EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

Selected Research Topic number: **SRT-i03**
Version: 1.0

Title: Photon-based metrology for future semiconductor manufacturing

Abstract

Progress in the semiconductor industry requires smaller and more complex 3D nanostructures which also incorporate novel materials. However, in order to support the manufacturing of such complex nanoelectronic devices new and sophisticated lithographical manufacturing technologies are needed. This requires the development of improved or novel photon-based approaches to provide the compulsory fast and non-destructive metrology for process control and could be achieved by novel and improved developments in soft X-ray, lensless imaging, optical quantum size-effects, optical critical dimension (OCD) and 'big data' processing methods.

Keywords

Optical critical dimension (OCD) metrology, lensless imaging, soft X-ray, semiconductor manufacturing.

Background to the Metrological Challenges

The production of the complex 3D nanostructures required by current semiconductor technology is unattainable without the metrology able to provide in-line and off-line characterisation of those structures. Among the different dimensional parameters, critical dimensions (CDs) are by far the most important measurands. However, in order to fulfil the requirements of different processing steps and manufacturing technologies a variety of different tools are required.

Currently, there is no single method capable of providing the required data structure and combinations of toolsets, and this will become more apparent with the increasing device complexity in 3D nanostructures. Therefore, new metrological approaches for 'big data' information treatment and handling are needed to exploit the synergy of different tools and methods.

OCD methods are fast, non-destructive, in-line capable, very sensitive to most relevant structure parameters and offer a high 3D capability. They are widely used in process development and control and for in-line metrology. They also offer high statistical relevance and are suitable for simultaneous multi-parameter measurements. However, the main challenges with OCD methods are potential parameter cross-correlations and the ambiguity inherent within model-based analysis. These issues will become more significant as more structure parameters and more complex geometries have to be addressed. Current OCD methods also face issues with sensitivity, due to the comparably large wavelength of the radiation used with respect to the ever shrinking structures. Further to this there are issues with structure dependent material parameters (dielectric functions) for instance by quantum confinement. Therefore novel or essentially enhanced metrology is urgently required for OCD, both for image-based local probing with enhanced resolution as well as for fast ensemble probing with enhanced sensitivity and performance.

Soft X-ray imaging currently represents a valid alternative to OCD methods when spatial resolutions of the order of (a few) 10 nm are needed. This technique is particularly appealing for biological applications in the so-called water window but soft X-ray imaging could also play a very important role in metrology for the semiconductor industry. However, the spatial resolution for soft X-ray imaging is currently limited by the manufacturing capabilities of the required diffractive optics (zone plates). A solution to this, could be lensless imaging, which is a way to circumvent this limitation as the optics is replaced by computational methods.

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 development of metrological capacity for photon-based semiconductor manufacturing.

The specific objectives are

1. To develop traceable and validated lensless imaging methods (including radiation sources) for the spectral range 10 nm to 1 nm for soft X-rays and 10 nm to 0.1 nm for hard X-rays with a target lateral resolution of better than 1 nm and a penetration depth of 100 nm.
2. To produce validated methods for optical critical dimension (OCD) measurements. This should include both novel methods and the extension of existing methods for new spectral ranges (e.g. soft X-ray scatterometry and hyperspectral scatterometry); for increased sensitivity and for the analysis of size driven optical quantum effects.
3. To develop validated and robust methods for 'big data' information treatment and handling. This should include demonstration of the feasibility of big data information treatment and handling and the potential on speed and accuracy of this approach for photon based semiconductor manufacturing.
4. To implement novel OCD methods for the reliable characterisation of challenging structures such as real-life structures which are non-periodic in the x, y-plane; fully 3D structures, and gate-all-around Field Effect Transistor structures.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (semiconductor manufacturers), standards developing organisations (ISO, CEN) and end users (e.g. semiconductor manufacturing and the electronics sector).

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.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this 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 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 semiconductor manufacturing and the electronics 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.