High-temperature multilayer coating of source collector mirror

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Introduction

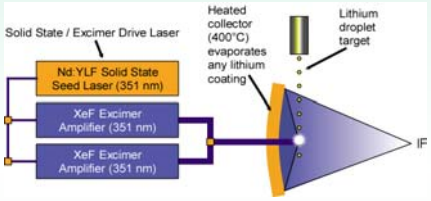
The EUV source output power and lifetime including collector optics lifetime have been identified as key issues for EUV lithography. In order to meet these requirements a heated collector concept was realized for the first time.

An ellipsoidal collector substrate with an outer diameter of 320 mm was coated with a laterally graded high-temperature multilayer. The interface-engineered Mo/Si multilayer coating was optimized in terms of high peak reflectivity at 13.5 nm and a working temperature of 400 °C. Barrier layers were introduced on both interfaces to block thermally induced interdiffusion processes of molybdenum and silicon and to provide long-term optical stability of the multilayer at elevated temperatures.

An average normal-incidence reflectance of about 41 % at 13.5 nm was measured after heating. After initial annealing at 400 °C for one hour no degradation of the optical properties of these multilayer coatings occurred during both long-term heating tests for up to 100 hours and multiple annealing cycles.

The successful realization of this high-temperature sub-aperture collector mirror represents a major step towards the implementation of the heated collector concept and illustrates the great potential of high-temperature EUV multilayer coatings.

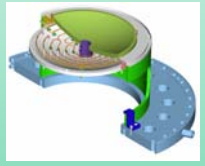
Cymer's HVM EUV source concept



Collector lifetime challenges

- Thermal stability of multilayer
- EUV induced carbon growth and oxidation
- Sputtering of multilayers
- Source material buildup on collector
- Source material diffusion into multilayer
- Deposition of source material contaminations
- Deposition of material sputtered from source hardware

High-temperature collector mirror concept



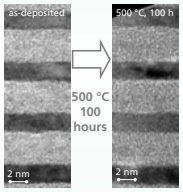
Collector mounting and heating

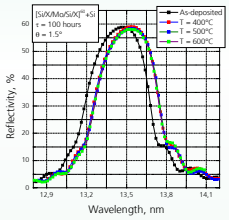
First 320 mm collector in optical test setup

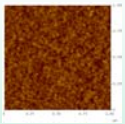
Technical setup: NESSY

Technology	dc magnetron sputtering
Conception	sputter down, circular substrate motion
Substrate size	up to 650 mm diameter
Substrate stations	1 x Ø 650 mm / 2 x Ø 450 mm / 3 x Ø 300 mm
Sputter sources	4 sputter sources, 600 mm x 125 mm
Thickness homogeneity	± 0.1 % on 150 mm, ± 0.2 % on 300 mm

High-temperature Mo/X/Si/X multilayer

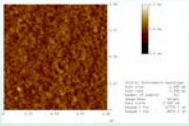






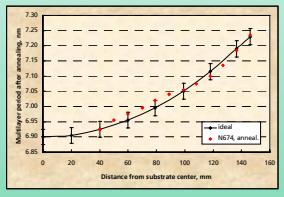
AFM of Mo/X/Si/ X, as-deposited, rms-roughness: σ = 0.12 nm

500 °C
100 hours



AFM of Mo/X/Si/X after 500 °C / 100 h, rms-roughness: σ = 0.14 nm

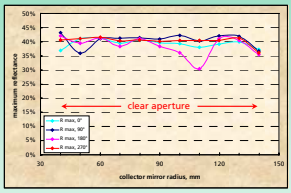
Lateral multilayer gradient optimization



Multilayer gradient, ideal and experimental data.

Error bar: Δd/d = 0.37 % corresponding to: λ = (13.50 ± 0.05) nm.

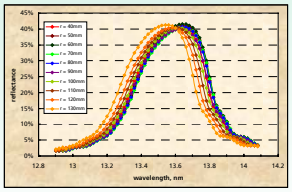
Reflectance of high-temperature collector



Maximum reflectance of high-temperature collector mirror.

Measurements: Physikalisch-Technische Bundesanstalt Berlin

Reflectance of high-temperature collector



Measurement of reflectance along a line within clear aperture of collector mirror.

Measurements: Physikalisch-Technische Bundesanstalt Berlin

Optical properties of high-temperature collector

- Average reflectance of collector mirror: R_{av} = 41 %,
- Average reflectance of silicon test sample: R_{av} = 54 %,
- Center wavelength of collector mirror: λ = (13.5 ± 0.1) nm,
- FWHM > 0.45 nm.

Summary

- Proof of high-temperature collector mirror concept,
- First high-temperature multilayer coating of LPP source collector mirror realized,
- Mirror diameter: 320 mm - largest multilayer collector mirror coated to date,
- Thermal stability of high-temperature Mo/X/Si/X multilayer up to 600 °C,
- First EUV light reflected at Cymer's test stand.

Acknowledgements

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