

Table-top HHG EUV scatterometry for roughness and structural parameters evaluation in nano-stacks

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Abstract. Extreme ultraviolet (EUV) or soft X-ray scatterometry is a powerful technique enabling contactless non-destructive structural characterization of patterned nano-stacks with down to sub-nanometer precision¹. The technique requires coherent EUV / soft X-ray radiation and is thus typically limited to a synchrotron or free-electron laser facilities. With the continual improvement of table-top high-harmonic-generation (HHG) sources over the last few decades, this approach has become feasible in a lab-scale environment. Here we present EUV scatterometric results obtained using the coherent 92 eV HHG source in imec's AttoLab on grating-type samples highly relevant for semiconductor industry. Roughness characterization was performed via direct detection of scattered light utilizing a synthetic aperture and high-dynamic-range detection coupled with noise suppression techniques. Structural parameters (CD, pitch, height, angles, layer and interlayer diffusion thicknesses) were obtained by fitting the sample model to match simulated diffraction patterns to the experimental ones. The latter were acquired through a wide angular scanning (ranging 0 to 65° from grazing). The simulated patterns were calculated by propagating light (using JCMSuite software) through a model of the structured sample. The results demonstrate sub-nanometer precision and are in good agreement with AFM and TEM measurements.

Here we present the results on EUV scatterometry applied to roughness characterization by analysing scatter light, and structural parameters determination with sub-nanometer precision via model fitting utilizing 3D light propagation software and experimental angular-scanning diffraction measurements. The schematic of the experimental setup is shown in Fig. 1.

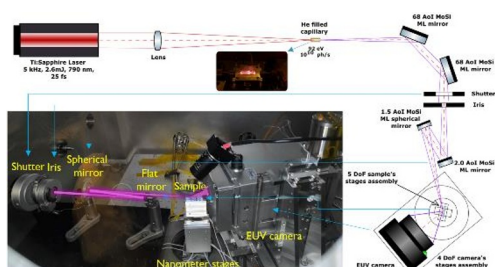


Fig. 1. Table-top HHG EUV scatterometry experimental setup in imec's AttoLab.

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Roughness characterization was performed on a Ru thin film generated by ion beam deposition (IBD). Direct detection of the scattered light was achieved by utilizing a synthetic aperture and high-dynamic-range (HDR) detection scheme. Additionally, noise suppression techniques were applied to improve signal-to-noise ratio (see Fig. 2). The experimentally obtained spatial intensity distribution of the EUV light was deconvoluted with 4 Gaussians in order to extract the intensity and width of the scatter. From these parameters roughness and correlation length values were derived. The comparison with atomic force microscopy (AFM) measurements performed on the same sample is presented in Table 1.

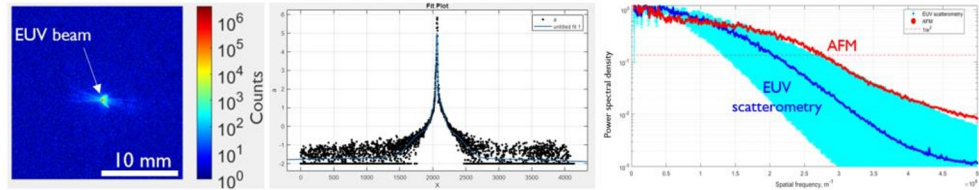


Fig. 2. HDR image of reflected EUV beam (left), intensity distribution along vertical axis in log scale (center), and power spectral density curves (right)

Table 1. Sample parameters derived from simulation

	Roughness (RMS Rq), nm	Correlation length (T), nm
EUV scatterometry	0.52 [0.47-0.72]	4.9 [3.9-7.3]
AFM	0.60	3.6

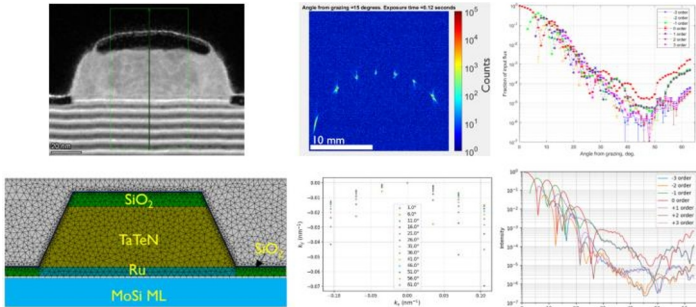


Fig. 3. Patterned nano-stack structural parameters scatterometry measurement: high-angle annular dark field TEM image of the sample (top left), an example of experimental diffraction pattern (top center), distributions of diffraction orders intensities as a function of angle from grazing (top right), meshed sample model in JCMSuite (bottom left), simulated spatial (bottom center) and intensity (bottom right) distributions of diffraction orders

Structural parameters (critical dimension, pitch, height, angles, layer and interlayer diffusion thicknesses) of a patterned nano-stack multilayer mirror with lines of TaTeN absorber on top (Fig. 3) were used as variables in the model utilized to generate synthetic diffraction patterns with JCMSuite software [2].

The values of these parameters were derived by fitting the simulated diffraction patterns to the experimental ones. We present promising preliminary results that demonstrate sub-nanometer precision and are in good agreement with AFM (for roughness) and transmission electron microscope (for structure) measurements.

References

1. L. M. Lohr, et al, "Nanoscale grating characterization using EUV scatterometry and soft x-ray scattering with plasma and synchrotron radiation," Appl Opt **62**(1), 117 (2023).
2. "JCMSuite," <https://jcmwave.com/jcmsuite>.