EMRP Call 2011 - Health, SI Broader Scope & New Technologies

Selected Research Topic number: **SRT-n04**
Version: 1.0

Title: Graphene metrology

Abstract

Graphene, a single layer of carbon atoms, is steadily making inroads into the applications presently relying on semiconductor heterostructures. The proposed JRP should capitalise on the European lead in graphene science, technology and metrology to underpin the emerging graphene industry with confidence in the potential of this material based on advanced metrology. Quantum electrical metrology, functional scanning probe microscopy and 3D nano-analysis techniques could be used to support the development and application of graphene electronic devices capable to sustain and extend performance scaling substantially beyond the fundamental limits of conventional technologies.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Health, New Technologies & Fundamental Metrology on pages 9, 11and 25.

Keywords

Epitaxial graphene, quantum Hall effect, quantum resistance standard, quantum dot, quantum current standard.

Background to the Metrological Challenges

There is a demand for continued dimensional and functional scaling of electronic devices. This is being met by the development of new materials (such a graphene), which can extend performance substantially beyond the fundamental limits of conventional technologies.

To facilitate the rapid development and uptake of graphene based devices there is a need to improve understanding of nanoscale graphene properties (bulk properties are well-understood), and to develop suitable measurement techniques to support fabrication of prototype devices. Many significant issues exist, including; depositing atomically uniform thicknesses of films, patterning and etching with low edge defects, understanding the carrier distribution in epitaxial graphene, and how this is affected at the interface with the substrate, and development of basic fabrication techniques such as doping, contacts, gating, etc, and integration. These issues can be supported through the development of validated methods for low dimensional metrology and electronic characterisation of nanoscale devices.

The market for graphene electronics is expected to grow rapidly in the next decade, particularly for reliable graphene based products such as capacitors and high frequency FETs.

Graphene based devices also have potential as metrological devices. Firstly to close the quantum metrology triangle through the development of quantised current devices like single electron transistors (SETs), and developing transportable quantum resistance standards bringing metrology closer to end users.

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.

This JRP shall employ a complex of measurement methods to support the development of fabrication technologies and innovative applications of graphene-based devices.

Specific objectives are:

1. To acquire/adopt technology for fabrication of graphene samples and devices necessary for metrology applications, including good quality wafers, suitable electrical contacts, packaging etc.
2. To develop methods to characterise graphene devices:
   - Physical characterisation of layers/interfaces/contacts and devices including electrical properties, uniformity, dimensional aspects, carrier density.
   - Characterisation of 'graphene chemistry', including graphene/substrate interface chemistry, (near-) surface chemistry, impurities.
   - Electrical characterisation, including high precision quantum Hall measurements in DC and AC regimes (up to 10 kHz) on 2DEG devices and electron transport measurements on graphene quantum dots and/or ribbons.
3. To assess and develop new metrology applications for graphene devices at NMI's and industry, e.g. electrical quantum standards for resistance and current.

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, and standardisation and regulatory bodies, is strongly recommended.

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.

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 (e.g. letters of support) is encouraged.

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

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 electronics sector.

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. 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.