Ion beam sputtering of DLC/Si multilayer mirrors

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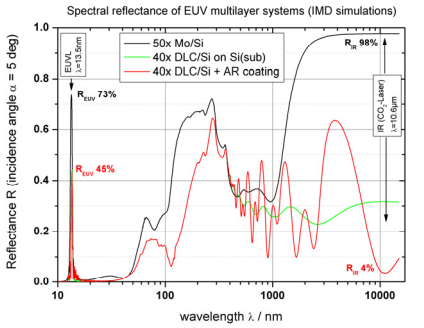
Motivation

Conventional EUV mirrors are coated with Mo/Si multilayers with an EUV reflectance of up to 70%. In the infrared (IR) range the reflectance is typically above 80%. In EUV tools powered by a CO_2 LPP source, this high IR reflectance allows scattered laser radiation to propagate into the tool, where it results in a significant heat load on the system. The suppression of this unwanted IR radiation can be done by spectral purity filters such as thin foils, transparent grids or reflective gratings. All spectral filters are characterized by a loss of EUV intensity and often limited in heat load by cooling requirements.

We present a new type of EUV multilayer mirror that has near-zero reflectance at 10.6 µm. This is achieved by the development of a DLC/Si multilayer interference coating that is substantially transparent to infrared (DLC - diamond-like carbon). The multilayer coating is subsequently incorporated as the top part of an antireflection coating designed to minimize reflection at 10.6 µm wavelength.

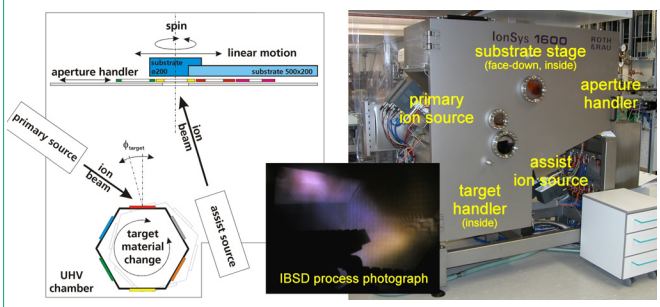


IMD[1] simulations of the spectral reflectance of EUV multilayer systems

[1]: D. L. Windt, "IMD - Software for modeling the optical properties of multilayer films," Comput. Phys. **12**, 360-370 (1998)

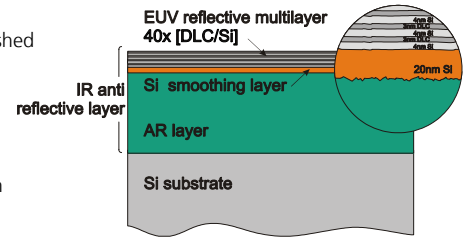
Multilayer Fabrication

- Deposition of the Si smoothing layer and the DLC/Si multilayer by Ion Beam Sputter Deposition (IBSD) in a dual source arrangement

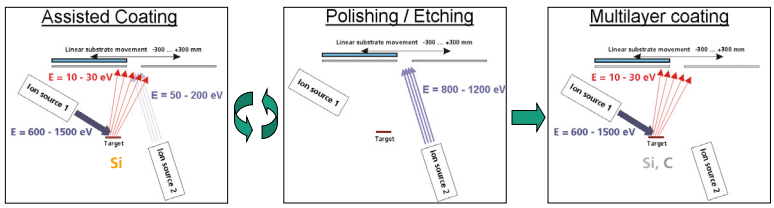


Principle of the large-area IBSD (left) and front view of the deposition chamber (right) at IWS Dresden. Substrates with dimension up to 500x200 mm² can be handled via a load-lock.

- Pre-coating of double side polished Si-wafers with **IR-AR layers** (industrial standard process)
- Deposition of the **Si smoothing layer** by alternating (assisted) deposition and etching steps
- Deposition of the **DLC/Si multilayer**



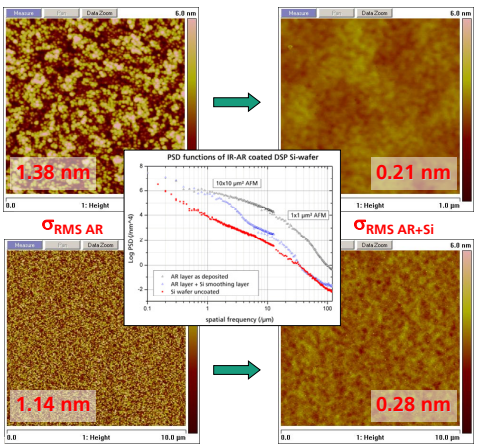
Schematic design of the infrared-transparent EUV mirror



Experimental Results

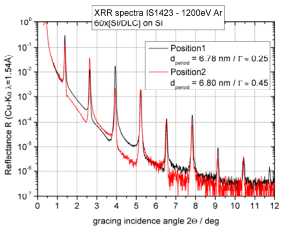
- Smoothing of the IR-AR coating

AFM characterization of the **Si smoothing layer**



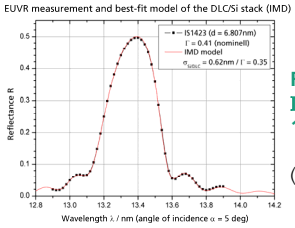
AFM images and PSD functions of the AR coating before and after smoothing (right with additional 20 nm Si)

- Optimization of the DLC/Si multilayer stack



Variation of Γ and deposition conditions (e.g. ion energy)

XRR characterization of a Γ graded 60x [DLC/Si] without IR-AR pre-coating

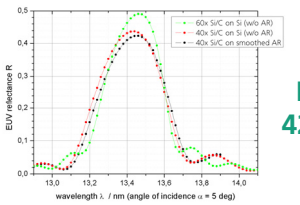


$R_{EUV} \approx 50\%$
$\Gamma \approx 0.4$
1200eV Argon

(60x [DLC/Si] on Si)

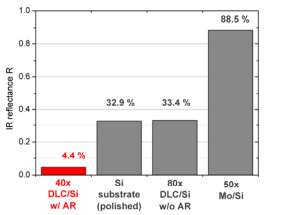
EUVR measurement and IMD simulation of a 60x [Si/DLC] multilayer

- EUV / IR characterization of a prototype mirror



R_{EUV} 42.5%

EUVR spectra of Si/DLC ML deposited on smoothed IR-AR pre-coatings and on pure (superpolished) Si samples (measured at PTB Berlin)



R_{IR} 4.4%

Measured infrared reflectance (@10.6 µm) at normal incidence of the DLC/Si mirror with IR-AR design (red), without AR layer and for a conventional Mo/Si mirror (grey)

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