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

Selected Research Topic number: **SRT-n06**
Version: 1.0

Title: Measurement of the focal spot size on X-ray tubes with spot sizes down to 100 nm

Abstract

A new generation of X-ray tubes with nanometre capabilities have been developed for use with digital radiography and computed tomography (CT) for quality assurance in electronic industries visualising nanometre structures in integrated circuits. However, the performance of these inspection systems depends on the spot size, shape, and stability of the spot position and currently no standardised measurement methods exist for spot sizes below 5 µm. A measurement algorithm has been proposed for spot sizes of 1 – 5 µm and initial tests have been performed with numeric modelling tools, however further work is needed to improve the algorithm for spot sizes down to 100 nm and to develop a standardised method.

Keywords

X-ray, focal spot, spot position, nanometre gauge, nano computed tomography, X-ray microscopy

Background to the Metrological Challenges

For the materials sciences, energy engineering and microelectronics sectors, nano-CT systems are used for the non-destructive analysis of structures and defects in materials, and to enable the investigation of structural and functional materials and to facilitate in-situ monitoring. Currently high resolution digital radiography and CT is used to provide a reduced focal spot sizes of below 5 µm with achievable voxel sizes of 200 nm. However, the resolution of smaller structures could be achieved by a combination of synchrotron radiation or nano-focus tubes and X-ray optics. Thus considering the recent development of nanometre structures in highly integrated electronics, and end users requirements, methods for the spot size, shape, and position of X-ray tubes from 100 nm to below 5 µm are needed.

Currently, focal spot size information from different manufacturers varies by more than a factor of 2 for similar resolutions and manufacturer information is often given in terms other than spot size. In addition to this no international standard or guideline exists for the measurement of spot sizes down to 100 nm and there is no standardised procedure to enable metrological comparison between European and international products. . Therefore, for repeatable accurate measurements to be performed, standard measurement methods are needed for X-ray tubes with spot sizes down to 100 nm, as well as inter- and intra- laboratory comparisons of such methods.

A first approach for the measurement algorithm was proposed for spot sizes of 1 – 5 µm and first tests were performed with numeric modelling tools. However, for repeatable accurate measurement it is necessary to test and improve the algorithm also for spot sizes < 1 µm before standardisation

Further to this, new measurement methods will require quantitatively characterised nanometre gauges, which are used for spot size, shape, and position measurements. Numerical algorithms also need to be developed for the spot parameter measurements (i.e. size, position, shape) using such nanometre gauges.

The development of novel and optimised methods for X-ray microscopy with spot sizes down to 100 nm should also enable the performance evaluation and provide the possibility of evaluating other parameters that may influence the spot size evaluation, such as shape and spot location fluctuations, different target materials, target angles, reflection and transmission targets.

EURAMET MSU, Hampton Road, Teddington, Middlesex, TW11 0LW, UK
Phone: +44 20 8943 6666 Email: msu@npl.co.uk
msu.euramet.org

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

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 metrology research necessary to support standardisation in X-ray microscopy.

The specific objectives are

1. To develop traceable and improved measurement methods for determining the spot size, shape, and position of X-ray tubes from 100 nm to 5 µm including the uncertainty of the measurements (precision and bias). In addition, to develop a reference method for the measurement of the spot parameters of X-ray tubes below 5 µm including the measurement uncertainty.
2. To develop traceable methods to characterise nanometre gauges used for the measurement of the spot size, shape, and position of target designs, taking into considering line pattern and edge structures.
3. To develop improved numerical algorithms for the spot parameter measurements (i.e. size, position and shape) made using nanometre gauges. This should include software implementation using numerical modelling and an evaluation of other parameters affecting spot size.
4. To perform inter- and intra- laboratory comparisons of the methods developed in objectives 1- 3 and from the results optimise the methods further.
5. To contribute to the standards development work of the technical committee CEN TC 138 WG 1, ISO TC 135 SC5 and others where suitable to ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who will use them, and in a form that can be incorporated into the standards at the earliest opportunity.

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

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.6 M€, and has defined an upper limit of 0.8 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.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

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 Microelectronic material sciences and Microbiology sectors.

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.

Additional information

[1] CEN/CENELEC identified this topic as one of their priorities. Details are available at:

https://msu.euramet.org/current_calls/pre_norm_2017/documents/CEN_priorities/cen_priority_013.pdf