EMPIR Call 2015 – Health, SI, Normative and Research Potential

Selected Research Topic number: **SRT-s03**
Version: 1.0

Title: Metrology for electrical scanning probe microscopy

Abstract

Electrical scanning probe microscopes (eSPM) have demonstrated their ability to provide rapid feedback on device development and production. However, there is a need to develop modelling and instrumentation for quantitative analysis through an established metrology of electrical quantities at the nanoscale. A specific focus should be on the traceable measurement of current and impedance using eSPM including development of standard samples and probes, uncertainty budgets and calibration procedures. This is critical in a number of industries such as consumer electronics, healthcare, security and energy devices.

Keywords

Electrical scanning probe microscopes, eSPM, microelectronics, nanoelectronics, nanoscale measurements, standards, uncertainty budget

Background to the Metrological Challenges

Electrical, optical, and magnetic products and systems require contacts or connections to micro- and macroscale devices and systems. Present instrumentation used to characterise and view nanoscale contacts in three dimensions is not adequate for accelerating innovation and therefore commercialisation. The standards and measurement methods associated with such instrumentation make it difficult to assess performance, reliability, and durability. Based on the analysis of the state-of-the-art in nanoscale contacts conducted by IEC TC113, various key technology and standardisation issues have been identified. Standards need to be established to define the nanomaterials being used in a nanoscale contacts or nanoscale interconnect, and to specify the control parameters crucial for successful formation of the nanoscale contacts or nanoscale interconnects. A deep understanding of all surface effects will need to be achieved before consistent manufacturing of nano-sized devices can take place. Nano-sized devices differ significantly from macroscopic devices that are not as much affected by surface conditions and boundary effects. Probe measurements for extracting resistance values for conductive nanomaterials (nanowires, nanosheets) need to be standardised for all research and manufacturing efforts. Measurement techniques to indirectly measure electrical properties accurately need development and standardisation.

Despite its tremendous advancement in the last 20 years, scanning probe microscopy is still not understood as a really quantitative experimental technique. Uncontrolled variations in probe shape, electrical properties and environment on the nanoscale require a precise calibration for each measurement condition. However, the uncertainty on these measurements is in most cases larger than 100 %. As technology moves towards nanoscale, where dopants might control the behaviours of devices, a better accuracy and precision is required to understand the performance and failure mechanism of these products. The field is, however, mostly focused on specific materials properties, limiting therefore the extension of the techniques to other technologically important materials.

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 traceable measurement and characterisation of current and impedance using electrical scanning probe microscopes (eSPM).

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The specific objectives are

1. To develop electrical reference standards to establish traceability to the SI of nanoscale electrical measurement carried out by electrical scanning probe microscopes (eSPM) in order to improve reliability and comparability of such instrumentation.
2. To develop reliable 3D multi-physics modelling based on analytical or numerical approaches in order to evaluate the effect of the tip-sample electromagnetic interaction as well as tip shape and material on the electrical measurement.
3. To establish uncertainty budgets and develop reliable protocols and calibration methods to reduce uncertainty by 50 % for the key electrical measurands; capacitance, resistance and contact potential difference
4. To develop a European laboratory network for electrical nanometrology gathering industrial, academia R&D labs and NMIs, jointly supporting dissemination towards stakeholders and engaging with the parties to deliver standard test samples and probes, uncertainty budgets and calibration procedures to enhance the competitiveness of European industry.

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.

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 electronics industry.

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.