EMPIR Call 2019 – Energy, Environment, Normative and Research Potential

Selected Research Topic number: **SRT-g13**
Version: 1.0

Title: High throughput metrology for nanowire energy harvesting devices

Abstract

Harvesting energy from renewable sources like solar, waste heat and mechanical movement is a recognised solution for sustainability, with the shift now moving from macro- and microscale to nanoscale devices, in particular those based on nano-structured materials with high aspect ratios, and nanowire (NW) arrays. Rapid technological advances are being made but the devices demand high throughput and reliable metrology in order to optimise fabrication of these photo-voltaic, thermoelectric and piezoelectric NW arrays. To map the performance and conversion efficiency of NW energy harvesting devices and to link their overall properties with those of individual NWs, traceable surface metrology and scanning microwave microscopy (SMM) optimised for high throughput needs to be developed, validated and standardised.

Keywords

Renewable, energy harvesting, nanowires, solar cells, thermo-electric, electro-mechanical, surface metrology, scanning probe microscopy, scanning microwave microscopy

Background to the Metrological Challenges

Over the last few decades there have been great efforts to make energy supply and consumption more sustainable. Harvesting energy from renewable sources like solar, waste heat and mechanical movement is seen as a prominent solution to our world energy problems with the shift now moving from macro- and microscales to nanoscale devices. Due to their extremely small physical size and high surface to volume ratio, nanowire (NW) based energy harvesting systems, including photovoltaic solar cells, thermoelectrical and electromechanical energy nanogenerators have gained tremendous interest and achieved encouraging progress. While novel designs and materials for various energy harvesting devices indeed offer many potential benefits, they also bring challenges for testing and characterisation.

EMRP project ENG02 obtained results for the characterisation of the averaged properties of electromechanical energy harvesters. However, a quantitative link and correlation between the performance of a single NW and that of the overall device is lacking. Currently, NW systems and devices contain quite unique materials with different functional mechanisms and possess distinguishable physical, optoelectrical and mechanical properties. Typical photo-voltaic, piezoelectric, and thermoelectric NW arrays can have uniform dimensions with diameters typically varying from 50 nm to 1 µm and aspect ratios from 1 to 100. In comparison, the NW devices may range in dimension from ~ cm^2 to several m^2. In addition, the measurement of thermoelectric properties need to be improved to take into account inaccuracies due to probing force and tip-material interaction. Quality control of these energy harvesting systems is therefore highly challenging and high throughput metrology is necessary.

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 energy harvesting devices based on vertical nanowire (NW). The specific objectives are

1. To develop traceable measurement methods for high throughput nanodimensional characterisation of NW energy harvesters (> 10^8 NWs/cm^2) including 3D form (cylindrical, prismatic, pyramidal) and sidewall roughness.
2. To develop traceable measurement methods for high throughput nanoelectrical characterisation of semiconductor NW solar cells using conductive AFM for current-voltage characteristic and conductivity (between 10^{-3} to 10^4 S), SMM for doping concentration variation (between 10^{15} to 10^{20} atoms/cm^3 with an accuracy better than 10 %), and MEMS-SPM for lateral resolution (< 50 nm).
3. To develop and validate traceable measurement methods and models for high throughput nanomechanical characterisation of NW devices, and electromechanical energy harvesters taking into account local bending and compression of NWs including the development of a traceable MEMS-SPM (< 10 pm depth resolution) for fast simultaneous nanomechanical and electrical measurement of semiconductor and polymer piezoelectric NWs.
4. To develop and validate traceable measurement techniques for thermoelectrical characterisation, based on fast areal thermal imaging, of NWs (thermal conductivity lower than 10 W/(m·K) with an uncertainty < 10 %) under different scanning speeds and tip-surface contact.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (IEC TC 113 and IEC TC 82) and end users (solar cell and energy generator manufacturers).

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, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

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 projects ENG02 and NEW05 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

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 energy 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.