NANOMETROLOGY AND ITS ROLE IN THE DEVELOPMENT OF NANOTECHNOLOGY; AN OVERVIEW OF THE STATE OF THE ART AND AN OUTLOOK ON FUTURE DEVELOPMENTS BY THE EUROPEAN NATIONAL METROLOGY INSTITUTES

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In order to ensure that results in nanotechnology can be compared quantitatively and parts are interchangeable, the measurements made must be traceable. This means that standards should be used which are linked through a traceable chain to the corresponding SI-unit, i.e., the Meter, the Kelvin, … , of the measurand. Due to the quite different nature of nanotechnology the conventional standards, measurement methods and instrumentation are no longer sufficient or cannot reach the desired uncertainty/accuracy. Therefore there is a need for a new branch of metrology, the so-called nanometrology. This is a multidisciplinary kind of metrology since it is not limited to a particular SI-unit. The presentation will focus on the traceability of dimensional quantities, such as length, size, shape, and roughness.

The role of our institute just like other National Metrology Institutes (NMIs) is to provide this traceability of measurements to (inter)national standards thereby making measurements quantitatively comparable and trade possible. For these reason NMIs develop and improve standards to fulfill the needs of their national industry and society. Since there is international trade there exist also an international metrological infrastructure. The CIPM (Committee international the Poids et Measure) is the worldwide link between the NMIs. It gets its authority from “The convention of the Metre”, a diplomatic treaty between fifty-one nations. Further every region in the world has is own linking body. For Europe this is EURAMET. One of the tasks of the CIPM and its working groups, in cooperation with the regional bodies, is to establish the degree of equivalence between national measurement standards of the NMIs and to provide mutual recognition of the calibration certificates issued by the NMIs. This is done by reviews of the NMIs as well as by carrying out comparisons on artifacts and standards.

Also for nanometrology the equivalence between the NMIs needs to be established. One of the differences between nanometrology and “classical metrology” are the huge investments in money and man-hours by the NMIs that are necessary to keep up with the demands of industry and science. It is therefore no longer possible for every NMi to develop the necessary standards and measuring instruments individually. For this reason in 2001 an “Initiative on nanometrology” was started by EURAMET. As part of this Initiative an inventory of the efforts and visions of the NMIs was made in 2002-2003 and in 2006 a roadmap for nanometrology was set-up. The main challenges we identified in this roadmap are:

a. Nanoparticle standards

b. Scanning probe microscopy to support nanotechnology

c. Displacement metrology at the nanometre scale

d. 2D- and 3D-instrumentation with nm uncertainty

In this presentation the current state of the art in nanometrology will be given. The main instruments such as the metrological Atomic Force Microscope will be presented, see figure 1. Focus will be on the metrological nature of these instruments as compared to most instruments on the market. Comparisons in nanometrology on physical standards will be presented, showing the need for traceability as well as demonstrating what is currently possible.

Based on the nanometrology roadmap and the key challenges the European NMIs are currently setting-up joint projects to take the next steps in getting traceable standards, measurements and instruments for nanotechnology. Important issues here are:

- Probe sample interactions in AFM, Scanning Electron Microscopy (SEM) and optical Scatterometry. These measurement techniques have fundamentally different probe sample interaction effects. This limit the agreement of the measurement results as well as the full potential of the individual techniques.

- The need for new physical standards, especially for nanoparticles. Here standards and procedures for determining size, shape and distribution need to be developed with an accuracy of better than 1 nm.

- New means and methods for the traceable characterisation of crucial dimensions relevant to industrial, economic and scientific development

- New traceability routes. The traceability of length measurements is currently exclusively assured by optical interferometry. Today's applications in nano- and semiconductor-technology ask for resolutions far beyond the nanometre. So new ways and standards to provide traceability at the atomic scale will be explored.

An overview of these developments and joint projects will be presented.

Figures:

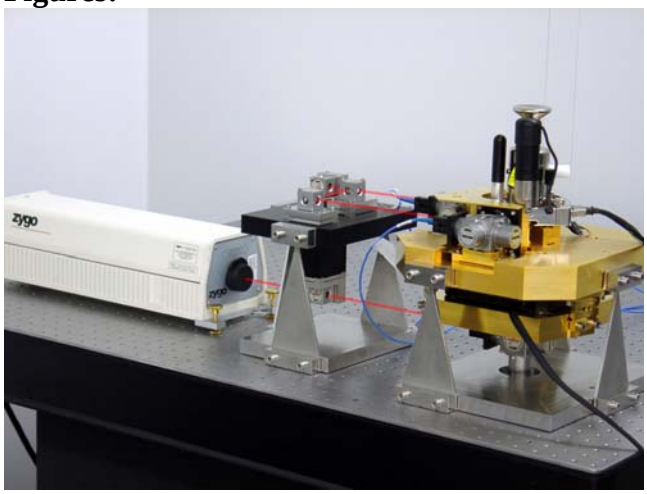

Figure 1: Overview of a metrological AFM set-up at NMi VSL. The measurement system is a 3 axes laserinterferometer. The beam from the laser source (left) is split into 3 beams (middle section) and fed into the interferometer optics (right).