

EUV Metrology at PTB for the European EUV Lithography Program

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The development of EUV lithography (EUVL) is critically based on the availability of a suitable metrology. The industrial demand for high accuracy characterization of EUV components is met at the laboratory of the Physikalisch-Technische Bundesanstalt (PTB) operated at the electron storage ring BESSY II. Using stable and well characterized synchrotron radiation, PTB performs the characterization of optical components (reflectometry), the calibration and characterization of EUV radiation detectors and sources and lifetime characterization of optics and sensors.

The EUV reflectometry facility is capable of at-wavelength metrology of full-size EUVL optics with a maximum weight of 50 kg. 5-steradian collector mirrors for LPP EUV sources with an outer diameter of 670 mm have recently been measured (Fig. 1). To meet the increasing demands of metrology for future EUV technology development, the measurement capabilities are permanently upgraded. For peak reflectance, an uncertainty of 0.1 % is achieved with a reproducibility of 0.05 %¹. The long-term reproducibility of the center wavelength is 1 pm, with a short-term repeatability below 0.1 pm. Its uncertainty of 2 pm is given by the reference wavelength, the Kr 3d5/2-5p resonance. These measurement services provided a basis for the coating development within the European EUCLIDES and MEDEA projects². The measurement of the photocurrent emitted from the mirror surface was developed as a versatile tool for the determination of the phase of the reflected radiation relative to the mirror surface³. At a dedicated beamline, lifetime tests of optics and detectors under EUV irradiation are examined in different residual gas atmospheres, which can be altered over a wide parameter space⁴.

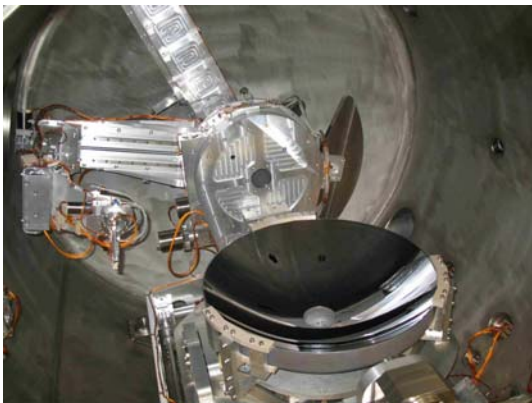


Figure 1 5-sr EUV collector mirror for a Cymer Inc. LPP EUV source coated by Fraunhofer IOF mounted in the EUV reflectometer at PTB.

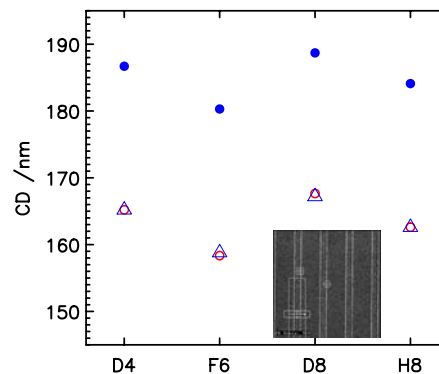


Figure 2 CD of absorber lines at several test fields of an EUV photomask: Open circles are scatterometry and closed circles CD-SEM, the triangles are CD-SEM offset by -21.4 nm. Inset: CD-SEM image.

Based on a cryogenic radiometer as primary reference detector, PTB calibrates EUV detectors for source characterization like multilayer-reflection band-pass monitors as well as spectrographs or other diagnostic devices. EUV scatterometry is being developed as a tool for the characterization of structured surfaces like those on EUV photomasks⁵ (Fig. 2).

Representative results from PTB's widespread cooperations in the field of EUV technology will be discussed.

¹ F. Scholze, J. Tuemmler, G. Ulm, *Metrologia* 40, S224-S228 (2003)

² H. Meiling, V. Banine, P. Kuerz, N. Harned, *Proc. SPIE* 5374, 31 - 42 (2004)

³ Robbert van de Kruijs, E. Zoethout, E. Louis, A. Yakshin, I. Nedelcu, F. Bijkerk, S. Muellender, H. Enkisch, G. Sipos, M. Wedowski, M. Weiss, "Mo/Si multilayers for EUVL", *PXRMS 2004: 7th International Conference on the Physics of X-Ray Multilayer Structures*, Sapporo 2004

⁴ R. Klein, A. Gottwald, F. Scholze, R. Thornagel, J. Tuemmler, G. Ulm, M. Wedowski, F. Stietz, B. Mertens, N. Koster, and J. V. Elp, *Proc. SPIE* 4506, 105-112 (2001)

⁵ F. Scholze and C. Laubis, *EMLC 2008*, 374-382, VDE VERLAG GMBH Berlin und Offenbach (2008)