

P21 – Traceable Calibration of Micro- and Sub-Micro-Newton Forces

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The Working Group Nanoforce Metrology for Tactile Sensors of PTB is engaged in determining the probing forces of stylus instruments and the stiffness of AFM cantilevers. In recent years different types of micro force sensors based on piezoresistive and electrostatic principles have been developed. The motivation for the development of force sensors in the micro- and sub-micro-Newton force range was micro-components with very low hardness. These lead to scratches and considerable measurement uncertainties when measured with stylus instruments with probing forces in the mN range. By reducing the probing forces it was, therefore, possible for the first time to measure soft surfaces non-destructively.

PTB has developed transfer standards to calibrate the stiffness of AFM cantilevers and the probing forces of stylus instruments.

A piezoresistive cantilever-type standard for the calibration of stiffness and force has been developed (Fig. 1). The cantilevers are manufactured by the Institute for Semiconductor Technology of Braunschweig Technical University. Metrological investigations have been carried out at PTB since 2002. For a detailed description of the calibration setup and the calibration procedure, see Doering et al. at the IMEKO Conference 2002.

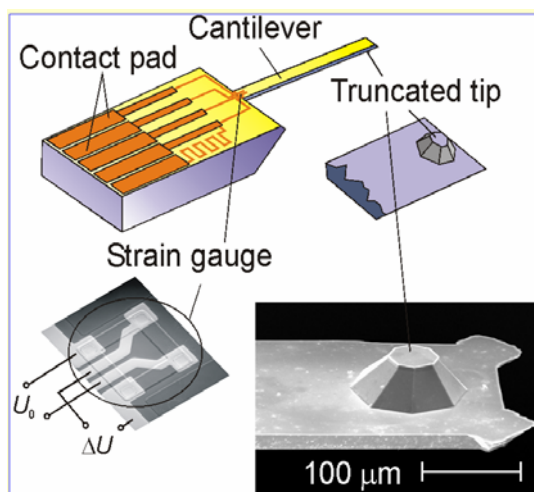


Fig. 1: Cantilever-type standard

Furthermore, an electrostatic comb-drive MEMS actuator with a multi-folded spring system has been developed for the measurement of AFM cantilever stiffness and probing force (Fig. 2). Details are published in TM 06/2009 by Gao et al. In the article the principle of measurement, the design, the manufacture, and the assembly of the MEMS as well as the first test results and the performance parameters achieved are described.

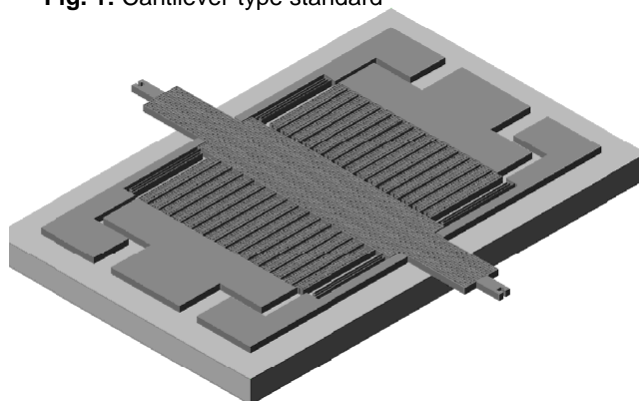


Fig. 2: Electrostatic comb-drive MEMS force

PTB is able to calibrate the sensors described in the nano- and -in future- also in the pico-Newton range. The sensors and the force and stiffness calibration set-ups are described in the poster.

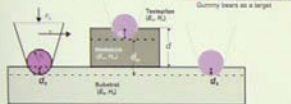
Traceable calibration of micro- and sub-micro-Newton forces



Motivation

The motivation for the development of force sensors in the micro- and sub-micro-Newton force range was micro-components with very low hardness. These lead to scratches and considerable measurement uncertainties when measured with stylus instruments with probing forces in the mN range. By reducing the probing forces it was, therefore, possible for the first time to measure soft surfaces non-destructively.

$$\Delta d = d_1 - d = d_2 - d_0$$

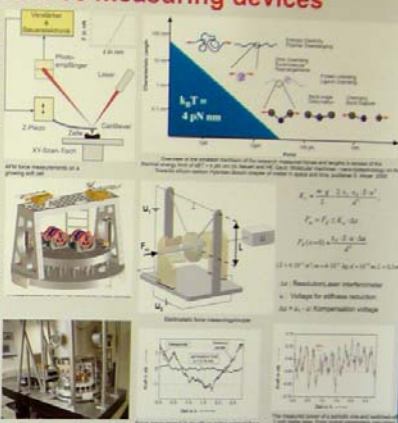


When measuring coating thicknesses cause different deformations of the surface (d_1, d_2) in relation to the measured thickness on the top value of d_0 .



Nanoforce measuring devices

The measurement principle of the nano-force measuring device is based on a disc pendulum that is deflected by the force to be measured. The electrostatic deflection is compensated with the help of external capacitor electrodes measured the voltage expended. To compensate for the electrostatic force is the electrostatic stiffness reduction; by the inherent stiffness of the pendulum of 0.13 Nm to 0.007 Nm is reduced, increases the sensitivity of the system. To compensate for disturbing seismic vibrations and thermal drift, in addition to the actual measurement system, a second, identical reference system attached.

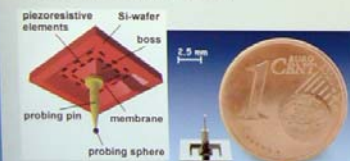


First long-term measurements of air over a period of 3 hours showed a noise (standard deviation) of the measuring device of 160 pN (low pass filter frequency: 0.02 Hz). The first force measurement at the limit of sensitivity of the prototype system, the force was determined; the pressure exerted by the light of a He-Ne laser with an output of 7 mW. The measured value of 28 pN is smaller than that by only 9 pN from power of the laser light and reflection factor of the pendulum disc) calculated force.

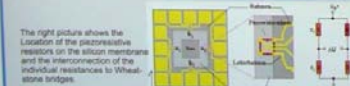
Micro force probing systems developed in PTB

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3d boss-membrane sensor



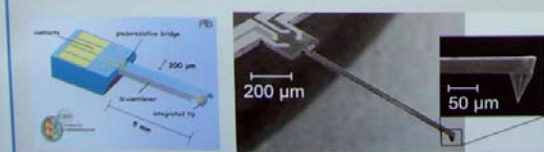
After calibration of the bending stiffness and the output signals as a function of the deflection of the probe can be used as well as coordinate both as a force sensors. The advantages of these probing devices are the sensitivity at nanometer range.



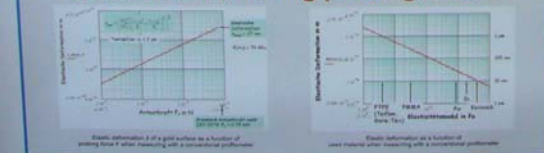
The right picture shows the location of the piezoresistive resistors on the silicon membrane and the interconnection of the individual resistors to Wheatstone bridges.

The 3d boss membrane sensor was developed in cooperation with the Institute of Microtechnology (IMT) of the TU Braunschweig (Prof. Buttgenbach) and the Carl Zeiss GmbH, Oberkochen.

Piezoresistive 1d cantilever



Deformations during probing forces



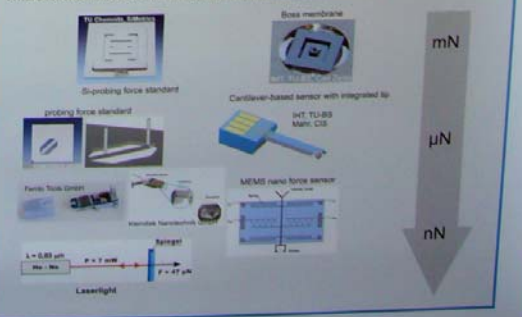
Micro- and Nano-Force metrology

The calibration of measuring equipment for small forces consists of a micro-force electronic balance, a nano positioning device and a bridge amplifier.



Micro- and Nano force transfer standards

Wherever small forces are to be measured, transfer standards are used.



Physikalisch-Technische Bundesanstalt Braunschweig und Berlin
Working group Nanoforce Metrology for Tactile Sensors