EMPIR Call 2014 – Industry and Research Potential

Selected Research Topic number: **SRT-i24**
Version: 1.0

Title: Optical metrology solutions for next generation lithography

Abstract

Nano-electronic devices impact all areas of life with enormous economic and social impact. Despite continuous structure size decreases, metrological challenges are evident through the move from planar to complex 3D devices. Beyond the 22 nm-node, most metrology solutions are insufficient or are not yet developed. Non-imaging optical to X-ray-solutions are hoped to play an important role, but considerable effort is required to enhance current methods like scatterometry and ellipsometry to validate novel methods like Mueller polarimetry or GISAXS. Important issues such as EUV- , in-die- and hot-spot-metrology, as well as optical parameter characterisation in ultrathin layers and nanostructures, need to be addressed.

Keywords

Semiconductor manufacturing, next generation lithography, nanoelectronics, multi-parameter metrology, scatterometry, ellipsometry, Mueller-matrix ellipsometry, GISAXS, EUV metrology, CD metrology

Background to the Metrological Challenges

The International Technology Roadmap for Semiconductors (ITRS) roadmap for future technology states that for nodes beyond 22 nm, metrology solutions for the important dimensional measurands, like critical dimension (CD), line edge roughness (LER) and overlay are not yet defined [1]. Despite ongoing continuous shrinking of structure sizes, challenges are driven by the move from planar to complex 3D devices. Optical metrology has followed the metrology needs of the semiconductor industry, primarily by reducing the wavelength of the light; but going beyond the optical spectral range towards much shorter wavelengths, such as EUV and X-rays, scattering methods [2, 3] have shown to be promising metrology options. Research and development is now needed to develop a reliable metrology solution.

Reliable measurements of optical properties in ultra-thin films and nano-sized structures are an essential pre-condition for current and future lithographical manufacturing processes; and with future trends in lithographical manufacturing, new requirements such as 'in-die metrology', to enhance the usable space on the wafer, are needed. With the introduction of EUV lithography, EUV masks are a new type of mask with very challenging requirements in terms of substrate and blank defect inspection, characterisation of reflective multilayers, as well as absorptive layers and dimensional characterisation of complex absorber structures. Methods for dimensional structure measurements and for layer characterisations are now required.

Scanning Electron Microscopy (SEM) is currently the most important tool for mask and wafer metrology, but there are difficulties in measuring (in particular complex) 3D structures. For future technology nodes the SEM will be an important and inevitable metrology tool. However, enhanced challenges are expected for the sub 20 nm pitch and sophisticated modelling will be required beyond the 16 nm node. Alternatively, non-imaging optical techniques such as spectroscopic reflectometry scatterometry or ellipsometry (Optical Critical Dimension metrology (OCD)) are widely used in process development and process control. OCD methods are fast, non-destructive, in-line capable, very sensitive to most structure parameters and offer a high 3D capability; but, as yet, have no measurement traceability. OCD is expected to be the technique for in-line metrology and statistical relevant process monitoring, and is expected to be the principal tool for optical metrology of future manufacturing technologies down to the 8 nm node.

It is important to have both an imaging technique and a spectroscopic technique available for any CD metrology application, in order to provide complementary data for successful CD metrology [4]. New options for increasing the measurement capabilities of the optical systems by extending the range of measured optical properties (e.g. Mueller-Polarimetry or Phase Sensitive Scatterometry [1]) are required to strengthen the traditionally strong and leading European position regarding optical metrology in the semiconductor industry.

EURAMET-MSU
National Physical Laboratory
Hampton Road, Teddington,
Middlesex, TW11 0LW, UK

Phone: +44 20 8943 6666
msu@npl.co.uk
www.euramet.org

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 the development of optical solutions to meet the challenging metrology requirements of upcoming manufacturing processes and lithography technology nodes to support and enable future nanoelectronic devices.

The specific objectives are

1. To increase the measurement capability of state of the art optical methods, such as optical reflectometry, scatterometry or ellipsometry for structures of sub-20 nm half pitch, in the IR, VIS or UV/DUV spectral range; and to develop and validate novel optical metrology approaches, such as X-Ray Scatterometry, Mueller-Polarimetry and Phase Sensitive Scatterometry including suitable mathematical models and procedures for these novel approaches. The target uncertainties for the measurement of parameters such as Critical Dimension (CD) are well below the 1 nm level.
2. To address new and enhanced metrology requirements associated with the increasing complexity and upcoming processes:
    - evaluation of measurement approaches for 'in die metrology' at target fields drastically reduced in size
    - optical measurements providing 'multi parameter metrology' combining measurements of e. g. different structure dimensions, overlay, focus for control of the lithographic process
    - dimensional metrology on complex 3D structures (such as FinFETs) as well as measurements of a-periodic structures (e. g. hot-spots), with all kinds of defects such as necking, line-end push-back and pull-outs and bridging
3. To extend modelling and data analysis algorithms to 3D by implementing fast methods for surrogate models (e. g. polynomial chaos and reduced-bases methods) to cope with increases in the computational cost for 3D structures, to enable process control by indirect methods such as scatterometry and to develop mathematical procedures for reliable determination of roughness parameters and methods to deal with parameter cross-correlations and associated uncertainties for reduced feature dimensions.
4. To develop optical and actinic metrology methods (for dimensional structure measurements, layer characterisations and to provide the fundamental basics for defect and imaging metrology requirements) for next generation lithography (NGL) methods in particular for EUV and EUV photo-masks; and to evaluate and address the metrological challenges of novel NGL solutions like Mask-Less (ML 2), Direct Self-Assembly (DSA) or Nano-imprint (NIL) lithography.
5. To develop reliable methods for measuring optical properties (such as transmission, absorption, optical thickness and complex refractive indices) of ultrathin layers and nanostructures and to develop new standards for (in situ) comparison of these different methods and instruments.
6. To engage with industry that exploits lithography technology in order to facilitate the take up of the technology and measurement infrastructure developed by the project, to support the development of new, innovative nanoelectronic devices, thereby enhancing the competitiveness of EU industry.

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 and EMRP JRP IND17 (Scatterometry) ‘Metrology of small structures for the manufacturing of electronic and optical devices’.

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 lithography related optical 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.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] http://www.itrs.net (reports: 2011 Edition, 2012 update, 2012 winter presentations, e.g. http://www.itrs.net/Links/2012Winter/1205%20Presentation/Metrology_12052012.pdf)

[2] V. Soltwisch et al.: Nanometrology on Gratings with GISAXS: FEM Reconstruction and Fourier Analysis, SPIE 9050 (2014), 9050-36 (to be published)

[3] C. Settens, et al.: Critical dimension small angle X-ray scattering measurements of FinFET and 3D memory structures, Proc SPIE 8681 (2013), 86810L

[4] B. Bunday et al.: Gap Analysis for CD Metrology Beyond the 22 nm Node, Proc. SPIE 8681 (2013), 86813B