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

Selected Research Topic number: **SRT-s22**
Version: 1.0

Title: Thermophysical metrology at the micro and nano scale

Abstract

To enable improvements in product performance through the understanding of microstructure-property relationships, for example for pharmaceuticals, thin films and organic electronics, there is need to be able to characterise material properties on the micro and nano-scale. This JRP should develop and establish validated, quantitative methods and procedures for traceable measurements of thermal, thermophysical and thermo-mechanical properties of micro and nano-scale structured materials and products, focusing on thermal transport properties and transition behaviours.

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 35 and 36.

Keywords

Thermal conduction, thermophysical properties, thermo-mechanical, scanning thermal probe microscopy, AFM

Background to the Metrological Challenges

To realise the benefits and optimise the performance of micro and nano-structured materials, products and thin films, designers need to understand and thus be able to characterise their thermal, thermophysical and thermo-mechanical properties on appropriate length scales. However, established techniques are not suited for micro and nano-scale thermal, thermophysical and thermo-mechanical property measurements. Without appropriate metrology, future developments in such materials and products will be hindered. For example, with polymeric thin films there is evidence that their properties, for example their glass transition temperature, can be affected by the film thickness due to confinement issues, rendering design based on properties measured using large-scale specimens inadequate. A second example is in the use of nanoparticles and nanotubes in coatings to increase thermal conduction: it is essential to know the physical properties of nanoparticles and thin films in order to use them successfully in new products. Application areas for this metrology include electronics, organic electronics, pharmaceuticals, polymers and nanoparticles.

Numerous industry sectors such as semiconductors, automotive, aerospace, information and communication technologies are implicitly and deeply concerned with thermal properties and heat transfer management. The International Technology Roadmap for Semiconductors (ITRS) highlights the need for metrology to characterise structure and properties of materials at the nanometre scale, referencing the need for thermal properties of nanotubes in their emerging research materials challenges for thermal management in microelectronics thermal interfaces and packaging applications.

Atomic force microscopy (AFM) based scanning thermal microscopy (SThM) measurements, operated in various modes, provide significant potential for meeting these requirements for thermal, thermophysical and thermo-mechanical properties measurements on the micro and nanoscales. However, currently they do not provide reliable quantitative information for such properties.

Established measurement methods for heat transfer properties cannot access properties on the micro-scale due to their approach and/or size limitations. Thus such methods fail to identify local changes in properties, and establish their relation to microstructure. Local probing techniques based on AFM are currently being developed for example conductive AFM and magnetic AFM to probe such properties on the micro and nanoscales and while AFM-based scanning thermal microscopy has been developed for probing micro-scale thermal properties, and is commercially available, currently it does not provide reliable quantitative information for heat transfer properties.

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 thermal, thermo-physical and thermo-mechanical properties of micro and nano-scale structured materials and products, focusing on thermal transport properties and transition behaviours.

The specific objectives are

1. To develop quantitatively reliable techniques (e.g. scanning thermal microscopy, photoreflectance microscopy, infrared photo-thermal radiometry) for the measurement of thermal, thermophysical and thermo-mechanical properties (e.g. temperature, thermal diffusivity, thermal conductivity, glass transition temperature) at the micro and nanoscales.
2. To compare different thermal scanning probe microscopy techniques in order to determine the key parameters influencing the measurements and to develop associated uncertainty budgets for the techniques.
3. To develop models for the heat transfer due to the scanning thermal probe – specimen interaction.
4. To develop reference materials and devices, and associated validation and calibration procedures for traceable temperature and thermal properties measurements on the micro and nanoscales.
5. To compare the different techniques for measuring thermal properties at the micro/nanoscale (e.g. SThM, photoreflectance microscopy, infrared photo-thermal radiometry) and to develop associated uncertainty budgets for the techniques.

Proposers should include target ranges and uncertainties based on documented industrial needs.

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.

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 materials sector.

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.