

## **Title: Traceable three-dimensional Nanometrology**

### **Abstract**

Driven by key enabling technologies, such as nanotechnologies and advanced nanomanufacturing, the advance of the existing three-dimensional nanometrology facilities and the development of new and accurate ones is required. This will include a significant improvement of the main traceable techniques, scanning probe and scanning electron microscopy, and the development of reference materials. To further decrease the measurement uncertainty, hybrid metrology, which combines inputs from different sources, could be implemented. The final goal should be to realise calibration services with an uncertainty below 1 nm. The improved accuracy will help to increase the yield of devices, allow smaller and faster devices and save energy and resources.

### **Keywords**

Traceable three-dimensional metrology, Line width, Step height, Pitch, Roughness, Nanoparticles, Atomic force microscopy (AFM), Scanning electron microscopy (SEM), Probe sample interaction

### **Background to the Metrological Challenges**

Progressive miniaturisation of advanced nanomanufacturing techniques currently delivers nanodevices with feature sizes below 22 nm. Accurate measurement of the dimensions is a crucial task for process development and quality control. Specifically, high measurement accuracy below 1 nm is demanded. However, the dimensional nanomeasurement accuracy of the most frequently used industrial tools (for instance, SPM, SEM, scatterometry) are typically (much) worse than 5 nm if they are not accurately calibrated. This is due to the limits from either the probe geometry (e.g. in SPMs and SEMs) and/or modelling errors (e.g. SEM and Scatterometries).

Reference materials are used to calibrate and characterise industrial instruments. 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 probe size (i.e. tip geometry of AFM, and beam size of SEM) is inadequate. Moreover, reference standards to meet current and future requirements for the measurements of line width are currently unavailable.

By addressing the fundamental metrology challenges for precision- and nanotechnology, this work will also support many other industries including: mechanical engineering; electrical engineering; optical engineering; micro system technology; nanobioscience and the nanoparticle for environment metrology.

### **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 protocol.

The JRP shall focus on the realisation of traceable calibration services in three-dimensional nanometrology with an uncertainty less than 1 nm.

The specific objectives are

1. To reduce the three-dimensional nanomeasurement uncertainty to less than 1 nm for nanodimensional measurands (including line width, height, pitch, and edge/width roughness) on engineered nanostructures and nanoparticles.

2. To widen the understanding of probe sample interactions in AFM and SEM measurements for reducing the measurement uncertainty. In particular, to study the tip-sample interaction-force of AFM width and nanoparticle measurements; to model the image formation of SEM; and to investigate the influence of thin water layer and/or the static electric charging on AFM measurements.
3. To develop reference materials for three-dimensional nanometrology tools including AFM and SEM. In particular, to realise test structures for characterising the tip geometry in AFMs and the beam size in SEMs and reference standards for width and sidewall roughness measurements.
4. To reduce the noise level of metrological AFMs to 0.1 nm (rms), to raise the scanning speed up to 1 mm/s, and to extend the scanning range to a few mm by further developing the state-of-the-art optical laser interferometry and/or x-ray interferometry.
5. To develop industrial solutions for hybrid metrology with the concepts of both data fusion and instrument fusion. To facilitate the take up of the technology and measurement infrastructure developed by the project by the measurement supply chain (accredited laboratories, instrument manufacturers) and end users (semiconductor industry, precision engineering, optical industry, nanotoxicity researchers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

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 NEW01 TREND and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 21 % 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,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the instrumentation manufacturers for semiconductor sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”.

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.