EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-i19**
Version: 1.0

Title: Nanoscale probing of transport across interfaces

Abstract

Europe's semiconductor strength is in the manufacturing of complex systems. Although produced in smaller quantities, they represent substantial added value to end products. In the near-future these high-performance applications will require semiconductors with higher mobility or lower-cost technologies based on polycrystalline materials. The common metrological requirement is the accurate nanoscale measurement of material transport properties. Recent tools combining methods such as electron microscopy and scanning probe microscopy have emerged, but do not fulfil current industrial requirements for reliability. Improved metrology will deliver a key competitive edge to EU companies and will support manufacturing excellence.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on "Grand Challenges" related to Industry & Fundamental Metrology on pages 9, 14, 25 and 39.

Keywords

Polycrystalline materials, nanoprobe, thermoelectric, photovoltaic, high-mobility materials, scanning probe microscopy, electron and ion beam techniques, heterostructure, transport, carrier density, nanoelectronic.

Background to the Metrological Challenges

The main markets for semiconducting nanomaterials are thin-films for displays or photovoltaics, and for devices based on p-n junctions for sensing and high-power applications. Polycrystalline materials are widely used in these applications as they deposit over a large area at a low cost. The semiconductor industry faces serious challenges as devices are becoming more highly integrated with higher density and lower power consumption. Beyond silicon, the industry is looking at higher-mobility materials, such as Germanium, III-V and nanomaterials. In all these applications, the electric and thermal transport metrology is behind the needs of the manufacturing sector.

Low temperature deposition of thin films is becoming increasingly important with a growing range of polycrystalline thin-films being used in devices. The metrology community needs to develop databases of nanoscale materials properties with entries for critical materials stacks. Such measurements will also be useful to quantify process variation and to optimise manufacturing processes.

Metrology has enabled the scaling down and cost reduction of semiconductor based materials and devices. The next challenge is to measure reliably and accurately new materials and nanostructures for the development of the next-generation of products. New applications in the automotive, aerospace, security and health sectors will require very high levels of reliability to guarantee proper operation during their lifetime. New characterisation methods will need to be sufficiently traceable to establish the quantitative relationships between composition, structure, and function. Trusted testing procedures will only be achieved by the implementation of standardised procedures that can be implemented with a minimum of effort.

Current state-of-the-art metrology suffers from the trade-off between lateral resolution and electric or thermal resolution. The main requirement of the manufacturing sector is to improve the physical accuracy of resistivity, current, capacitance and temperature measurement, while keeping the best lateral resolution available using, for example, atomic force microscopy.

Scientific and Technological 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 JRP-Protocol.

The JRP shall focus on the traceable measurement and characterisation of transport across interfaces using nanoscale probing.

The specific objectives are

1. To validate new metrological tools for the development and the rapid qualification of emerging devices, sensors or materials based on nanostructured semiconductors.
2. To develop methods to measure nanoscale (sub-50 nm) charge carriers density (within 0.1 % accuracy) and transport (sub picoampere or fraction of Kelvin) in complex nanostructures. This should enable the:
    - Isolation and characterisation of grains in complex heterostructure devices or materials.
    - Correlation of scanning probe measurement with standard non-destructive characterisation techniques.
    - Development of reliable tools and workflows to measure the transport of carriers between the interface in-situ.
3. To model the electron collection efficiency in an e-beam system.
4. To validate accurate measurement using scanning microwave, kelvin, current or resistive microscopy in grains smaller than 50 nm.
5. To provide a clear exploitation path to reduce the cost of manufacturing and the time to market.

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.

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

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call. The available budget for integral Research Excellence Grants is 42 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the semiconductor, micro- and nanoelectronics manufacturing sectors.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.