Dual Ion Beam Sputter Deposition for EUVL Optics

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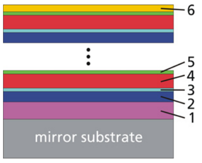
Introduction

Ion beam sputter deposition (IBSD) is considered to be the appropriate technology for the coating of Mo/Si multilayers on mask substrates.
However IBSD not only produces reflection coatings with low defects. IBSD also offers the advantage to coat substrates not having the lowest possible level of surface micro-roughness with high reflectance multilayers [1]. This capability helps to reduce the manufacturing costs of mirror substrates and is specially interesting for optics that have to be replaced regularly.
Another beneficial aspect concerns the possibility to use reactive sputter processes. Due to the spatially separated target and substrate regions and the possibility to use the assist ion source, an excellent process control is given. The possibility to deposit dielectric films is important for the development of new capping layer materials.

In IWS Dresden a new IBSD machine IONSYS1600 from Roth & Rau AG has been installed. The machine is equipped with two linear ion sources to ensure the scalability of the technology for substrates with diameters of even larger than 450 mm.
In order to improve the flexibility of the multilayer design, 6 different target materials are available.

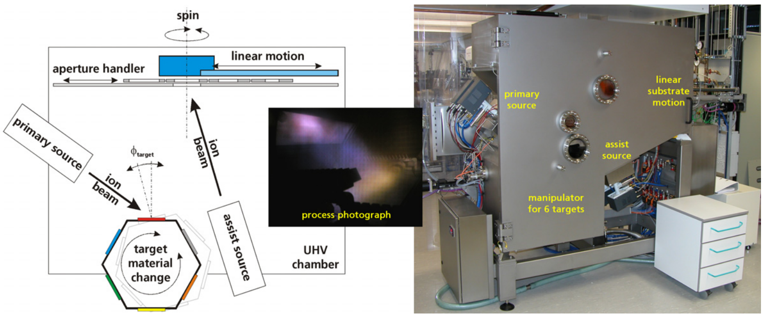
Scheme of the general EUV reflection coating design



1 – smoothing or adhesion layer
2 – molybdenum
3 – barrier layer material 1
4 – silicon
5 – barrier layer material 2
6 – capping layer

[1] E. Spiller, S. L. Baker, P. B. Mirkarimi, V. Sperry, E. M. Gullikson, D. G. Stearns: *High-performance Mo/Si multilayer coatings for extreme-ultraviolet lithography by ion-beam deposition*, Applied Optics 42 (2003) 4049-58

Multilayer fabrication



Left hand side: Schematic view of the arrangement for the large-area IBSD. Two linear electron cyclotron resonance ion sources are used for primary sputtering and layer growth assistance or etching.

Right hand side: Photograph of the IBSD machine. Substrates with diameters of up to 200 mm can be handled via the load-lock, larger substrates with lengths of up to 500 mm or diameters of up to 450 mm have to be introduced via the front door.

Technical data:

Vacuum:
- process chamber: $p < 2 \cdot 10^{-8}$ mbar
- load lock: $p < 5 \cdot 10^{-7}$ mbar

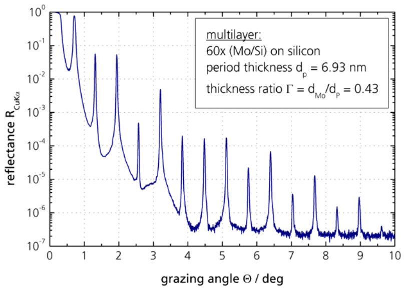
Substrates:
- circular up to ∅ = 200 mm via load-lock and up to ∅ = 450 mm via front door
- rectangular up to L = 500 mm

Targets:
- number of different materials: 6
- size: 400 x 200 mm²

Ion beam sources:
- primary for sputtering
- secondary for assisting and etching
- excitation principle: ECR = electron cyclotron resonance
- grid size: 400 x 100 mm²
- ion energies: E = 50 - 2000 eV

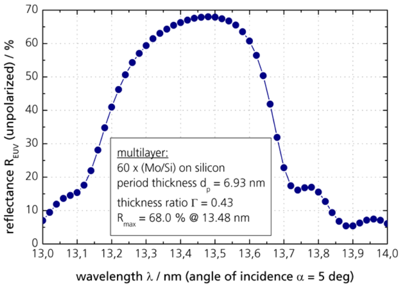
Experimental results

Cu-Kα reflectometry



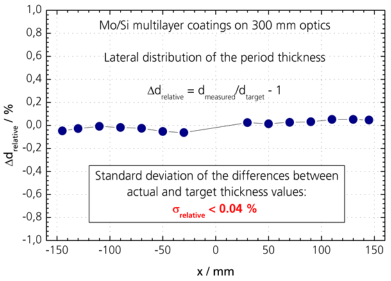
Result: Excellent stack regularity
Result: Low layer roughness

EUV reflectance



Mo/Si multilayers without barriers
Result: $R_{EUV} = 68\ \%$ at $\lambda = 13.5$ nm

Thickness uniformity



Outstanding uniformities over large areas
Result: $\sigma_{relative} < 0.04\ \%$ over 300 mm

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