Title: Optical metrology for appearance of advanced functional surfaces

Abstract

The understanding of the effects of modern functional surfaces needs an adequate linkage of derived quantities like e.g. colour, gloss, translucency, texture, fluorescence, etc. in varying geometries to basic optical material properties like reflectance and transmittance. The proposed research should set up and fully characterise adequate measurement capabilities, identify relevant geometries, develop an irreducible set of calibration schemes for characterisation and bridge the gap between the macroscopic optical appearance and the microscopic structural properties. Further, the necessary mathematical tools and data analysis algorithms mandatory to provide the link between optical properties and surface geometries should be developed.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008 in the following sections;

Page 9 "Metrology R&D for applied and fundamental metrology",

Page 12 "Physical measurements of visual perception for product quality and security purposes. Product quality requests a quantifying metrology on what was a subjective assessment of appearance."

Keywords

Reflectance, transmittance, appearance, fluorescence, Bidirectional Reflectance Distribution Function (BRDF), multi-geometry, modern functional surfaces, scattering, mathematical modelling, generalised ellipsometry.

Background to the Metrological Challenges

The appearance of a product is important for several industries, e.g. automotive, cosmetics, paper, printing, packaging, solar cell, steel industries, etc. This holds not only for the aspect how a product looks, but also quality, reliability and reproducibility control during production. The look and the optical functionality of a product surface are determined by its structure and texture. The design and production of surfaces with specific characteristics and purposes require the knowledge of the structure, its interaction with the incoming light as well as the possibility to measure the optical properties in a sufficient manner. None of these three prerequisites are currently appropriately fulfilled for the ab-initio calculation of optical properties.

Standard measurements in spectrophotometry deal with the characterisation of materialised white, grey or colour standards, e.g. opal glasses, barium sulphate pellets or ceramic tiles. Typically measurements are made in standardised geometrical configurations, e.g. diffuse irradiation and detection under 0° (d:0°) or directional irradiation under 45° with subsequent detection under 0° (45°:0°). However, even for these so-called cooperative standard materials, the reflection behaviour is not only wavelength dependent but also varies strongly with the geometry. This effect might be even more dramatic for more complex standards that have specific features concerning angle and wavelength dependence. Thus, the industry needs traceability, consultation and support for multidimensional, in- and out-of-plane reflection geometries.

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 aim of the JRP is to meet the demand from industry to describe the overall macroscopic appearance effect of advanced functional surfaces by developing and improving methods for measurement and to predict the optical properties of structured and textured surfaces. The JRP should provide validated and reliable optical measurements/methods with traceability wherever it is practicable to do so.

The specific objectives are:

1. Setup and improvement of traceable measurements in the field of appearance measurands, such as colour, gloss, texture, translucency, and fluorescence. The optical properties of functional surfaces will be measured in multi-geometrical configuration in the visible and close-by spectral ranges with improved spectral and spatial resolution and reduced measurement time.
2. Determination of the structural properties of surfaces by improved optical methods like scatterometry and microscopy and bi-directional reflectance distribution function (BRDF).
3. Identification of the minimum set of calibration schemes needed for surface characterisation by using different types of functional surfaces (like multilayer structures and coatings on substrates, gratings with pitch values in the micrometer and sub-micrometer range, photomasks, standard reference materials...). Set up public domain database for functional surfaces and their appearance measurements.
4. Modelling of the relation between the optical properties and the three-dimensional structures by rigorous computation of electromagnetic fields, solution of the inverse problems, evaluation of measurement uncertainties, and development of fast algorithms for in-line measurements, based on simplified models.

Proposers shall give priority to work that meets documented industrial needs and that which supports transfer into industry e.g. by cooperation and/or by standardisation.

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

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.

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 the relevant industrial 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 3 years duration.

Additional information

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

[1] CIE 175:2006, “A framework for the measurement of visual appearance”, International Commission on Illumination, 2006.

[2] A. Höpe, K.-O. Hauer, “Three-dimensional appearance characterisation of diffuse standard reflection materials”, accepted for publication in Metrologia

[3] S. Holopainen, F. Manoocheri, E. Ikonen, "Non-Lambertian behaviour of fluorescence emission from solid amorphous material”, Metrologia 46, S197–S201, (2009) doi:10.1088/0026-1394/46/4/S12

[4] M. Wurm,_ F. Pilarski, B. Bodermann, “A new flexible scatterometer for critical dimension metrology“, Review of Scientific Instruments 81, 023701 (2010)

[5] P.-E. Hansen, L. Nielsen “Combined optimisation and hybrid scalar-vector diffraction method for grating topography parameters determination, Materials Science and Engineering B 165, 165-168 (2009)

[6] R. Model, A. Rathsfeld, H. Gross, M. Wurm, B. Bodermann “A scatterometry inverse problem in optical mask technology”, J. Phys. 135, 012071 (2008).

[7] H. Gross, A. Rathsfeld, “Sensitivity Analysis for Indirect Measurement in Scatterometry and the Reconstruction of Periodic Grating Structures”, Waves in Random and Complex Media 18, 129-140 (2008).