Nanomanipulation with Force Feedback

The tip strikes back

Imagine a tool with 2 nanometer resolution that is controlled by a joystick and answers with the corresponding force feedback. Manipulating small objects manually becomes very intuitive, because the operator uses his own senses for controlling the stage. The forces applied to the tool tip can be so high, that even imprints in diamond surfaces can be produced.

Figure 1:
The setup containing the xyz-stage and the force sensor with the tool tip.
The accessible volume is 20 x 20 x 20 mm^3. The resolution is 2 nm for each axis.

The setup

The tool includes a manipulation stage for three dimensional movement, a tip, the calibrated force sensor for measuring the applied force and a force feedback joystick (see Fig. 1).

The manipulation stage is realized with modules from our Nanorobotics series. Two “NMT 20“ modules and one “NMT Z20” lead to a working range of 20 x 20 x 20 mm^3 at a resolution of 2 nm for each axis. The shown setup operates top down and allows to work with samples of different size. Other NMT modules with strokes between 5 and 70 mm are also available for this application.

The sensor is sensitive enough to give the operator a strong feedback signal, when a few mN force are applied:

The force feedback joystick can induce forces into the hand of the operator between 0 and 10 N. This range can be scaled to the force range of the tip by software. The operator feels the hardness of a surface in his hand, when he tries to push the tip into this surface. A hard sample hits back at the moment the tip collides with it. A soft sample increases the force slowly when the tip moves into it.

The diagrams in Fig. 2 show a measurement of the pressure the stage imposes upon the sample, when it is moved along the z-axis. The tip was moved against a steel plate in fine positioning mode (right diagram). The retraction of the tip causes a faster decrease of the force, an imprint was made. The left diagram of rubber was made in coarse step mode and shows a more elastic behaviour. The maximum force can be about 0.5 N.

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Processing material in Electron Microscopes

If the above setup is mounted in a Scanning Electron Microscope (SEM), very small objects can be manipulated. Figure 3 shows small plastic bubbles filled with ink that are pierced with a Nanomanipulator. The operator controlling the tip can feel the elastic resistance of the bubbles when he moves the joystick. This information can be used to optimize the production of carbon copy paper.

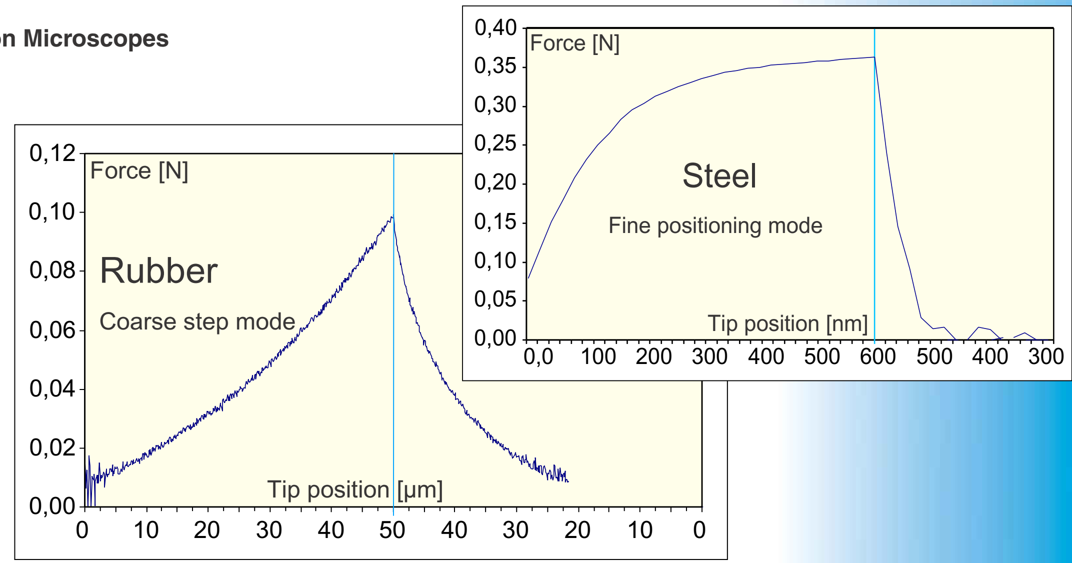

Fig. 2: A tip is moved into rubber (left diagram) and steel (right diagram). Behind the vertical line the tip is retracted.

If the stage is used in coarse step mode it is possible to induce very high pressure. In this mode the tool works comparable to a jackhammer and even imprints in diamond surfaces can be made, see Fig. 4.

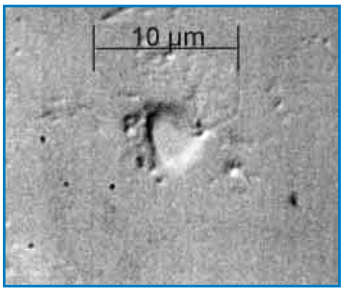

Fig. 4: Imprint in a diamond surface.

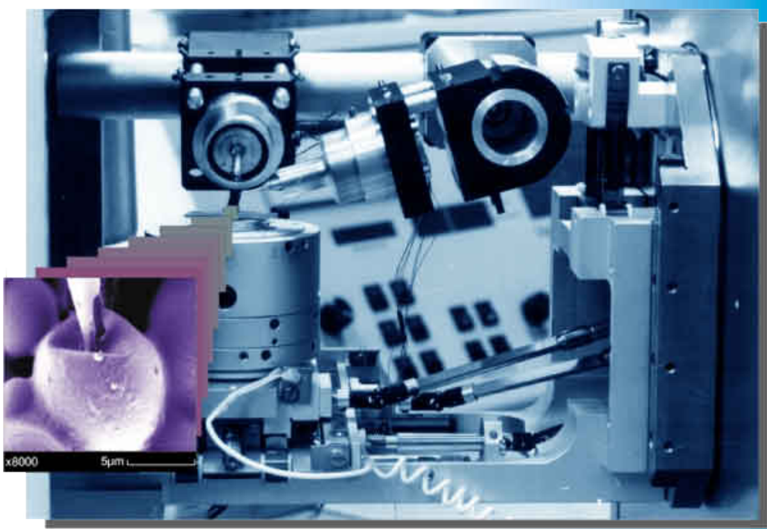

Fig. 3: Two Nanomanipulators in a Scanning Electron Microscope.

Figure 5 shows imprints in a nickel surface. The picture and the profile of the nickel sample was measured with our Atomic Force Microscope (AFM).

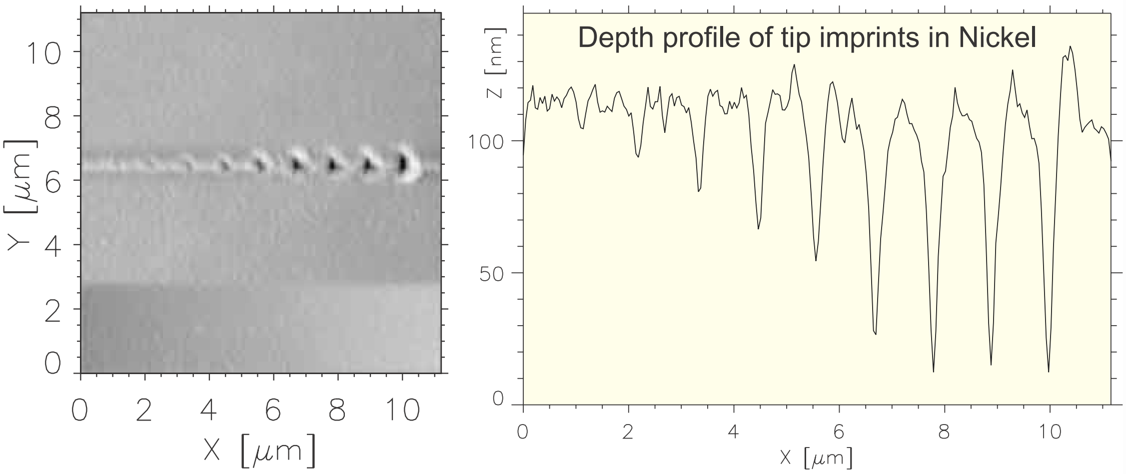

Fig. 5: Imprints with different depth in nickel and a line profile of the nickel surface.

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