THE SPM AS A TOOL

THE „NANO-HAMMER“

The Scanning Probe Microscope (SPM) cannot only image surfaces, its tip can also be used to process the surface and produce nano-structures.
With the standard cantilever-microscope the tip sitting on a flexible arm can only apply small forces. This article describes an SPM which increases the applicable forces about 1000 times by the use of Nanomotors and even makes tip imprints in diamond surfaces possible.

The principle
The detection of the sample surface with a shear-force sensor decouples the sensitive sensor from the movements of a tool towards the sample. The shear force sensor oscillates parallel to the surface and the amplitude of the oscillation is measured. Within a short distance between sensor and sample shear-forces occur, which cause a damping of the oscillation.

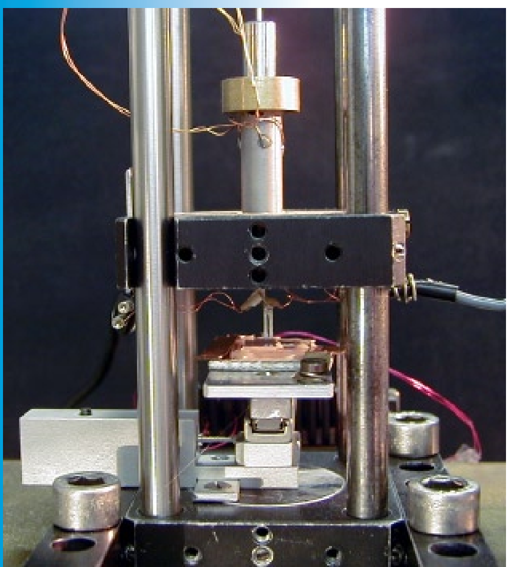
Fig.1: Photo of the SPM-setup

A tube-scanner performs the movement in x- and y-direction parallel to the surface. The z-movement of the tip is realized by a Nanomotor inside of the tube-scanner (Fig. 1).
The sample-carrier is fixed by two clamps on top of a small Nanorobotics XY-stage. The sample can be moved within 5 x 5 mm^2 underneath the sensor head, the positioning resolution is better 1 nm. Thanks to the relatively large positioning area it is also possible to mount several samples on the same carrier and inspecting them without reloading the SPM. All other XY-stages of our Nanorobotics series can be used as well, including absolute positioning versions for image mapping.
A brass cube with rubber-feet is sufficient for oscillation-isolation of the complete SPM setup. Additional damping systems are not required.

The tool…
The maximum force that a typical cantilever SPM can apply is about 0.3 mN.
The force limit of our shear force SPM is defined by the force limit of the z-Nanomotor: between 0.30 and 0.35 N. Therefore the maximum force is 1000 times bigger than that of a typical cantilever SPM. Since the tip is in line with the carrier tube of the Nanomotor, bending of the carrier tube or breaking of the shear-force-sensor by transverse forces is avoided. Assuming a contact area of 1 micron^2 between tip and sample, a force of 0.3 N is equivalent to a pressure of 3x1011 N/m^2 or 3x10^6 bar. To compare: an typical African elephant with a weight of 5 tons standing on one foot with a foot diameter of 400 mm applies a pressure of 4x106 N/m^2, which is by a factor of 100 smaller than the pressure of the SPM.

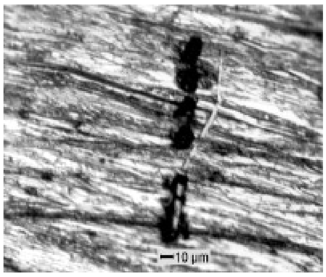
Fig.2: Tip imprints in copper, size about 17 µm x 23 µm, depth: 5 - 8 µm

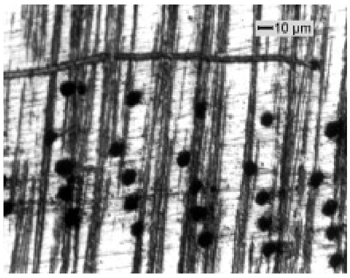
Fig.3: Tip imprints in steel, size about 9 µm x 12 µm, depth: 3.5 - 5 µm

… in operation
Several imprints of a diamond tip were made, pressing the tip into the sample with multiple coarse steps for maximum depth. After every imprint of a dot the sample was moved with the xy-stage. Afterwards an image of the sample was made with an optical microscope:

Klocke
Nanotechnik

The SPM as a Tool

The sizes of imprints made with the same force differ by a factor of 2 in steel and copper. This value correspond to the values of the material hardness.

Mold in a diamond surface

Fig. 4 shows a mold in a diamond surface, produced by the tip “hammering” in coarse step mode into it several times with accelerations of 50G.

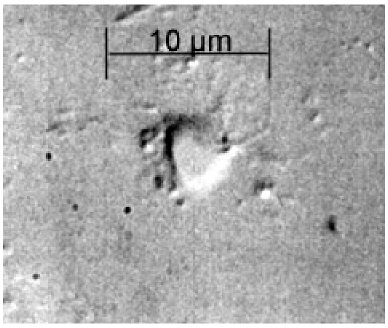

Fig.4: Mold in a diamond surface

By the continuous pulse waves a piece of diamond was broken out of the sample surface. The process works with very little abrasion of the tip.

Cut in a glass surface

With the same orientation of the tip a scratch in glass was produced. The thickness of the line is about 1.5 µm.

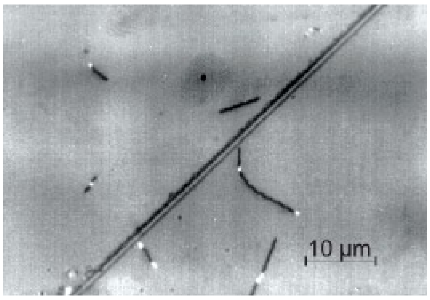

Fig.5: Cut in a glass surface

On the left and right side of the scratch flakes are visible, which were produced by the scratching process.

The microscope as a tool

A diamond tip was used as engraving and measuring tool for all experiments. The SPM-pictures were taken with the same tip immediately after processing the surface.

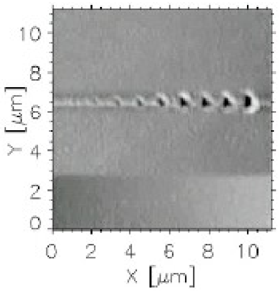

Fig.6: Imprints of the diamond tip in nickel

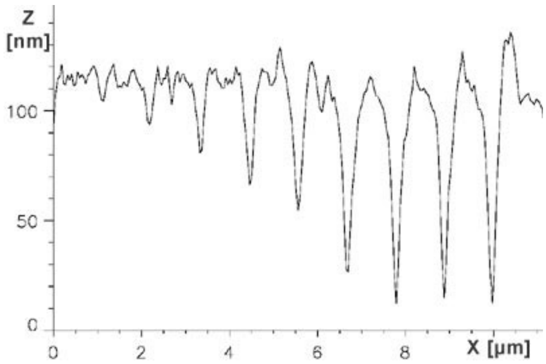

Fig.7: Profile of the imprints

Fig. 6 & 7 show several imprints in nickel with increasing depth, measured in SPM mode and as line-scan. Imprints in nickel, stainless steel and glass do not show significant differences despite the different material properties.

Six imprints in sapphire

Even reproducible tip imprints in sapphire can be

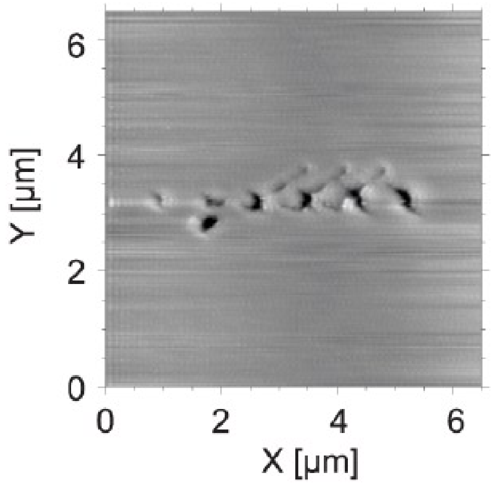

Fig.8: Imprints in Sapphire

made with the same precision as in soft nickel. The mold underneath the second imprint was present before the sample was processed.

Only processing of diamond surfaces can cause the breakup of the diamond tip if it is not a single crystal. In other words: the small Nanomotor is strong enough to break diamonds!

Since the SPM can measure quantitatively the depth of the produced structures, an algorithm to engrave 3D-structures in surfaces is possible. Bitmaps could be transferred onto the surface three-dimensionally, transforming color information into a 3D profile.

Precision made in Aachen:

Klocke Nanotechnik

Germany:
Pascalstr. 17
52076 Aachen

Phone: +49-2408-95099-20
Fax: +49-2408-95099-26

www.nanomotor.de
info@nanomotor.de