Title: Two dimensional lattices of covalent- and metal-organic frameworks for the Quantum Hall resistance standard

Abstract

Graphene is an excellent material for realising the Quantum Hall resistance standard (QHRS), however, its electronic properties strongly depends on sample preparation history and critically on the substrate to which it is deposited. To alleviate these issues, assessment and benchmarking the potential of novel honeycomb two-dimensional (2D) lattices of covalent- and metal- organic frameworks (2D-COF/MOF) for realising the QHRS is needed. If successful, the impact will go beyond the metrological benefits to various emerging technologies, such as solar energy conversion, sensing, membranes, optoelectronics and spintronics.

Keywords

Quantum Hall Resistance Standard, Quantum Hall Effect, Metal-Organic Frameworks, Covalent-Organic Frameworks

Background to the Metrological Challenges

The uniqueness of graphene as a QHRS relies on its energy band structure, which is defined by Dirac cones. This peculiar electronic structure is a direct result of the underlying hexagonal symmetry of graphene. This symmetry makes the graphene carriers to behave as massless relativistic particles resulting in a graphene to respond well under magnetic fields. Although the Dirac energy band diagram of graphene represents an optimum towards QHRS in metrology, in practice, employing graphene in electronics devices (even beyond metrology) is still challenging to achieve.

To date, there is a plethora of Dirac materials that have been introduced and characterized in the literature, such as graphyne, topological insulators, hexagonal assemblies of CO molecules, honeycomb lattices of inorganic quantum dots, ultra-cold atoms trapped in hexagonal optical lattices and, more recently, 2D lattices of metal- and covalent- organic frameworks (MOFs and COFs respectively). Among the available Dirac materials, the large chemical and morphological tunability as well as the scalability of 2D COF/MOFs compounds might offer solutions for bypassing several drawbacks found in graphene for realising QHRS.

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 the traceable measurement and assessment of the potential of 2D organic- and metal-organic frameworks for realising the QHRS.

The specific objectives are

1. To develop single layered two-dimensional Dirac covalent- and metal- organic frameworks in which graphene-like hexagonal structures are obtained from trigonal organic ligands. The chemistry, morphology and electronic properties of 2D-COF/MOFs should be tuned in an atomically precise and scalable manner.
2. To perform traceable multi-scale characterisation on the 2D-COF/MOFs samples by describing their electrical properties as a function of sample's area and the nature of the employed substrate (prior and after integration into QHRS devices).

3. To perform QHE measurements on the manufactured devices and to assess the potential of 2D-COF/MOFs materials for realising the QHRS. Specifically, to benchmark QHRS devices based on these samples vs those based on graphene and AlGaAs/GaAs heterostructures.
4. To establish appropriate protocols, quality schemes and traceability and facilitate the take up of the technology and measurement infrastructure developed in the project by the metrology community and in the development of emerging technologies such as solar energy conversion, sensing, membranes, optoelectronics, spintronics etc.

Proposers shall give priority to work that aims at excellent science exploring new techniques or methods for metrology and novel primary measurement standards and brings together the best scientists in Europe and beyond, whilst exploiting the unique capabilities of the National Metrology Institutes and Designated Institutes.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP SIB51 GraphOhm and EMPIR projects, 16NRM01 GRACE and 18SIB07 GIQS and how their proposal will build on those.

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

EURAMET also expects the EU Contribution to the external funded partners to not exceed 40 % of the total EU Contribution across all selected projects in this TP.

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 materials sector.

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.