EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-i06**
Version: 1.0

Title: Traceable Critical Dimension metrology of engineered nanodevices

Abstract

The production of optical devices and semiconductor devices such as microprocessors and DRAM chips needs precise manufacturing and Critical Dimension (CD) metrology of engineered nanodevices and the measurement uncertainty for these nanodevices needs to be reduced to below 1 nm, for the next generation of devices.

These requirements necessitate the robust and reliable calibration of scanning microscopy instruments such as Scanning Electron Microscopy (SEM) and Scanning Probe Microscopy (SPM). Test structures characterised with TEM could help to reduce the uncertainty of SEM and SPM measurements, but further work is needed as there are currently no reference materials for engineered nanodevices for TEM, SEM and SPM and no test structures for transferring TEM and SEM measurements to scanning microscopy instrumentation. In addition, a major contribution to the uncertainty of SEM and SPM is the effect of probe-sample interactions and so a better understanding of probe tip characterisation, image reconstruction, probe-sample interactions and electron distribution in scanning microscopy samples is also required.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Industry & Fundamental Metrology on pages 9, 25 and 39.

Keywords

Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), Transmission Electron Microscopy (TEM), Critical Dimension (CD) metrology, nanodevices

Background to the Metrological Challenges

The CD characterisation of nanodevices uses a number of non-destructive techniques. For fast, in-line quality control, scatterometry is predominatly used, but this method is not suited for the measurement of single structures. For off-line inspection, SEM is used, as it is a relatively fast imaging technique with high lateral resolution. However, the disadvantage is that SEM only provides limited information on structure heights and therefore edge detection algorithms are sensitive to corner rounding. For 3D measurements, SPM is the method of choice, but compared to other techniques SPM is rather slow.

With scanning microscopy methods the major contribution to their uncertainty budget is the effect of probe-sample interactions, which can currently only be quantified to a certain extent. A possible solution to this is the use of transfer standards that have already been characterised to the highest available accuracy, such as crystalline silicon standards, measured with TEM and/or XRM. Measurements with SEM and SPM using such well-defined transfer standards should enable the development of models of probe-sample interactions, leading to the required improvement in measurement uncertainty through the corrections of imaging artefacts. At present NIST has developed a single crystal critical dimension reference material (SCCDRM) that makes use of single-crystal silicon and preferential etching to pattern the structures and high resolution transmission electron microscopy (HRTEM) for measuring the structure size, using the Si lattice spacing as an inherent length standard. Others have also produced silicon CD standards, however, in all of these structures, only individual geometrical properties (CD, sidewall angle) are well defined which is not sufficient for a complete analysis of SEM and SPM image formation.

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From an instrumental point of view, SPM used for 3D metrology need special probes and specific scanning concepts, as instead of measuring only vertical forces on flat samples, these instruments have to measure forces at sidewalls. Therefore, it is necessary to determine an effective tip size, which includes the effect of different force interactions at different surface slopes and material dependencies.

Due to its high lateral resolution and measurement speed, SEM is a standard instrument for CD metrology; however, absolute CD measurements are only feasible if a definite correlation between the SEM signal profile and specimen topography can be established by physical modelling. There is a variety of simulation programs currently available for SEM modelling, but the critical point of CD evaluation at the nanometer scale is that structure size and structure shape cannot be examined independently, i.e. the shape of the structure strongly influences the SEM image and thus the CD evaluation. Therefore, it is necessary to verify SEM modelling and CD evaluation in real measurements at well-defined nanostructures.

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 providing traceable measurements of Critical Dimension (CD) and the characterisation of engineered nanodevices using scanning microscopy (SEM and SPM).

The specific objectives are

1. To develop traceable reference materials for engineered nanodevices for use in TEM, SEM and X-ray microscopy.
2. To improve the uncertainty of scanning microscopy measurements to less than 1 nanometre and to provide high-quality test structures for transferring TEM and SEM measurements to scanning microscopy instrumentation.
3. To improve the uncertainty of SPM metrology by increasing the understanding of tip characterisation, image reconstruction, probe-sample interactions and electron distribution in scanning microscopy samples.
4. To develop hybrid metrology modules for the accurate measurement of advanced 3D nanodevices. Such modules must be compatible with CD metrology data formats for SPM and SEM.
5. To produce fine probes for the measurement of nanodevices with high aspect ratios (< 10:1), the possible deformation of probe and/or sample structures must to be taken into account.

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.

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

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call. The available budget for integral Research Excellence Grants is 42 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 (e.g. 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 industrial and nanotechnology 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.