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

Selected Research Topic number: **SRT-s15**
Version: 1.0

Title: Traceable small force metrology

Abstract

The measurement of small forces is needed in a large variety of applications like micro-assembly factories, and robotics, MEMS, nano-manipulation, biological and biomedical research, material characterisation, etc. The development of these applications is being hindered by the fact that small force measurement is not traceable to the SI. This SRT calls for the development, in strong collaboration with industry, of new traceable primary standard systems for small forces. This includes the improvement of high precision mass comparators, the evaluation and development of new primary standards, the development of positioning sensors with a resolution of a few nm, as well as the development of the appropriate transfer standards.

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 and 25.

Keywords

Micro force, traceability of small forces

Background to the Metrological Challenges

The ability to measure small forces are key to a large variety of scientific research fields like biology, micromechanics, physics, material science or medicine. The establishment of SI traceable primary standards in this area will significantly improve the comparison of results and the comprehension of new phenomenon. For instance it would allow microbiology research to make the step forward from qualitative to quantitative observations in some areas. Micro forces are also used in medical applications like the new imaging technique based on the vibration response to a micro-force used in cardiac surgery where the insertion of cardiac valve is piloted by micro force sensors to avoid vein lesions.

Depth sensing indentation and atomic force microscopy (AFM) are two techniques that are typically used in nano- and biomechanics. In material science, instrumented indentations are used for the determination of hardness and elastic modulus, through relations between applied force and indenting depth. These methods have been extended to forces of a few nN and a displacement of few nm for example for characterising coatings and films used in the automotive or semiconductor industry. AFM has a resolution of nanometres and can probe interaction forces with a resolution of pN, and so is used for determining the mechanical properties of nano-materials and for measuring interactions between molecules.

Although these methods are currently used in material science, industry and bio-technology, they can produce ambiguous results because of the lack of traceability. Mechanical properties established by means of nano-indentation instruments from different manufacturers often do not agree with each other and Young’s modulus measured by AFM using different cantilevers can differ by orders of magnitude. These inconsistencies are hindering a successful commercialisation of nano- and bio-technology.

The establishment of traceability for small forces, covering a range from mN down to some tenth of µN will need a strong collaboration between European metrology institutes and instrument manufacturers. The development of fast and high precision load cells, needed for instance in real-time application of biotechnology, will require industrial effort in the field of dynamic force measurement.

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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 development and characterisation of new traceable force primary standard systems operating at the nanoscale level and the development of the appropriate transfer standards for very small forces.

The specific objectives are

1. To develop and characterise new force primary standards covering the range from 100 µN to 100 nN.
2. To design and develop a force application stage and a position captor with a resolution of a few nm.
3. To evaluate the metrological performance of the transfer standards for very small forces currently available, to develop the theoretical concept for a new generation of transfer standard and to develop of the first prototype of the new transfer standard.
4. To develop recommendations for a standardised methodology for the calibration of different types of instruments.

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 nanotechnology and biotechnology 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.