Subproject B6: „Force-Sensor Arrays"

- **Prof. Dr. rer. nat. habil. Michael Hietschold**

Background and Motivation

Scanning Probe Microscopies (SPM) have revolutionized our understanding of the nanometer, molecular and atomic world. They have offered unprecedented spatial re-solution, highly local physico-chemical measurements, and even controlled action – from nm-lithography to atomic manipulation. They have introduced most of the pre-viously speculative features of nanotechnology into reality of the labs.

A serious drawback on the way to broad application has been, however, the opera-tion of all these scanning probe methods with only one single tip. This leads to rather slow and inefficient performance, especially on the macroscopic scale. As an way out of this drawback miniaturization and parallelization lead to multiple-probe methods which use independently operating tips. Perhaps the most famous development in this line is the "millipede" from IBM Zurich.

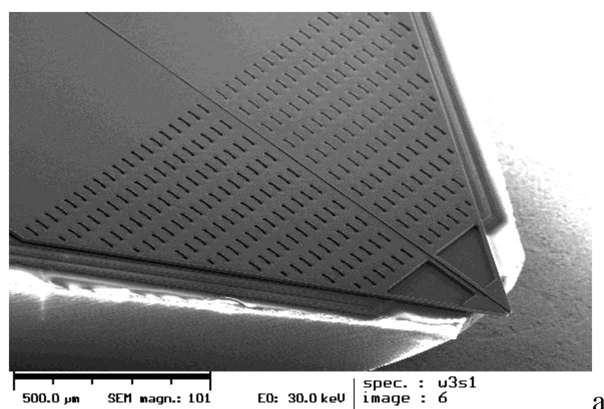
Project-strategy

Parallelization of the versatile scanning force microscope means arrangement of more than one miniaturized cantilever-tip probes on one and the same chip. To have as many options as possible, these cantilever-tips should be able to work in the dy-namic mode. Electrostatic actuation and optional detection of the cantilever elonga-tion by either laser beam deflection or a capacitive measurement have been chosen.
An important issue is not only to fabricate the microstructures and to publish nice images of them but to implement a routinely working microscope unit. This demands an accompanying development of a microscope head contacting and housing the microchip which is compatible to an existing microscope stage and of a special digital control and data acquisition which is tailored to perform real work using these multiple-tip chips.
As a first step, two independent cantilevers on one chip with a tip-distance in the order of 10 µm have been implemented.

First results

Fig. 1a shows a two-cantilever structure with integrated tips fabricated from a silicon chip bonded on a Pyrex glass substrate which carries counter-electrodes and wiring. Fig. 1b shows the specially developed microscope head. Fig. 1c is a TEM micro-graph of the integrated probe tips.
Topographic imaging has been performed with each of the two cantilever tips on a special test-grating as well as on a diamond thin-film. The images have been taken in the dynamic non-contact force microscope mode. Both methods of tip-elongation detection have been successfully checked. Fig. 2 shows the images of a test grating obtained with the two tips of one microchip. The lateral shift of the imaged areas corresponds to the distance of the tips.

Fig. 1: Microchip forming 2 cantilever-tip tongues bonded on a Pyrex substrate (a), location of this chip in a schematic side-view of the specially designed SPM head at the lower reflection point of the red laser beam (b) and TEM micrograph of the 2 tips integrated in the foremost part of the cantilever tongues (c)



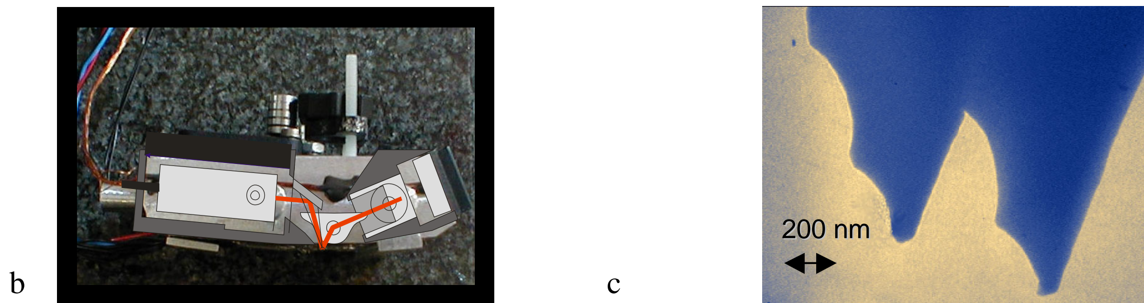
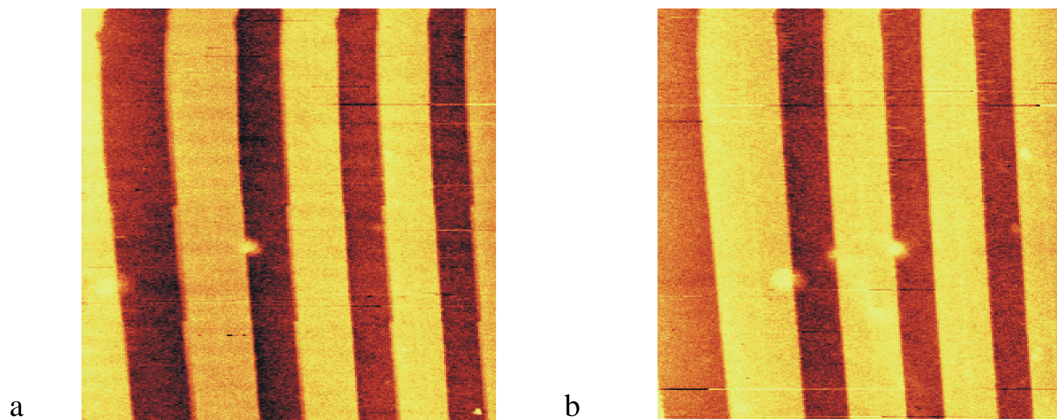
b  c

Fig. 2: Topography of a test grating imaged with the left (a) and right (b) tip of the 2-cantilever-SFM in the non-contact modus (scanned area 16 x 16 μm^2)

a  b

As a second application a temporary MESFET has been created by pressing two conductive tips on a silicon surface. The device characteristics have been measured and compared to a simulation.

Future prospects:

Development in the next period will be along the following lines

- further improvement of the 2-cantilever chip
- development of a chip carrying 3-5 cantilever-tips.

Special tasks accessible could be: simultaneous imaging and analysis using tips operating in different modes on neighbouring areas on the sample surface. Highly localized measurement on microstructures, crystallites or selected interfaces.

References

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For more information: Prof. M. Hietschold
TU Chemnitz, Institut für Physik
D-09107 Chemnitz
hietschold@physik.tu-chemnitz.de