TOPIC DESCRIPTION: Metrology for Solar Cells and Solar Thermal Conversion

Abstract

The European solar cell market is growing exponentially and has a significant world market share. However current generation products are still uncompetitive against fossil fuel energy generation and are thus negligible players in the energy production market. Improved measurement techniques are essential for the support of the development of novel and more efficient cell production technologies, for the evaluation of solar cell conversion efficiency, and for the understanding of degradation effects.

Solar thermal systems for heating and hot water applications are a simple way of using renewable solar energy. On larger scale, solar thermal power plants are being developed for the generation of electricity. Even though the technique is well known and standards are available, there are still improvements to be made particularly in estimating the energy produced and in the characterisation of the thermal, chemical and physical properties of the absorber of the solar module, especially for high-temperature, high-power installations.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008 [1], section on "*Grand Challenges"* related to *Energy* on pages 8 and 23.

Keywords

Photovoltaic, photocatalytic, photoelectrochemical, solar cell, crystalline silicon solar cell, thin-film solar cell, dye sensitised solar cell, organic solar cell, characterisation of solar cells; nano-structured surfaces; solar-power, renewable energy source, sustainable energy source, efficiency, temperature sensor, humidity sensor, oxygen sensor, long-term stability, energy conversion efficiency, solar equipment, pyranometer, property of absorber, solar thermal energy, solar heating.

Background to the Metrological Challenges

The EU Directive on the 'Promotion of the Use of Energy from Renewable Sources [2] states that 22 % of Europe's electrical energy should come from renewable sources by 2010, that 20 % of Europe's total energy consumption should come from renewable energy by 2020. This aim seeks to reduce European greenhouse gas emissions, and minimise Europe's dependence on imported energy.

The growth of the **photovoltaic** industry in Europe during the past five years established a European leadership for this technology. A further development of the worldwide market for photovoltaics and hence, the establishment of more photovoltaic industry in Europe is expected in the future [3]. The photovoltaic world market are expected to increase from $16 billion in 2007 to $30 billion in 2010, and in 20 to 30 years solar energy could provide up to 30 % of the world energy consumption [4].

Despite the many drivers towards the use of solar energy, implementation is currently negligible, accounting for just ~0.04% of world energy consumption in 2005 [5], though growing by about 30% year-on-year since 2005 [6].

A major barrier to market for solar cells is the energy cost/efficiency ratio. Thus considerable reduction of solar cell production cost and the development of novel technologies are necessary. The target is a reduction of the cost of electrical power delivered solar cell devices by about an order of magnitude.

Crystalline silicon devices represent over 94% of the current installations. Silicon technology is a mature one and significant breakthroughs in efficiency are unlikely, therefore new, more cost efficient production technologies, to be underpinned by metrology, are required.

Roll-to-roll processing of thin film solar cells on flexible substrates like plastic or metal foils is considered a promising direction of development for the inexpensive manufacturing of solar modules. The primary materials of the dye solar cell (DSC) are cheap and they can be processed into cells with simple solution based printing techniques. However, a challenge of organic DSC is their long-term stability [7, 8, 9], requiring new measurement procedures for a more comprehensive understanding of these devices.

Losses of solar cells due to reflectivity can be reduced by using special design of topographic structures as well as coatings in the nanometre range. Textured surfaces like black silicon, i.e. etched structures, have an improved efficiency. The key parameters are the surface topography of the solar cell (surface texture, black silicon), the reflectivity of thin films or coatings and the reduction of the amount of silicon per watt energy. Another way to improve the solar cell efficiency is by utilising the phenomena known as light trapping in solar cells.
This requires the traceable measurement of:

- surface reflectivity properties / optical reflection
- topographic structure and thin films coatings, with microscopic and non-imaging measurement techniques in the nanometre range
- correlation of the surface properties with efficiency properties
- chemical states of absorber and buffer layers

European manufacturers are technology leaders for **solar thermal technology**. Two types of measurements are considered as key for improvements:

1) Traceable measurement of the incident sun light irradiance. This is currently measured using pyranometers, which are also used for the calibration of photovoltaics. Research should be performed to improve calibration uncertainty of reference pyrheliometer as well as to establish full SI traceability, and to define calibration procedure for pyranometers reducing the present uncertainty levels.
2) The ratio of solar absorptance to infrared emittance defines efficiency of the collector (higher numbers are more efficient). Accurate traceable measurement of these figures, especially for complicated geometries, is required.

Scientific and Technological Objectives

Proposers should aim to address all of the stated objectives below. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol.

The objectives are based around the PRT submissions. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

Energy conversion using solar cells and solar thermal devices is recognized as most valuable sources of sustainable, renewable energy. The overall objective of this topic is to underpin advances in quality, efficiency, lifetime, and production efficiency of such devices through metrology in order to promote their widespread use. With respect to solar-thermal energy conversion the research shall concentrate on innovative high-power and high temperature devices.

1) Metrology for Solar Cells:

Development of measurement techniques and methods, if suitable through establishing traceability, addressing all types of solar devices, such as c-Si, thin-film, organic, multi-junction etc, and packages on macroscopic and microscopic scale. This shall include

a) electrical, optical, thermal, physical, chemical, structural and mechanical properties of solar devices and coatings for solar cells
b) efficiency measurements of solar cells (electrical efficiency, conversion efficiency)
c) lifetime measurement of solar cells and identification of substances and processes leading to degradation,

2) Metrology for Solar Thermal Technology

a) Develop and validate methods for measurement of solar irradiance, solar absorptance and infrared emittance.

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.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

In your JRP submission please detail the impact that your proposed JRP will have on the following Directive of the European Commission:

- “Promotion of the use of energy from renewable sources” Directive 2009/28/EC [2]

You should also detail other Impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”.

You should detail how your JRP results are going to:

- Feed into the development of urgent standards through appropriate standards bodies
- Transfer knowledge to manufactures and government policy departments
- Develop an appropriate European accreditation, testing and standards infrastructure for solar cells and solar thermal panels.

Additional information

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

[1] European Metrology Research Programme. Outline 2008 Edition - November 2008, http://www.euramet.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/docs/EMRP-outline2008.pdf&t=1248796946&hash=9da9ceb781370f04c322ac48068deca5

[2] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

[3] European Photovoltaic Industry Association: "Global Market Outlook for Photovoltaics until 2013", April 2009, Global_Market_Outlook_Until_2013.pdf at http://www.epia.org/index.php?id=18

[4] nano.de – Report 2009 of the German Federal Ministry of Education and Research, p 35, http://www.bmbf.de/pot/download.php/M:0+nano.DE-Report+2009/~DOM;/pub/nanode_report_2009.pdf, page 41

[5] Installed PV power as of the end of 2005; IEA Photovoltaic Power Systems Programme, (www.iea-pvps.org/isr/01.htm).

[6] Cartlidge, E., Physics World, 20 7 pp20 (2007)

[7] Egbert Figgemeier and Anders Hagfeldt, "Are dye-sensitized nano-structured solar cells stable? An overview of device testing and component analyses", International Journal of Photoenergy, vol. 6, no. 3, pp. 127-140, 2004. doi:10.1155/S1110662X0400016

[8] J. M. Kroon, N. J. Bakker, and H. J. P. Smit, et al., "Nanocrystalline dye-sensitized solar cells having maximum performance," Progress in Photovoltaics: Research and Applications, vol. 15, no. 1, pp. 1–18, 2007.

[9] M. Toivola, L. Peltokorpi, J. Halme, P. Lund, "Regenerative Effects by Temperature Variations in Dye-Sensitized Solar Cells", Solar Energy Materials and Solar Cells, 91, 2007, 1733-1742