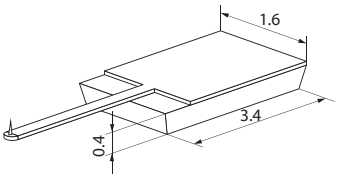


SEM image of the SCD tip end.

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.

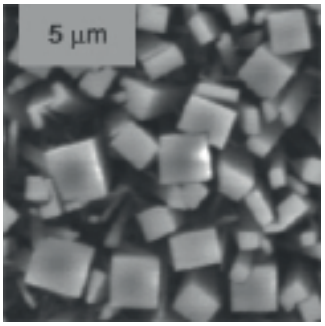
Part Number	Resonant Frequency, kHz	Spring Constant, N/m	AFM mode
D10	**10**	0.15	Contact mode
D80	**80**	3.5	Tapping mode. Force modulation. Contact mode.
D160	**160**	5	Tapping mode. Contact mode on hard surfaces.
D300	**300**	40	Tapping mode. Non-contact mode. Contact mode on hard surfaces. Nanoindentation.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

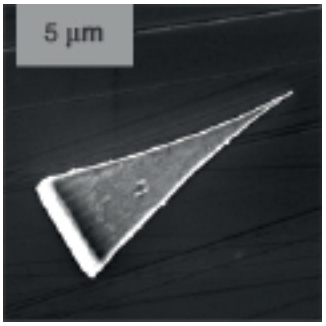
bAtch™ gRowth & aTtachment

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.

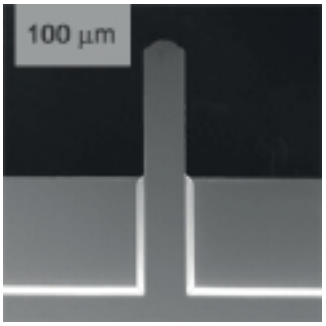
ART™ technique provides highly reproducible production at reasonable costs. Images below illustrate some of the key stages of the technology.



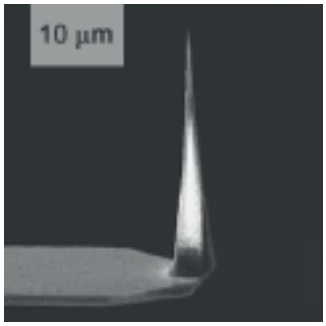
Film of diamond crystals. SEM image.



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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