Title: Vision based dimensional metrology

Abstract

Vision based dimensional metrology systems are widely used in quality control applications as they are fast, non-destructive and contamination-free. Such systems are well suited to in-line process control and in-line metrology applications; however, further development is needed to enable precise, traceable optical measurements of 2D feature sizes. Vision based bidirectional measurements require the intensity level (threshold), at which the optical profile corresponds to the real edge position, to be known. So far fixed values have been used, even though the dependencies on the properties of the sample and the optical system are well known. This currently limits the measurement uncertainty to 0.5 µm. A software package to calculate these values and a metrological infrastructure need to be realised for traceable optical bidirectional measurements with uncertainties of 0.1 µm in an industrial production environment.

Keywords

Bidirectional measurements, optical microscopy, machine vision, optical coordinate measurement machines, ISO 10360-7, traceable measurements, modelling of optical imaging

Background to the Metrological Challenges

There are few internationally recognised bidirectional optical calibration services available with only PTB offering optical linewidth calibrations. Two other NMIs offer linewidth measurements but only on (special) photomasks, and one accredited laboratory calibrates special types of photomasks. Unfortunately, the use of photomasks is limited as they are too short for the calibration and testing of most optical CMMs because the minimum length requirement of ISO 10360-7 cannot be met. Therefore an efficient, flexible and application oriented calibration infrastructure for customer samples is required.

Reliable bidirectional calibrations or standards supporting the performance of these tools are difficult to obtain and they are expensive. Consequently, the requirement to perform bidirectional measurements in the course of acceptance and verification tests has been removed from ISO 10360-7. Therefore the optical CMMs used for these measurements are calibrated using a standard which has been certified by other means. This leads to uncertainty and limits the smallest achievable MPE-values. The industry needs a fast and easy to use software module to calculate the threshold value for different illumination and imaging modes. New industry guidelines on the experimental requirements, procedures, and the main uncertainty contributions and limits are also needed. This missing measurement capability impedes the improvement / development of products based on micro parts.

To achieve an uncertainty below 0.1 µm (k=2) for bidirectional measurements a dimensional standard with a high structure edge quality is required, as well as knowledge of the materials and optical material parameters of both the substrate and the structures. Currently, a complex three step calibration is required because software is not available and high resolution SPM or SEM is difficult due to e.g. charging effects, the small field of view and sample size limitations.

A measurement uncertainty of 0.1 µm (k=2) is sufficient in most cases. However, customers are often unaware of the specific problems of optical bidirectional measurements [1] and uncertainties as large as a few µm can be observed. Using high-end tools applying tactile probing a level of agreement of about 0.1 µm can be reached. This is the best that can be achieved using the constant threshold value recommended in good practice guide no. 39. However, if the correct threshold is used together with the appropriate instruments and measurement procedures, disagreements of as low as 20 nm are feasible [2].

In CMM metrology, data fusion is being investigated to determine if the measurement results of tactile and optical sensors and computer tomography can be combined. However, agreement will remain poor until the threshold issue is resolved and the optical measurements are performed correctly. In addition, using more advanced optical sensors will not solve the problem as the probe sample interaction is more complex. In the surface metrology area, the optical transfer function could be used to improve the measurement results if it can be determined accurately. However, the strong dependence of the optical profile on the shape and material parameters of the structures will require a transfer function to be determined each time these parameters change. The influence of the sample and the instrument also have to be separated.

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 proposal.

The JRP shall focus on the development of vision based dimensional metrology suitable for use with a wide range of industrial materials. The goal is to achieve traceable optical bidirectional measurement of features from 0.5 µm to a few mm with measurement uncertainties down to 0.1 µm.

The specific objectives are

1. To develop a model based image interpretation for vision based dimensional metrology systems, such as optical CMMs. To develop a traceable method for optical bidirectional measurements of 2D features from 0.5 µm to a few mm with uncertainties of 0.1 µm.
2. To develop algorithms and a software module to calculate the threshold value of bidirectional optical measurements for different illumination and imaging modes. This software module must be made available to instrument manufacturers and end users.
3. To develop calibration methods and calibration artefacts having uncertainties well below 0.1 µm for bidirectional measurands.
4. To develop guidelines to achieve measurement uncertainties down to 0.1 µm in an industrial setting.
5. To engage with industrial users that require the measurement of small dimensioned features to facilitate the take up of the technology and measurement capability developed by the project.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this and EMRP JRP IND17 (Scatterometry) ‘Metrology of small structures for the manufacturing of electronic and optical devices’.

In particular, proposers should outline the achievements of the EMRP project IND59 (Microparts) ‘Multi-sensor metrology for microparts in innovative industrial products’ and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,

- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge into industrial production.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects"

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- 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.

[1] S. Carmignato et al., Metrological performance of optical coordinate measuring machines under industrial conditions, 2010, Annals of the CIRP 59 497-500.

[2] Richter J et al., Calibration of CD mask standards for the 65 nm node:CoG and MoSi. In Proc.23rd European Mask & Lithography Conference.2007, SPIE 6533, 6533-53.