Title: Traceable characterisation of thin-film materials for energy applications

Abstract

Significant investment in advanced materials is required to achieve an energy efficient Europe and to extend Europe's leadership in energy technology and innovation. Thin film materials underpin numerous energy technologies and thus play a vital role in meeting targets on emissions, electricity availability and reduced cost. Thin films for energy applications are used in new photovoltaics, power electronics and solid state LED lighting and energy efficient windows (as low emissivity (low-e) thin film coatings). However, such technologies require innovative metrology and modelling to enhance device functionality and currently traceable measurement and characterisation of the physical and chemical properties of advanced thin film materials for energy applications is lacking.

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 8, and 23.

Keywords

Thin films, renewable energy, photovoltaics, power electronics, energy efficient lightening, materials metrology, analytical techniques, modelling, correlation of functionality

Background to the Metrological Challenges

Advanced thin film technology is vital for state-of-the-art renewable energy conversion devices, efficient power electronics, energy-efficient windows and lighting devices. Currently, the thin film materials part of the power electronics sector is worth £13.5 billion in the global market and is growing at a rate of 10 % per year. Innovative substrates and devices for high voltage power electronics will provide significant progress in the fields of energy efficiency, reliability and lifetime at reasonable costs. The ability to determine the wavelength-dependent dielectric function, spatial and chemical composition, and structure of the thin film materials in high voltage power electronics is crucial for their optimisation and modelling. However, the parameters extracted using existing single methods can be unreliable and therefore new multi-method approaches are needed.

In order to improve the performance and efficiency of thin films for energy applications for example in photovoltaics, solid state LED lighting and energy efficient windows, their often complex physical and chemical properties need to be correlated with device functionality. In particular, the traceable measurement and characterisation of the compositional, chemical, and electronic structure of advanced thin film materials for energy applications is required.

Validated characterisation is also needed to support development of energy applications with longer lifetimes and to accelerate deployment of new technologies. As currently there is a lack of appropriate methods to investigate stress factors in materials properties that could affect their durability. For large-area devices, in-line characterisation is crucial for ensuring high-quality cost-effective production. Existing non-destructive methods analysis often rely on parameters obtained in ideal samples leading to large discrepancies in different measurement methods. Therefore, the accuracy of current optical inspection methods need improving.

Common to most energy applications, heat transfer and thermal management has a direct impact on the lifetime, performance and reliability of devices. Therefore, understanding the thermal behaviour of thin films, is key to improving the performance of devices, and requires knowledge of their thermal properties (thermal conductivity, thermal diffusivity, specific heat). However, important issues are how to accurately measure these properties in the temperature range that the thin films operate at and how to study the relationship of these properties with the microstructure and composition of thin films.

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 advanced thin film materials for energy applications such as organic solid state lighting, third generation photovoltaics, low-e coatings and power electronics.

The specific objectives are

1. Development of models for the interpretation of advanced materials measurements and their correlation to product performance.
2. Traceable determination of the correlation between material composition and electronic structure over a broad spectral range. This should include the production of reference standards, calibration samples and reference measurement techniques.
3. Validation of measurement techniques for depth, selectivity and sensitivity for thin film energy materials such as novel compound materials with matrix elemental depth gradients, organic/inorganic hybrids, multi-layered structures and nano-structured surfaces, layers and interfaces.
4. Development of validated methods for the thermal characterisation of thin films as a function of temperature and for multi-parameter characterisation of energy thin film materials under specific stress conditions.
5. Development of large-area characterisation methods for process optimisation in thin-film energy material production, including fast contact and non-contact methods.

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. In particular, proposers should outline the achievements of the EMRP project IND07 (Thin Films) 'Metrology for the manufacturing of thin films' and how their proposal will build on those.

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 (eg 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 energy and industrial 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.