Evaluation of magnetron sputter deposition as multilayer coating technology for EUVL projection optics

Stefan Braun[1]*, Thomas Foltyn[1], Peter Kürz[2], Andreas Leson[1], Maik Menzel[1], Stephan Müllender[2], Stefan Schädlich[1], Thomas Westerwalbesloh[2]

[1] IWS Dresden, Fraunhofer-Institut für Werkstoff- und Strahltechnik, Winterbergstr. 28, D-01277 Dresden, Germany
* E-mail: stefan.braun@iws.fraunhofer.de, phone: +49.351.2583.432, fax: +49.351.2583.314
[2] Carl Zeiss SMT AG, Carl-Zeiss-Str. 22, 73447 Oberkochen, Germany

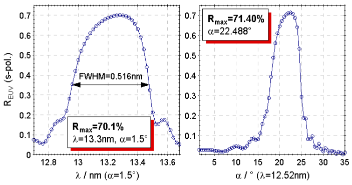
Introduction

Magnetron sputter deposition (MSD) is an effective technology for the coating of EUV reflection multilayers with high reflectances of R ~ 70 %. Typically a full stack can be obtained in 1-2 hours, depending on the mirror size. Despite these positive aspects, several questions remained open concerning the suitability of MSD for the coating of EUVL projection optics in a production environment:

1. Is it possible to get λ-matchings of > 99.9 % for different substrate geometries? --> Answer: **YES!**

2. Does the precision of the lateral period thickness distributions on curved optics meet the specifications? --> Answer: **YES!**

3. Is it possible to reduce or to effectively compensate the compressive stress of the multilayers? --> Answer: **YES!**



EUV reflectance of Mo/Si multilayers with carbon barrier layers made by MSD (substrate: silicon wafer, capping layer: silicon)

Reproducibility

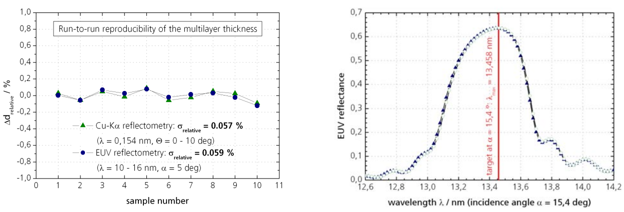
MSD without in-situ thickness control
=> Extremely high reproducibility of the coating process necessary

Parameters influencing the layer thickness:
- geometric arrangement (e. g. target-substrate distance)
- discharge power of the magnetrons
- base pressure of the chamber
- pressure of the sputtering gas
- substrate movement

Optimization and stabilization of all relevant parameters

=> Run-to-run thickness reproducibility of σ_r < 0.06%

Result: λ-matching > 99.9 %



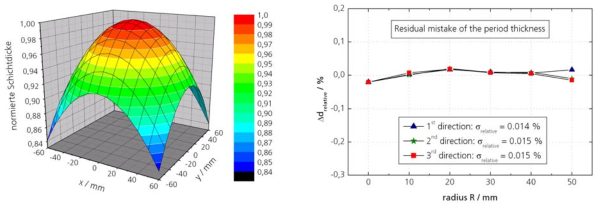
Left hand side: Relative thickness differences of 10 coatings made under the same deposition conditions
Right hand side: EUV reflectance spectra of two coated EUV mirrors showing the λ-matching of > 99.9 %

Precision of the layer thickness gradients

Substrates:
- convex or concave aspherically curved surfaces
- curvature radii down to 300 mm

Thickness profiles:
- nonlinear gradients with lowest possible deviations to the theory
- typically, gradients with rotational symmetry have to be coated, but arbitrary thickness distributions are also possible with MSD

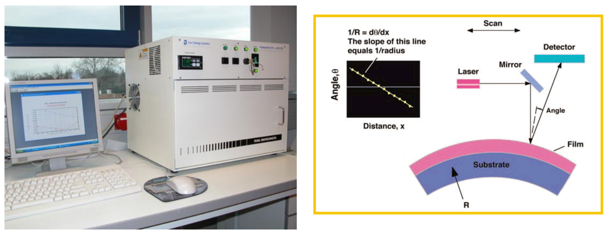
Result: Residual thickness errors $\sigma_{relative}$ < 0.02 %



Left hand side: Typical relative thickness profile of Mo/Si multilayers on convex or concave curved substrates
Right hand side: Relative thickness differences between the EUV measurements and the theoretical values.

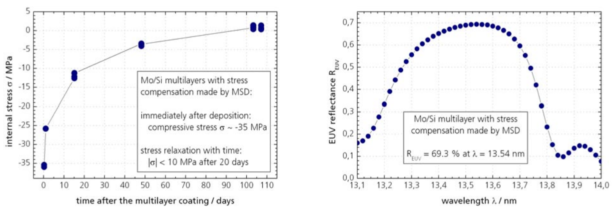
Internal stress

The internal stress of EUV multilayers can be determined by measuring the wafer curvature before and after deposition of the coating and applying Stoney's equation.



Development of low-stress MSD coatings
Result: Internal stress σ ~ -200 MPa with R_{EUV} > 69.5 %

Development of stress compensation layers
Result: Stress-free multilayers with R_{EUV} > 69 %



EUV reflection coatings with stress compensation made by MSD
Left hand side: Stress relaxation with time
Right hand side: EUV reflectance

Fraunhofer Institut Werkstoff- und Strahltechnik