Reconstruction of nanoscale gratings based on EUV reflectometry data and machine learning techniques

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For the investigation of the patterning quality of an industrial lithographic fabrication process, periodic grating arrangements are manufactured in specific areas of a wafer to serve as a test structure. Spectroscopic investigation techniques are used for characterizing these gratings in a statistically significant way over a µm-extended region. However, this so-called optical critical dimension metrology (OCD) with wavelengths in the visible or ultraviolet spectrum faces significant challenges due to the relatively weak light-matter interaction. Alternative techniques such as small angle X-ray scattering (SAXS) also face technical issues due to a photon flux too low to satisfy the industrial requirements as well as due to measurement spot sizes exceeding the sizes of industrial metrology targets significantly.

The alternative approach discussed in this paper is spectroscopic EUV reflectometry (SEUVR), which provides high material and parameter sensitivity for nanoscale gratings due to strong light-matter interaction and small wavelengths. To extract several geometrical parameters of a grating structure (critical dimension, period, height) from spectrally resolved reflectivity measurements, a model-based approach is useful. In this approach, experimental data is compared with simulations to determine the grating parameters (Fig. 1, left).

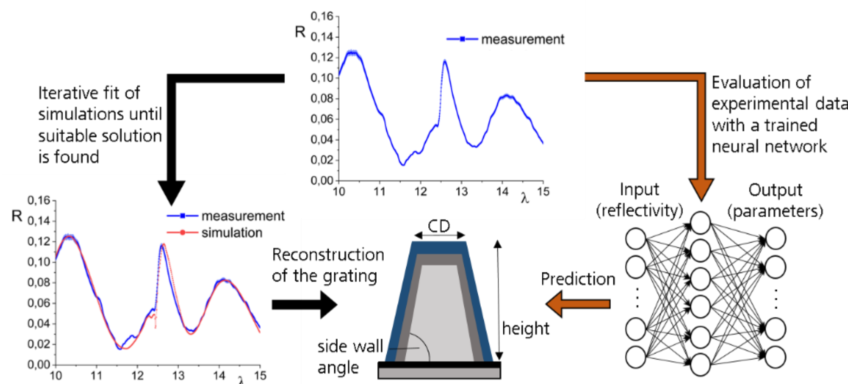

***Fig. 1** Outline of a nanoscale grating reconstruction process based on EUV reflectometry using a model-based approach (black arrows) such as fitting and a model-free approach (brown arrows) e.g. neural networks. In this case the reflectivity for a 2D grating with five different materials is shown and evaluated.*

Model-based approaches are very slow, as each measurement requires new, complex simulation computations. In addition, both the required time and the result depend sensitively on the initialization parameters of the simulation process.

In this contribution an alternative approach from the domain of machine learning is discussed, namely the training and the performance of a general regression neural network (GRNN) to predict suitable grating parameters from reflectivity measurements (Fig. 1, right). This model-free approach provides a much faster determination and is independent of the initialization process. Together with sensitivity analysis for certain parameters, the problem of uniqueness of a solution and cross correlations are evaluated. Both methods and mixed concepts are investigated and benchmarked against each other to demonstrate the pros and cons of model-free, model-based and mixed-model approaches in the domain of nanoscale grating metrology.