EMPIR Call 2019 – Energy, Environment, Normative and Research Potential

Selected Research Topic number: **SRT-n03**
Version: 1.0

Title: Use of electrical key control characteristics to assess the degradation of graphene

Abstract

Graphene offers a variety of applications, but it can only be incorporated into electrotechnical products if its sub-assemblies are reliable, which must be investigated with appropriate methodologies. This has been highlighted in a normative research need expressed by CLC/SR 113 and IEC/TC 113. Proposals addressing this SRT should contribute to graphene metrology and support the future development of graphene products by developing and validating methods for the measurement of electrical key control characteristics (KCCs) (e.g. conductivity, mobility, doping level) of graphene, suitable for the long-term monitoring graphene degradation.

Keywords

Graphene, Electrical characterisation, Standardisation

Background to the Metrological Challenges

The potential of graphene-based nanotechnologies has long been recognised by the European Commission. For this reason, the Graphene Flagship has been established to support the industrialisation of graphene technologies and a cooperation is in place between this initiative and IEC/TC 113 “Nanotechnology for electrotechnical products and systems”. Although many standards on graphene are under development, it is necessary to tailor existing measurement methods to the characterisation of graphene materials, while developing new methods to fill identified metrology gaps.

CLC/SR 113 and IEC/TC 113 have agreed on a metrological need for “Measurement methods for key control characteristics of graphene, especially stability and reliability testing of graphene materials”, denoting the importance of the topic to the nanotechnology community.

Although several techniques exist for the measurement of electrical key control characteristics (KCC) in thin film materials, the extremely small thickness of graphene layers makes the application of these techniques challenging - especially for monitoring the KCCs during stress tests. Published data on the dependence of graphene electrical KCCs on environmental conditions, in particular temperature and humidity, are often inconsistent or even contradictory. Additionally, very few sources deal with the mid- and long-term time evolution of the KCC of graphene samples of commercial interest.

IEC/TC 113 is working towards the development of a testing methodology to provide quantitative lifetime data of graphene products, which should consider the evaluation of failure mechanisms and modes during accelerated stress testing, and extrapolation of laboratory test data to real environmental conditions. The first graphene reliability standard IEC TS 62876-3-1 “Nanomanufacturing - Reliability assessment - Part 3.1: Graphene - Stability test: Temperature and humidity” is under revision and it would benefit from more data to validate the methodology described in the standard. Additionally, industrial end-users would benefit from a good practice guide that can be used on the long-term monitoring graphene degradation.

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 protocol.

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The JRP shall focus metrology research necessary to support standardisation in KCCs for long-term and *in-situ* testing of graphene.

The specific objectives are

1. To improve existing and develop novel methods for the measurement of electrical key control characteristics (e.g. conductivity, mobility, doping level) of graphene, suitable for long-term monitoring of samples under different (including extreme) environmental conditions. This should involve the calibration of the measurement setup, traceability to SI units and national standards, and evaluation of uncertainty (including long-term, in-use, uncertainty contributions);
2. To validate the methods from Objective 1 with measurements on large-area graphene samples of commercial interest (e.g. films on substrate and test structures), under controlled environmental conditions. Time evolution and dependence of the electrical KCCs on environmental parameters, such as temperature and humidity should be investigated.
3. To carry out laboratory environmental tests to gather quantitative reliability data which should be analysed to extrapolate laboratory data to operating conditions, and serve as input quantities for lifetime modelling of graphene-enabled products.
4. To produce a Good Practice Guide for the industry sector based on the IEC/TC 113 template for standards.
5. To facilitate the take up of methods and technology developed in the project by standards developing organisations such as IEC/TC 113 and Graphene Flagship Standardisation Committee. To ensure that the outputs of the project are aligned with their need, communicated quickly to those developing the standards and to those who will use them, and in a form (e.g. Technical report) that can be incorporated into the standards (e.g. series IEC 62607-6-x and 62876-3-x) at the earliest opportunity.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Regulatory body or Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMPIR projects 16NRM01 GRACE and 15SIB06 NanoMag and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.8 M€, and has defined an upper limit of 1.0 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

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,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the electrotechnical and nanotechnology sectors.

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

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

CEN/CENELEC identified this topic as one of their priorities. Details are available at:

https://msu.euramet.org/current_calls/pre_norm_2019/documents/cen_priority_002.pdf