EMRP Call 2011 - Health, SI Broader Scope & New Technologies

Selected Research Topic number: **SRT-n13**
Version: 1.0

Title: Metrology of electro-thermal coupling for new functional materials technology

Abstract

High temperature functional materials are needed for sensing and actuation in aggressive environments for automotive, aerospace, energy, and electronics sectors. Ferroelectric materials are currently limited to around 300 °C where around 1000 °C required. New ferroelectrics and electrocaloric materials are emerging but currently traceable measurement of high field electromechanical, electrothermal and thermoelastic coupling at high temperatures and electric fields are not available. The development of these metrological techniques will facilitate faster development of the most promising materials and would provide a competitive advantage to European industry, resulting in higher efficiency and sustainability, reduced greenhouse gas emissions and improved safety and reliability.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Health, New Technologies & Fundamental Metrology on pages 14, 21 and 35.

Keywords

Piezoelectric, electrocaloric, ferroelectric, thermal properties, sensors, actuators, high temperature.

Background to the Metrological Challenges

Currently available ferroelectric materials used in actuation and sensing are mainly based on Lead Zirconate Titanate and are limited to around 300 °C, since ferroelectric materials that operate at higher temperatures up to 1000 °C have extremely low piezoelectric coefficients and are dominated by non-linear effects. There is a need for high temperature for applications such as flow control and pressure sensing (e.g. fuel injection nozzles for automotive and aerospace, and flow meters used in powerplants) Measurements of ferroelectric materials at high temperature require non-contact methods for strain measurement, and improved knowledge of the non-linear effects present.

Recent developments in electrocaloric materials (based on antiferroelectrics and relaxor ferroelectrics) have the potential to operate as solid-state temperature control for a variety of sensors. There are currently no standards for the measurement of the electro caloric effect, and improvement in both the theory and measurement would hasten development of the most promising materials.

The challenge of developing new high temperature and temperature coupled multi-functional materials technologies requires new metrology to traceably measure multi-functional coupling (electric field, strain, temperature) at high temperatures and electric fields. Development of reliable new devices based on these materials would be accelerated through the availability of accurate, traceable and reliable materials data for digital design and testing.

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 traceable metrology of thermal, elastic and dielectric properties of ferroelectric and electro-caloric materials at high temperatures and electric fields. This will support the development of new functional materials

The specific objectives are:

1. Develop a traceable direct measurement system for the assessment of electrocaloric bulk materials and thin films. Measurements are required at a wide range of temperatures up to 1000 °C, and at high electric fields.
2. Develop models of the coupling between thermal, electrical, and mechanical properties in ferroelectric and related materials, and their application to the metrology of electrocaloric and piezoelectric properties. Models should include non-linear contributions such as electrostriction and effects of high electric fields.
3. Develop traceable measurement of linear and non-linear coupling between electric displacement and strain to the electric field, stress and temperatures up to 1000 °C. Non-contact methods for measuring strain are preferred. (Traceable measurement of temperature distribution, thermal mapping, non-linear electrical, mechanical and optical quantities within the measurement environment are required.)

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 research, the involvement of the appropriate user community such as industry, and standardisation and regulatory bodies, is strongly recommended.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. Particularly this JRP should demonstrate how it goes beyond current nonlinear electrocaloric theory, such as the recently published paper “Influence of thermal stresses on the electrocaloric properties of ferroelectric films” by Zhang et al [1]

The proposed JRP may wish to build on the temperature measurement devices developed in the following EMRP Joint Research Projects:

- ENG06 Powerplants “Metrology for Improved Power Plant Efficiency”
- ENG02 Harvesting “Metrology for Energy Harvesting”
- IND01 HITEMS “High temperature metrology for industrial applications (>1000 °C)”

The total eligible cost of any proposal received for this SRT is expected to around the 2.7 M€ guideline for proposals in this call.

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 (eg letters of support) is encouraged.

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

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, aerospace, energy, and electronics sector.

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. 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

Proposers should establish the relevance of any references

[1] J. Zhang, S. P. Alpay and G. A. Rossetti, Jr. *Influence of thermal stresses on the electrocaloric properties of ferroelectric films*, Applied Physics Letters 98, 132907, 2011

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