EMPIR Call 2020 – Fundamental, Industry and Normative

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

Title: Electrical key control characteristics to control stability and reliability of graphene

Abstract

Graphene can be used in a wide variety of electrical applications. However, graphene can only be incorporated into electrotechnical products the material is proven to be stable and reliable, and to test this, new methods need to be developed. The need for these new methods has been highlighted by CLC/SR 113 'Nanotechnology standardization for electrical and electronics products and systems' and IEC/TC 113 'Nanotechnology for electrotechnical products and systems'. Such new methods should develop the metrology for graphene electrical key control characteristic (KCC) for long-term, in-situ monitoring and testing of stability and reliability. The new methods should also be used to provide quantitative lifetime data for graphene enabled products and used as input for the production of an industry sector based Good Practice Guide.

Keywords

Graphene, electrical characterisation, reliability, stability, key control characteristics (KCC), IEC/TC 113

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 was established to support the industrialisation of graphene technologies and shortly after the Flagship's setup a formal cooperation between it and IEC/TC 113 was begun. Although many standards on graphene are currently under development, existing measurement methods need to be specifically tailored to the individual characteristics of graphene materials, whilst 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 extreme thinness of graphene layers makes the application of these techniques challenging, especially when monitoring KCCs during stress tests. Electrical KCCs (e.g. conductivity, mobility, doping level) are not only relevant for the most demanding applications of graphene, but they also correlated with other physical and chemical KCCs and their possible degradation. However, current data on the dependence of graphene electrical KCCs on environmental conditions (i.e. for temperature and humidity) are often inconsistent or even contradictory. In addition, very little is known about the mid- and long-term monitoring of 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 real environmental conditions from laboratory test data. 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. In the absence of validated methods for the reliability and stability testing of graphene, IEC/TC 113 plans to publish a first version of the standard shortly, with the proviso to replace it with an improved standard within 3 years. The first version of the IEC standard will reflect the common experience of the graphene community; however, it cannot include the required level of test and validation due to the lack of methods for the reliability and stability testing of graphene.

EURAMET EMPIR MSU
Phone: +44 20 8943 6666 Email: EMPIR.msu@euramet.org
msu.euramet.org

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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.

The JRP shall focus on metrology research necessary to support standardisation in the use of electrical KCCs to control the stability and reliability of graphene.

The specific objectives are

1. To improve existing methods and develop novel ones for the measurement of electrical KCC (e.g. conductivity, doping level, mobility) of graphene, suitable for long-term monitoring of samples under different (including harsh) environmental conditions. This should include traceability to SI and evaluation of uncertainty contributions (including long-term).
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 perform laboratory environmental tests in order to gather quantitative reliability data. The laboratory data should be used (i) to extrapolate real operating conditions and (ii) as input quantities for lifetime modelling of graphene-enabled products.
4. To produce and to disseminate 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, CEN/TC 352, ISO/TC 229 and Graphene Flagship Standardisation Committee. To ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who will use them (e.g. graphene industry and electronics end users), and in a form (e.g. Technical report) that can be incorporated into the standards (e.g. IEC 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 project 16NRM01 GRACE and how their proposal will build on this.

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 graphene industry and electronics 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 identified this topic as one of their priorities. Details are available at:

https://msu.euramet.org/current_calls/pre_norm_2020/documents/cen_priority_006.pdf