Design and development of the CEM metrological long range scanning probe microscope

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The continuing miniaturization process in science and technology demands high resolution measurements with very low uncertainties (even below the nanometer level). Scanning Probe Microscopes (SPMs) have proved to be a unique and very efficient tool to investigate and characterize different surface properties at scales ranging from hundreds of microns down to tenths of a nanometer. The use of SPMs has become a very popular technique in science, technology research, and even in industry, but in order to ensure comparability of the obtained data traceability to the SI unit metre must be established.

This technique is applied to all sorts of disciplines such as precision engineering, semiconductor fabrication, material science, crystallography, life sciences and many others. There are two main reasons for this success. First, SPMs provide very good lateral and vertical resolution in comparison with other traditional techniques and local or average information of the surface can be inferred. Second, a variety of samples can be analyzed without any particular preparation or damage. The main drawbacks of the method are the small scan range (of the order of tens of micrometers in the lateral directions and of a few micrometers in the vertical direction), long scanning times and problems related to the properties of the standard piezo-tube scanners such as hysteresis, creep and drift.

SPMs, as well as any other instruments for which quantitative analysis is important, should be metrologically traceable, i.e. a measurement result should be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty. For this application, the "reference" is the definition of the metre through its practical realization. In Spain, The Spanish Centre of Metrology (CEM) is the Institution in charge of realizing and maintaining such National Standard.

In conventional SPMs (C metrological category of the metrological classification [1]) positioning is established by the voltage applied to piezos and the calibration relies on the usual physical transfer standards. Category B SPMs make use of a variety of different sensors such as strain gauges, encoders and capacitive or inductive sensors. Calibration is achieved by attaching interferometers or with physical transfer standards. Our goal is to go beyond this and build a Class A SPM with integrated laser interferometers in all the three axes. Traceability to the SI unit meter will rely on the wavelength of the lasers. It is important to emphasize that the interferometric system will perform a continuous monitoring and active control during measurements.

Our metrological SPM (class A) will contribute to reinforce the Spanish traceability chain (fig.1) by performing the calibration of physical transfer standards (step height, pitch, critical dimension standards) that will be used to calibrate categories B and C SPMs. One of our objectives is to extend the calibration capabilities of the SPM to large scanning areas and step heights. This will allow us to certify standards compatible with other instruments such as profilers or interference microscopes. According to the above motivations we are going to build a system that will combine a high precision and long range three dimensional nanopositioning and nanomeasuring machine (NMM) [2] -with a resolution of 0.1 nm over the range 25 mm x 25 mm x 5 mm- and a versatile scanning probe microscope as the sensor for surface analysis.

The NMM machine has been developed by the Institute of Process Measurement and Sensor Technology of the Technical University of Ilmenau and is manufactured by SIOS [3]. This machine includes three miniature HeNe laser interferometers used for position measurement and control at the nanometer scale, and allows Abbe offsets of less than 0.1 mm. They are installed in a thermally stable metrology frame, and the traceable measurements of objects can be done relative to it. The samples under study will be placed on the base plate of a corner mirror structure (three mirrors built as a solid corner mirror). The mirrors reflect the beams of the interferometers. In addition, the angular position of the corner mirror will be controlled by two angular sensors and the corner mirror itself will be moved by a 3D stage. The stage will operate in a closed loop controlled by the interferometric system.

The SPM machine will be adapted from the original Cervantes AFM [4] from Nanotec Electronica to allow compatibility with the NMM design. In order to improve the dynamic behaviour of the measuring system, an ultrafast piezo coupled to the cantilever holder will be added and allowed to move in the z axis. The SPM will be capable of operating in basic and advanced SPM modes including: contact mode, non-contact mode, diverse dynamic modes, measurement of electrostatic force, magnetic force and nanolithography (controlled nanomanipulation of the surface).

References:

[1] T. Dziomba, L. Koenders, G. Wilkening, Proceedings of SPIE, **5965** (2005) 59650C.1-59650C.12

[2] E. Manske, R. Mastylo, T. Hausotte, N. Hofmann, G. Jäger, "Advances in Traceable Nanometrology with the Nanopositioning and Nanomeasuring Machine" in "Nanoscale Calibration Standards and Methods: Dimensional and Related Measurements in the Micro- and Nanometer Range" edited by G. Wilkening, L.Koenders, Wiley-VCH Verlag GmbH&Co. KGaA, Weinheim, p 47-59, (2005).

[3] SIOS Meβtechnik GmbH, http://www.sios.de/ENGLISCH/PRODUKTE/NMM_ENGL.PDF, as of 02/2010

[4] Nanotec Electronica, http://www.nanotec.es/products/cervantes.php, as of 02/2010

Figures:

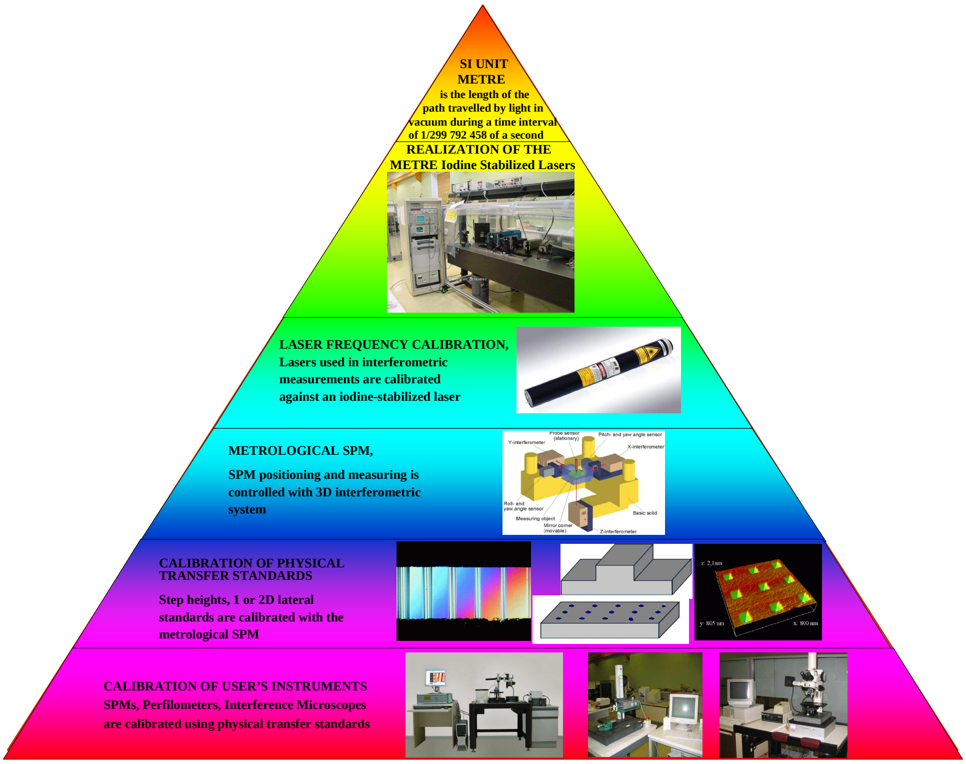

Figure 1. Traceability chain for scanning probe microscopes