EMRP Call 2013 – Energy and Environment

Selected Research Topic number: **SRT-g17**
Version: 1.0

Title: In-situ metrology for high capacity fuel cells and batteries

Abstract

The EU2020 strategy enforcing low-carbon emission identified as key components sustainable, secure, and competitive decentralised energy supplies at the point of use, e.g. for transportation, stationary energy supply, and consumer electronics. In order to facilitate this there is a need for the development of high capacity and long-lifetime batteries and fuel cells. This must be supported by the development and dissemination of the metrological and testing capability for in-situ measurements of critical parameters. These measurements are requisite for development of correlation models to advance the scientific understanding of e.g. electrochemical and degradation processes. Such information is not available yet but is essential for innovations in battery and fuel cell technology.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Energy and Environment on pages 23 and 24.

Keywords

Batteries, Fuel Cells, Electrochemical Energy Sources, Electrical Impedance Spectroscopy (EIS), Scanning Probe Microscopy (SPM)

Background to the Metrological Challenges

The need for reliable energy storage systems is emphasised by the 2011 Technology Map of the European Strategic Energy Technology Plan, the Royal Academy of Engineering Report on Future of Energy Storage (2012), and the King Review of Low-Carbon Cars (2007). Electro-mobility requires energy supplies allowing for driving distances of more than 200 km. This can be addressed through both electro-mobility and decentralised energy storage at the level of *traceable materials characterisation* for future energy systems.

Several test methodologies have been proposed in order to obtain the general characteristics of batteries such as power and energy densities, thermal behaviour, hysteresis curves, charge/discharge capabilities (e.g. see ISO 12405-1, ISO 12405-2 and IEC 62660-1/2). For comparison purposes, there is a need to use test procedures based on the investigation of material properties and related to relevant performance parameters. However, each test method is suited to obtain one-performance characteristics. Facing the above issues will be a huge progress beyond the state of the art.

The electrical characterisation and monitoring of State of Health and State of Charge of batteries via electrical capacity/conductivity has been demonstrated in an empirical approach [1]. In-situ, operando analysis techniques contain only the measurement of current, voltage, temperature – and in the case of fuel cells also inlet or outlet flow composition and quantity. Ex-situ spectroscopic analytical methods are routinely used for material characterisation. The characterisation of all battery parameters is mainly related to electrical measurements, TEM and SEM pictures, and X-ray related structural investigation.

For a clear interpretation, electrochemical measurement must be combined with either modelling or other physical measurements [2]. In-situ light or environmental scanning electron microscopy, neutron imaging or X-ray radiography have been able to show the liquid water distribution in fuel cells in 2D and even 3D, but focussed on mass transport; in-situ photoelectron spectroscopy enables the in-situ analysis of potential distribution in high temperature fuel cells [3, 4]. For batteries, techniques such as X-ray Absorption Spectroscopy and Moessbauer Spectroscopy have been evaluated [5]. Only a very few techniques, such as

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online electrochemical mass spectrometer studies, combine electrochemical and physical or chemical measurements, thus allowing for a proper interpretation of electrochemical measurements [6].

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.

The JRP shall focus on the traceable measurement and characterisation of high capacity fuel cells and batteries.

The specific objectives are

1. To develop sophisticated characterisation methods based on in-situ and complementary ex-situ quantitative metrology of electrochemical energy storage systems.
2. To undertake enhanced model-based analysis of processes at electrodes, failure mechanisms and degradation modes in batteries and fuel cells for the correlation of electrical / durability / reliability test results with changes in physical / chemical / material properties in order to improve understanding of failure mechanisms.
3. To supply well-characterised material systems, calibration procedures, reference measurement methods and test methodologies to industry.
4. To establish robust metrological frameworks for traceable and coherent measurements by combined in-situ metrology (e.g. imaging at the atomic- and nano-scale, chemical, structural, and compositional analysis) in order to enable a deep understanding of materials and improvement of technologies by the development of measurement techniques for the localised measurement of critical battery / fuel cell parameters including degradation / lifetime studies.
5. To combine the microscopic understanding of battery systems with electrochemical characterisation of battery cells and batteries in order to develop practical test methods for e.g. State of Charge and State of Health.

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 R&D work, the involvement of the user community such as industry, and standardisation and regulatory bodies, as appropriate, is strongly recommended.

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

EURAMET expects the average size of JRPs in this call to be between 3.0 to 3.5 M€, and has defined an upper limit of 5 M€ for any project. The available budget for integral Research Excellence Grants is 30 months of effort.

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 how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies.
- transfer knowledge to the automotive, chemical and energy sectors.

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

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 and includes 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 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.

Additional information

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

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