Development of nanometrology: programs, projects and standards

Olena Bocharova, Kharkov University of Radioelectronics (05.08.2011, PhD student. Ukraine, Kharkov, Kharkov University of Radioelectronics)

Abstract

Nanoscience and nanotechnologies are widely seen as having huge potential to bring benefits to many areas of research and application, and are attracting rapidly increasing investments from Governments and from businesses in many parts of the world. To support the growth in nanotechnology there has been considerable effort expended to develop reliable traceable nanometrology. The majority of this work has been done by national metrology institutes (NMIs), whose role is to ensure a reliable train of traceability of measurement to base standards, in this case the metre. The realization of traceability is achieved through primary instrumentation and often disseminated via transfer standards.

1. Development of nanometrology normative base

In June 2005, ISO formed a new Technical Committee to help focus the world's attention on standards that would support the growth of nano-related industries. The scope of that committee, ISO/TC 229 – Nanotechnologies, includes standardization in the areas of terminology and nomenclature; measurement and instrumentation; material specifications; and health, safety and the environment. The rapid development of nanotechnology has resulted in a largely uncontrolled growth in the number of terms used in both nanoscience and nanotechnology. A critical task for this ISO/TC continues to be the development and assembly of a controlled vocabulary for nanotechnology, with a set of uniform definitions and nomenclature, to facilitate communications and place legal and commercial transactions, standards and regulations on a firm foundation.

TC229 has established three Working Groups to progress identified priority areas of standardization via the above strategies.

WG 1: Terminology and nomenclature (terminology and nomenclature standards provide a common language for scientific, technical, commercial and regulatory processes);

WG 2: Measurement and characterization (measurement and characterisation standards provide an internationally accepted basis for quantitative scientific, commercial and regulatory activities);

WG 3: Health, safety and environmental aspects of nanotechnologies (health, safety and environmental standards improve occupational safety, and consumer and environmental protection, promoting good practice in the production, use and disposal of nano-materials, nanotechnology products and nanotechnology-enabled systems and products).

A coordinating effort for European metrology already exists with the European Metrology Research Programme (EMRP). The goal of this programme is a metrology-focused European coordinated Research and Development that facilitates closer integration of national research programmes. In addition to EMRP, several NMIs are also working on nanostandardization, both at the European (CEN) and international level (ISO). To name but a few nanostandardization committees:

- ISO/TC 229 Nanotechnologies, particularly WG 2 Measurement and characterization.
- IEC/TC 113 Nanotechnologies, particularly WG 2 (jointly with ISO/TC 229/WG 2).
- CEN/TC 352 Nanotechnologies.
- ISO/TC 201 Surface Chemical Analysis including also SPM as SC 9.

2. Dimensional nanometrology techniques

The most utilized technique for nanoscale measurement is the atomic force microscope (AFM) or scanning force microscope (SFM). Within many NMIs, both in Europe and worldwide, effort is being devoted towards development of traceable SFMs. The SFM is considered by some to be the instrument of choice for the long-term future measurements within nanometrology.

There are several areas where research is required to improve dimensional metrology with the SFM.
1. The measurement range needs to be extended in both scale directions. Research towards smaller measurement regimes involves the development of high stability, low-noise metrology SFMs with applications including, for example, the measurement of nanoparticles. Extension towards larger measurement ranges, of several millimetres, is also being explored to enable measurements with sub-nanometre accuracy on large objects, such as ultra-precision optics.

2. Moving from current “2½D” scanning techniques (sampling at equidistant points in the x-y plane to build a 3D measurement), to true 3D probing with novel sensors and data fusion models is regarded essential to satisfy future measurement tasks on large, complex objects. This requires the development of measurement strategies and 3D transfer standards for easy and fast calibration of instruments as well as algorithms to calculate measurement uncertainty of complex 2½D or 3D measurements.

3. Uncertainties reached by metrological SFMs are in the nanometre or sub-nanometre range for tip independent tasks such as step height or pitch. For the traceable measurement of nanostructures, structured surfaces, linewidth, diameter shape of nanoparticles and surface roughness using SFM, the shape and dimensions of the probe tip need to be determined, in order to make a correction for their effects on the image.

4. Tip shape estimation and consecutive correction of measured profiles (morphological filtering - erosion/dilation) suffers from rather large uncertainties, making them unsatisfactory for many (future) measurement tasks. The techniques require knowledge of the sample shape.

A current EMRP funded project NANOTrace has brought together six NMIs to develop and verify the performance of the next generation of optical interferometers. The target uncertainty for these interferometers is 10 pm. While the NANOTrace project is going some way towards meeting the requirements of the next generation of optical interferometers, the challenge will be to disseminate these to users outside of NMIs and to make picometre measurements less challenging.

Russia’s Government Metrology Service is represented by Federal Agency on Technical Regulating and Metrology. In order to solve the problems in high technology area, including nanotechnology, Technical Committee on Standardization TC 411 High-end Technology was created.

The Metrology Maintenance of Nanotechnology project was created in the context of International Organization COOMET on European-Asian Cooperation. The project is devoted to solving fundamental problems of metrology in nanotechnology. Russia, Belorussia, Ukraine, Slovakia, and Germany are counties-participants in this project. At the present moment in the context of this project the conception of metrology maintenance of nanotechnology and technology of transferring the measurement units into nanoscale have been developed.

3. Summary

The successful emergence and adoption of nanotechnology depends in part on the creation of a supportive scientific, industrial and social environment. The innovation developments are needed for solving problems with nanotechnology requirements in the measuring methods. Suitable methods need to be developed that can accurately measure the size and shape properties of the core components that will end up in existing and novel nanostructured materials. Good progress is being made and standards are being drafted and reference materials developed.

Bibliography


Authors:

PhD student Olena Bocharova
Kharkov University of Radioelectronics
Lenina Avenue 14
61166 Kharkov, Ukraine
tel. (066) 361 98 41
fax (057) 737 60 17
email: bocharova.alyona@gmail.com