Multilayer fabrication

Nanometer multilayers with single layer thicknesses in the range between 0.5 nm and 20 nm are synthesized using UHV thin film deposition techniques like sputtering or pulse laser deposition (PLD).

For EUV multilayers, the magnetron sputter deposition (MSD) is applied to produce multilayers with outstanding specifications:

- layer thickness uniformity: \( \geq 99.9 \% \)
- run-to-run reproducibility: 99.8 % - 99.9 %
- layer microroughness (rms): 0.15 nm - 0.25 nm
- EUV reflectance: R = 69.5 % - 70.1 % (\( \alpha = 13.5 \) nm, \( \lambda = 1.5 \) \( \lambda \))

In order to fulfill the BRAGG condition for multilayers, precise thickness gradients have to be deposited on curved substrates (spherical, aspherical, convex, concave). With MSD, we apply two techniques to fabricate such gradients:

- one-dim. gradients: suitable velocity profiles of the substrate motion
- two-dim. gradients: application of transmission masks

Typical precision of layer thickness gradients obtained using transmission masks. For one-dimensional gradients deposited with special velocity profiles of the substrate motion the precision is typically by a factor of 2 better.

Barrier layers in Mo/Si multilayers

EUV reflective coatings consist of MoSi multilayers with single layer thicknesses of \( \sim 3 \) nm (Mo) and \( \sim 4 \) nm (Si). On the interfaces between two adjacent layers interdiffusion of both materials occurs, which reduces the optical contrast and the EUV reflectance. In order to diminish the interface diffusion we developed tiny barrier layers. The modified multilayer system with up to four layers per period results in significant improvements compared to the standard system:

- higher EUV reflectance
- improved thermal stability
- improved long-term stability

Internal stress of EUV multilayer mirrors

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.

EUV reflectometry

The development of EUV reflective coatings requires the direct feedback of the optical behavior (lateral information about EUV peak positions, reflectance, FWHM). Therefore, IWS together with a number of other partners (Carl Zeiss, PTB, Bestec, MBI, AIS) has built a laboratory EUV reflectometer consisting of a laser pulse plasma source, a grid monochromator and a large goniometer chamber with following characteristics:

- wavelength range: 10 nm \( \leq \lambda \leq 16 \) nm
- maximum sample size: \( \Theta = 500 \) mm, thickness = 200 mm
- maximum sample weight: \( m = 30 \) kg
- reproducibility:
  - reflectance R: 99.8 %
  - peak position (wavelength \( \lambda \)): 99.98 %

By combining the options 1.-3. it is possible to obtain stress-free EUV multilayers with reflectances \( R > 69.5 \% \). However, it has to be considered that the annealing results in a period thickness contraction connected with a corresponding EUV peak shift.

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Preparation and characterization of multilayers for EUV applications

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