Development and Characterisation of Scatterometry Reference Standards

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Introduction

- Scatterometry (also: Optical Critical Dimension OCD), including reflectometry, ellipsometry... is an important metrology method widely used for process development & control in nanolithography
- Very high sensitivity with respect to variations of many important structure parameters
- Shows usually an excellent linearity to CD-SEM measurements
- However, often some significant measurement offsets with respect to CD-SEM measurements are observed, which are usually accounted for by introducing some dubious ‘bias’ values
- Accurate and absolute scatterometry measurements are quite challenging due to the relative complex data analysis
- Currently there is a lack of reliable scatterometry reference standard samples traceable to the Si unit meter

Objective

- Realisation of scatterometry reference standards: U(Cd) = 1 nm
- To improve significantly the tool matching between different types of scatterometers and also with microscopy tools (SEM, AFM,...).

Requirements:
- Design (sample size, materials, structuring) has to take into account the requirements of different types of scatterometers, SEMs and AFMs.
- Set of targets representative for current and future lithography technologies
- Good knowledge of optical parameters of the materials and of structure geometry details
- Stable over time
- Suitable for state of the art metrology tools (for industrial applications)
- Two different materials: silicon, dielectric (resist mimicking) material

Developed reference standards

AIMED SPECIFICATIONS:
- Material: silicon wafer with Si or Si,N structures
- Manufactured by e-beam lithography by HZB
- Size: sample (20 mm²), targets 1 mm² & (1x15) mm²
- Line gratings: periods (50-250 nm)
- Linewidths (25-132) nm
- Structure height (40-90) nm, edge angles = 90°
- Line edge roughness = 1 nm (rms), low corner rounding

Design for sample development and testing phase

Characterisation

Spectroscopic Mueller polarimeter Sentech SE 850 DUV

Structure model

Rigorous modelling for all ‘optical’ methods from NIR to X-ray
- Spectr. Ellipsometry / Mueller
- DUV Scattering
- EUV SAS
- GISAXS

Maxwell solver JCMwave:
- FEM allows to model arbitrary structures

Optimisation:
- Global: Particle Swarm or Differential Evolution
- Local: gradient based

Calibration

DUV goniometric scatterometer

Grazing Incidence Small Angle X-ray Scattering GISAXS: (1.7-10) keV

X-ray-scattering (GISAXS & EUV-SAS) is sensitive to:
- Structure geometry (CD, SWA,...)
- LER/LWR, Surface and interlayer roughness
- Superstructures (e.g. photolithography errors)

Additional calibrations:
- Spectroscopic ellipsometry / Mueller polarimetry
- Scanning electron microscopy (CD-SEM)
- Atomic force microscopy (CD-AFM)

First calibration results

- CD / nm
- Height / nm
- Side Wall angle°
- Curvature Radius
- Oxide Height / nm
- GISAXS (6.5 keV)
- DUV-Satt. (248 nm)
- EUV-SAS (1.3 keV)
- GISAXS (6.5 keV)
- DUV-Satt. (248 nm)
- EUV-SAS (1.3 keV)

Discussion and Outlook

- Process and design for high quality scatterometry standards developed
- Characterisation confirms good quality for edge roughness and angles
- Calibration of first Si samples currently performed with reasonable agreement. For final calibration combined data analysis including AFM, SEM and ellipsometry data will be applied.
- First Si,N samples have been manufactured and are currently characterised
- Calibration service will be offered in the future