EMPIR Call 2014 – Industry and Research Potential

Selected Research Topic number: **SRT-i15**
Version: 1.0

Title: Metrology for graphene characterisation

Abstract

There is much need for the development of protocols for the rapid and reliable electronic, mechanical and structural measurements for different types of graphene (e.g. CVD grown, epitaxial, etc.) and other 2D materials such as graphene oxide, fluorographene, 2D chalcogenides and heterostructures. This is an essential step in the worldwide effort to take these promising materials from the laboratory to the production line. The provision of methods that accelerate the translation of prototypes into products with predictable and reliable performance and lifetimes would provide European industry with a competitive advantage.

Keywords

Graphene, 2D materials, electrical characterisation, mechanical properties, work function, doping, adhesion

Background to the Metrological Challenges

Scientific and R&D interest in graphene has soared very rapidly and it is forecast that graphene will be sold into a range of applications, including radio-frequency identification (RFID), smart packaging, supercapacitors, composites, ITO replacement, sensors, logic and memory by 2018 [1]. So far, there have been limited measurements of the critical mechanical performance characteristics of graphene, with little metrology applied [2]. Hence, industrially-relevant methods need urgent development to enable market forecasts to be realised. However, there are several problems hindering the commercialisation of graphene; and based on consultation with industrial stakeholders, several main issues have been identified. First, there is much need for improvement in the consistency of the batch to batch properties of graphene materials (including the whole process flow, such as transfer to a variety of substrates and patterning) in order to increase yield and decrease overall production costs. The development of quick and non-destructive techniques would greatly benefit commercialisation, giving faster feedback for process development. Second, there is a requirement for a common understanding on what properties should be stated when raw graphene materials are sold, which is of importance when considering chemically exfoliated graphene material, where many companies with a willingness to utilise graphene are deterred by the frequent use of inferior materials. Finally, there are a number of essential properties, which currently have no standard techniques readily available. One example is adhesion, which, by its nature of being only 1-atom thick, graphene is always attached to another substrate. This is of high importance for various sectors, particularly the use of graphene in flexible electronics where delamination can be a problem. Adhesion is also important when considering long-life graphene barrier coatings.

Hence, there is a need for the development of non-invasive and efficient techniques for rapid and contactless measurements of electrical properties in industrially relevant environments (varying temperature, humidity and gaseous atmospheres) on a wide range of length scales; and the development of measurement methods and standardisation of the mechanical properties (i.e. adhesion strength and bonding energy to substrate) for atomically-thin 2D materials. The measurement of the adhesion energy of large-scale chemical vapour deposition (CVD) graphene with substrates is attracting much attention in the integration of graphene-based devices on a large scale. To take graphene-based products to market standardised techniques for assessing and classifying these materials are necessary. Relevant methods, typically applied to thin films, are frequently not suitable for graphene. As graphene features multimodal properties, it is essential to 'define standard procedures to measure these properties and to ensure consistent and repeatable quality of material in the market for different applications' (Graphene Flagship, Call on Standardisation, European Union FP7).

EURAMET-MSU
National Physical Laboratory
Hampton Road, Teddington,
Middlesex, TW11 0LW, UK

Phone: +44 20 8943 6666
msu@npl.co.uk
www.euramet.org

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 proposal.

The JRP shall focus on the traceable measurement and characterisation of relevant electrical and mechanical properties of graphene-based materials in order to facilitate and speed up their use in industrial applications.

The specific objectives are

1. To provide traceable methods for the measurement of key electrical parameters (e.g. sheet and contact resistance, carrier concentration, mobility and work function) of graphene and other 2D materials (e.g. graphene oxide, fluorographene, 2D chalcogenides and heterostructures) on different length scales (nm to mm range).
2. To develop and validate measurement and modelling tools to correlate the electrical, structural and optical characteristics of graphene and related materials in industrially relevant environments (e.g. temperatures ranging from -50 ^{o}C to +200 ^{o}C, humidity from 0 % to 90 % and differing gaseous atmospheres).
3. To validate measurement tools for the mechanical characterisation (e.g. adhesion) of graphene and relevant materials.
4. To engage with industry that manufactures and or / exploits graphene to facilitate the take up of the technology and measurement infrastructure developed by the project, to support the development of new, innovative products, thereby enhancing the competitiveness of EU industry.

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 – both through project steering boards and participation in the research activities.

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

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

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,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the graphene materials sector.

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

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.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] I. A. Ovid'ko, Mechanical Properties of Graphene. Rev. Adv. Mater. Sci. 34,1 (2013).

[2] http://www.idtechex.com/research/reports/graphene-markets-technologies-and-opportunities-2013-2018-000333.asp