Transfer Standards

for Scanning Probe Microscopy

The demand for quantitative dimensional characterization of nano- and microstructures significantly increases. This is driven for example by advances in semiconductor industry and many other fields of precision engineering. Manufacturing in these industries depends strongly on the performance of metrology equipment (e.g. SPM) to ensure and improve yield. Both suppliers and users of such equipment are in need of physical transfer standards to achieve quantitative measurement results. Traceability to the International System (SI) unit of length is an issue relevant to those who have to maintain ISO or other quality certifications.

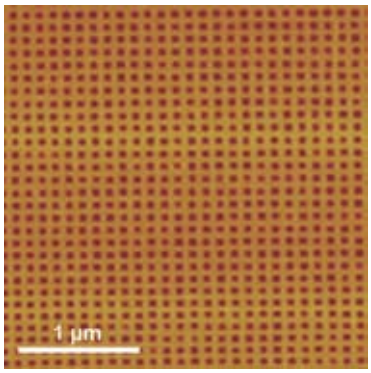
Photograph of a 2-dimensional pitch standard showing a 200 nm pitch at the center area.

Meet the Demand by Cooperation

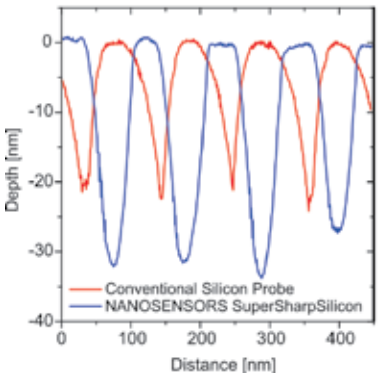
In cooperation with National Metrology Institutes (NMI's) in Europe NANOSENSORS™ has developed a set of physical transfer standards for SPM applications. These standards allow the calibration of the X,Y and Z axis of SPM equipment. In addition, certain system induced limitations of this equipment can be revealed and compensated. The German Physikalisch-Technische Bundesanstalt (PTB), Great Britain's National Physical Laboratory (NPL) and the Danish Institute of Fundamental Metrology (DFM) participated not only in the product definition phase. Their main task was the development of measurement techniques for calibrating the transfer standards. These institutions ensure the traceability to national standards. Through European (EUROMET) and international cooperations (Metre Convention) traceability to other worldwide metrology standards is achieved.

Two-Dimensional Lateral (XY) Standards with 100 nm, 200 nm or 300 nm Pitch

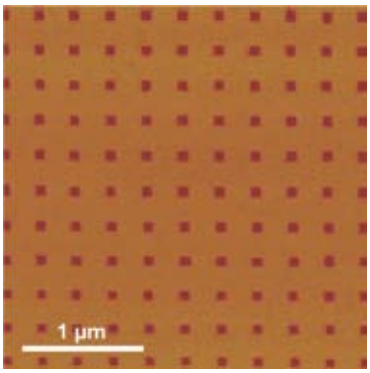
These types of transfer standards are intended for a precise x-y-calibration of the SPM scanning mechanism. They consist of 2-dimensional lattices of inverted square pyramids etched into silicon. Three types are available with 100 nm, 200 nm or 300 nm pitch respectively (order code: 2D100 / 2D200 / 2D300).



AFM image of NANOSENSORS™ 2D100 pitch standard.



Section of NANOSENSORS™ 2D100 pitch standard measured with two different probes.

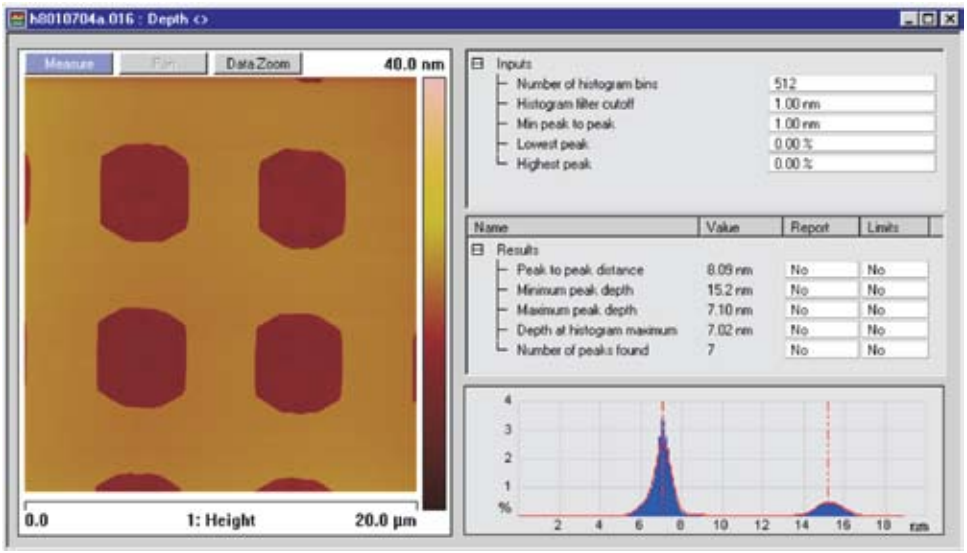


AFM image of NANOSENSORS™ 2D300 pitch standard.

Step Height (Z) Standard with 8 nm Nominal Step Height

The step height standard (order code: H8) is used for a precise calibration of the Z-axis of the SPM's scanning mechanism. The standard consists of multiple areas of hole and stripe arrays. The depth of these structures being etched into silicon is in the range of 8 nm.

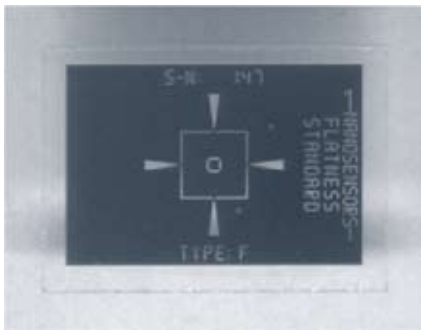
As a service for the customer NANOSENSORS™ includes a reference measurement for each H8 standard. In close time correlation a reference H8 standard which has been calibrated by the German national authority for metrology (PTB) is measured on the same instrument. From the given results the absolute height value may be calculated. Thus traceability to the PTB is achieved.



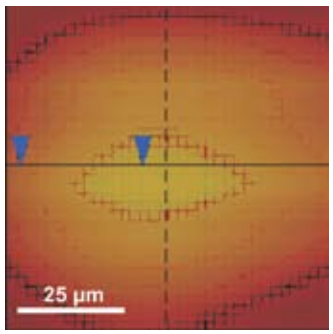
Z-height (depth) estimation by histogram evaluation of a 20 x 20 µm² area in the central pattern of the H8 standard. The step height equals the peak to peak distance of the spectrum.

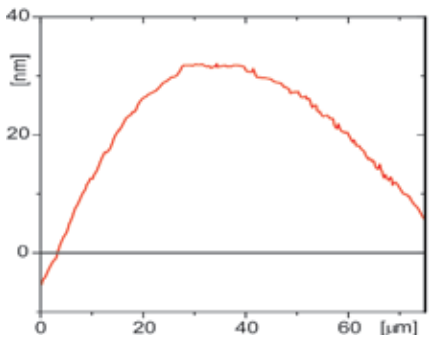
Flatness Standard

The flatness standard (order code: FLAT) consists of a super flat plane which is formed by a quartz substrate covered with a structured chromium layer. It is intended to be used to analyze and correct the scanner bow of the piezo scanner used in most Scanning Probe Microscopes. The standard is specified to offer a maximum peak to valley distance of 10 nm on a 100 by 100 µm² area.



Photograph of the flatness standard.





The AFM image (left) of the flatness standard shows a bowl-like distortion due to scanner bow. The AFM line scan (right) of the flatness standard (red line) in comparison to an interferometrically generated line scan (black line).

NANOSENSORS™ Assistance for Certification of Transfer Standards through PTB

For the transfer standards mentioned before NANOSENSORS™ is able to offer certification procedures by the German National Metrology Institute (NMI), the Physikalisch-Technische Bundesanstalt (PTB). This economic option is easy to use for the customer. NANOSENSORS™ delivers the transfer standards the customer has ordered directly to PTB for certification, negotiates and handles the time schedule for calibration procedures and finally ships the calibrated transfer standard to the customer or the appropriate distributor.
Calibration procedures follow the guideline VDI/VDE 2655 Part 1: Determination of Geometrical Quantities Using Scanning Probe Microscopes; Calibration of Measuring Systems, Berlin: Beuth Verlag. There are multiple options for the calibration method and the area of the standard that might be certified. The following table lists only basic information, please inquire for details to arrange the optimal certification method for your application.

Calibration Options

Type	Calibration by optical means	Calibration by SPM
2D100	not possible	one or more 10 x 10 μm^2 areas or full reference field
2D200	by optical diffractometry	one or more 10 x 10 μm^2 areas or full reference field
2D300	by optical diffractometry	one or more 10 x 10 μm^2 areas or full reference field
H8	by interference microscopy	different options
FLAT	by interference microscopy	not offered

General Remarks regarding Calibration and Traceability

The following introduction to the internationally followed principle of a traceability chain with special emphasis to nano-metrological aspects has been excerpted with kind permission from the paper TURNING SCANNING PROBE MICROSCOPY INTO A MORE QUANTITIVE METHOD by T. Dziomba, G. Dai, M. Ritter, M. Shaleev [June 2007, COOMET, Kharkiv, Ukraine].

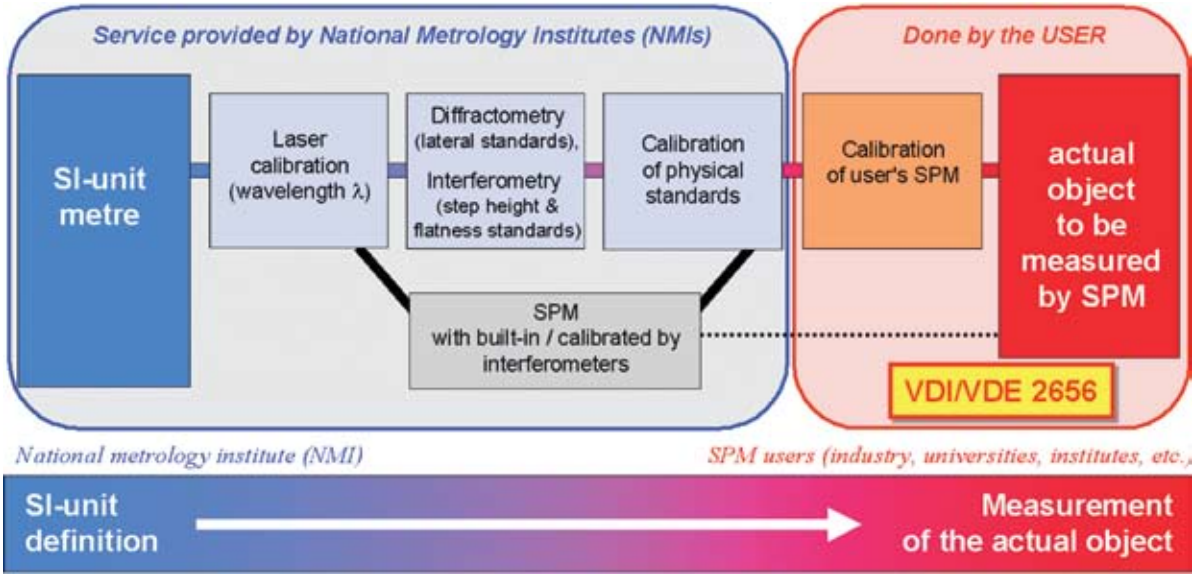
Traceability for SPM

In order to ensure worldwide comparability of SPM measurement results, traceability to the SI unit metre needs to be established for this measurement method in a similar way as already routinely practised for methods operating on a larger scale, e. g. coordinate measuring instruments or profilometers. Such a traceability chain as realized by PTB (see figure next page) requires the following elements:

- very stable high-accuracy SPM instrumentation (usually at NMIs) with direct traceability to the SI unit by built-in laser interferometers that monitor the translation of the SPM stage during measurement (so-called *"Metrological SPM "*) at PTB. The frequencies of the HeNe lasers used for interferometry are calibrated to an I_2-stabilized HeNe laser whose frequency is traceable to the Caesium clocks. In this way, the metre definition is directly applied.

Front page of a calibration certificate published by PTB.

- Certified calibration of *physical transfer standards* either by metrological SPMs or - as far as applicable - by other directly traceable instrumentation such as diffractometry (lateral standards) or interference microscopy (step height and flatness standards).
- Application of the certified standards for the *calibration of the SPM by the user* "outside" in industry, in other research institutes, in measurement service companies, etc. A prerequisite for the correct execution of the calibration process are written documentary standards or guidelines on SPM characterization & calibration methods e.g. VDI/VDE 2656.



Traceability chain for SPM.

Further Reading

Because Nano-Metrology is a vast and expanding field of research the following literature is proposed (this listing does not claim to be complete):

- Danzebrink, H.-U; Koenders, L.; Wilkening, G.; Yacoot, A.; Kunzmann, H.: Advances in Scanning Force Microscopy for Dimensional Metrology. Annals of the CIRP (2006), Vol. 55/2/2006
- Wilkening, G.; Koenders, L. (eds.): Nanoscale Calibration Standards and Methods, Wiley-VCH, Weinheim, Germany (2005)
- Korpelainen, V.; Lassila, A.: Calibration of a commercial AFM: traceability for a co-ordinate system; Meas. Sci. Technol. 18 (2007), pp. 395-403
- Dziomba, T.; Koenders, L.; Wilkening, G.: Standardization in dimensional nanometrology: development of a calibration guideline for Scanning Probe Microscopy. SPIE Europe Optical Design; Optical Fabrication, Testing and Metrology II, 5965 (2005) paper 12
- Dai, G.; Pohlenz, F.; Dziomba, T.; Xu, M.; Diener, A.; Koenders, L.; Danzebrink, H.-U.: Accurate and traceable calibration of two-dimensional gratings. Meas. Sci. Technol. 18 (2007), pp. 415-421

For more details please refer to the product datasheet on our website
www.nanosensors.com

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