EMPIR Call 2014 – Industry and Research Potential

Selected Research Topic number: **SRT-i09**
Version: 1.0

Title: Reference nanodimensional metrology for nanomanufacturing

Abstract

New traceable and accurate nanodimensional metrology facilities need to be developed in order to meet the needs of the nanomanufacturing sector, which is driven by continual miniaturisation. Nanodimensional reference materials should be developed and the traceable techniques used for device inspection and optimisation, e.g. scanning probe and charged particle microscopy, should be significantly improved. The measurement uncertainty of hybrid metrology, which combines inputs from different sources, should be further decreased and calibration services should be developed with an uncertainty below 1 nm. This improved accuracy will help to increase the yield of devices, will allow smaller and faster devices and will conserve energy and resources.

Keywords

Traceable nanodimensional metrology, critical dimension (CD), step height, pitch, line edge roughness/line width roughness (LER/LWR), sidewall angle (SWA), atomic force microscopy (AFM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), probe sample interaction, nanomanufacturing

Background to the Metrological Challenges

Reference materials, which are used to calibrate and characterise industrial instruments, and highly accurate and traceable calibration services are urgently needed in nanomanufacturing industries. Nanoscale standards, such as step height and lateral 1D/2D gratings have been developed in the last decade; however, suitable reference materials for accurately characterising the tip geometry of an AFM or the beam size of a SEM are inadequate. Also reference standards for the measurement of CD, LER/LWR and SWA do not exist and need to be developed. Similarly calibration services for CD are only available with very limited accuracy (>5 nm) and those for LER/LWR and SWA need to be established.

Metrological devices, in particular, metrological AFMs are the main workhorses in reference nanodimensional metrology, due to their versatile measurement capabilities. However, their calibration capabilities need to be improved, for example, metrological AFMs are unable to perform true 3D measurements and tip wear may be too severe to obtain stable results. The interferometers applied in these devices limit measurement performance in particular for the measurement of nanoroughness, CD and sidewalls. Similarly, most metrological AFMs have a limited measurement range (typically tens of micrometres) and speed (typically tens of micrometres per second). TEM is also being increasingly used for reference measurements of nanostructures. However, the possible damage of test structures during sample preparation needs to be understood in relation to image formation. Also sample preparation for TEM measurements is destructive; therefore methods need to be developed to enable the transfer of precise TEM information on sample dimensions to unaltered reference samples.

“Hybrid metrology”, which combines multiple metrology techniques, could be used to meet industrial measurement challenges. One type is data fusion, which combines measurement data from different instruments to improve measurement accuracy by sharing extra information and rectifying inter-variable correlations. Practical industrial solutions and data fusion software need to be developed. Another type is instrument fusion, which would combine different measurement techniques into one instrument e.g. AFM in SEM. This would avoid time consuming relocation of the AOIs (area of interest) of the specimen and it would allow simultaneous measurements of different probing techniques, offering a new approach to study tip sample interaction.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the proposal.

The JRP shall focus on measurements of the dimensional parameters (e.g., critical dimensions, height, sidewall angle, line edge and width roughness, corner rounding and footing) of nanostructures both on silicon wafers and photo-masks, on the development of reference materials, on the improvement of scanning probe and charged particle microscopy, and on the implementation of hybrid metrology. The overall goal is to realise calibration services with an uncertainty below 1 nm.

The specific objectives are

1. To develop test structures to characterise the tip geometry in atomic force microscopy and the beam size in scanning electron microscopy. To develop reference standards for measurements of critical dimensions, height, sidewall angle, line edge and line width roughness. The requirement is to reduce the uncertainty of the measurements and to disseminate traceable results below 1 nm.
2. To reduce the noise level of metrological atomic force microscopy to 0.1 nm (rms), to extend the scan range and velocity to a few mm and 1 mm/s, and to achieve quasi-equal (0.1 nm rms) probing sensitivity of 3D measurements.
3. To develop an industrial solution for hybrid metrology and software solutions for data fusion.
4. To quantify the probe-sample interaction in atomic force microscopy (interaction force, influence of water layers and electric charges), scanning electron microscopy (charging issue), and transmission electron microscopy (simulation of the image formation). The requirement is to reduce these contributions to the total uncertainty below 1 nm.
5. To engage with the nanomanufacturing industry and to promote the take up of the technologies and measurement capabilities developed by the project.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

In particular, proposers should outline the achievements of the EMRP project SIB61 (CRYSTAL) ‘Crystalline surfaces, self assembled structures, and nano-origami as length standards in (nano)metrology’ and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,

- Transfer knowledge to the nanomanufacturing sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects"

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.