Metrological SPM for quantitative traced measurements in the nanoscale

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The development of new technologies such as microelectronics, nanomedicine or NEMS where the size of the structures under study is decreasing continuously demands high resolution measurements with uncertainties in the nanometer range and below. Scanning Probe Microscopes (SPM) have been widely used to characterize surface properties in research and development institutions, and nowadays it is becoming important also in industrial fabrication and inspection.

These instruments, as many others where quantitative analysis is important, should not only be accurate but also metrologically traceable, [1] i.e. a measurement result should be related to a reference (the definition of the metre in the case of CDs) through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty. In conventional SPMs in which the position is determined from the electrical voltage applied to the piezo scanner, the calibration relies on physical standards. Other metrologically [2] more advanced systems use a variety of sensors (such as strain gauges, capacitive or inductive sensors) to measure position, in an active way not only to measure but also to control position (closed-loop configuration). The calibration of these systems is done either by temporarily connecting laser interferometers to the device or by measuring on high quality standards.

The system that the Centro Español de Metrología (CEM) has just installed in its Micro and Nanometrology Lab. is a reference system with integrated laser interferometers allowing direct traceability to the SI length unit, the metre, via the wavelength of the lasers. This Metrological SPM (MSPM) combines a high precision and large range 3D nanopositioning and nanomeasuring machine (NMM-1 from SIOS) [3] with a resolution of 0.1 nm over a range of (25 x 25 x 5) mm with a versatile scanning probe microscope Dualscope DS-95-50-E from DME and a laser focus sensor from SIOS.

The MSPM is supported by a thermally stable metrology frame and installed within an acoustic chamber. The intersection of the three measuring beams at contact point of the probe sensor allows the system to have a three dimensional Abbe offset free design. The sample under study is placed on a base plate of a corner mirror structure (three mirrors built as a solid corner mirror) reflecting the beams of the interferometers. In addition, the angular position of the corner mirror is controlled by two angular sensors and moved by a 3D stage operated in a close loop controlled by the interferometric system.

The MSPM is intended for the calibration and certification of physical transfer standards (step heights, lateral 1D and 2D standards) used in turn to calibrate other SPM systems and other instruments such as contact profilers and different types of microscopes (interference, holographic or confocal microscopes).

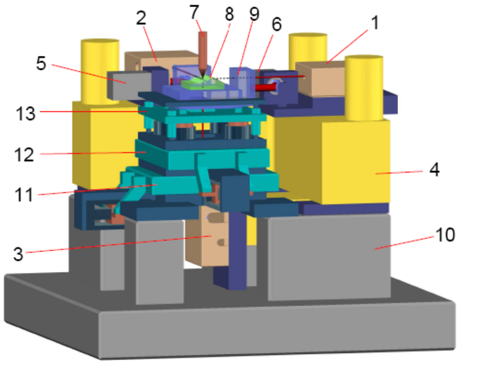
References

[1] Nanoscale Metrology, Editorial, Meas. Sci. Technol. **18** (2007).

[2] VDI/VDE 2656 –Part 1: Chapter 4.2 (pp. 10/11)

[3] SIOS Messtechnik GmbH, “Nanopositioning and Nanomeasuring machine, NMM-1” product brochure. http://www.sios.de/ENGLISCH/PRODUKTE/NMM_E.HTM as of 03/2011

Figures



Basic set-up of the NMM machine:
1 x-interferometer, 2 y-interferometer, 3 z-interferometer, 4 Zerodur® frame, 5 Roll and yaw angle sensor, 6 Pitch and yaw sensor, 7 probe system, 8 Measuring object, 9 Corner mirror, 10 Foundation, guide-drive systems of the 11 x-axis, 12 y-axis 13 z-axis

Fig. 1: Schematics of the NMM-SIOS system

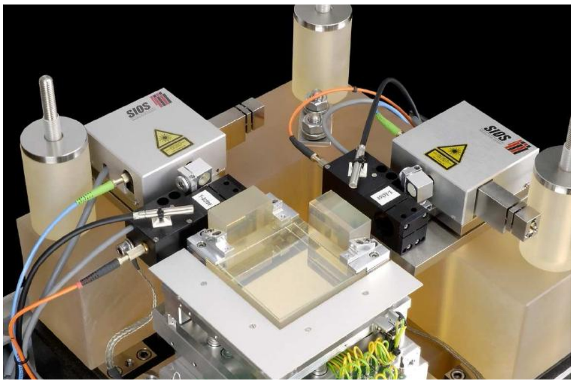


Fig. 2: Arrangement of Measurement Devices

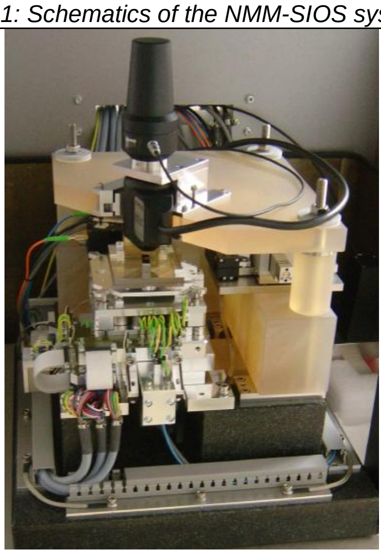


Fig. 3: AFM DME on top of the NMM, without the cover

Fig. 4: Metrological SPM at CEM