DLC/Si multilayer mirrors with IR antireflective properties at 10.6 µm

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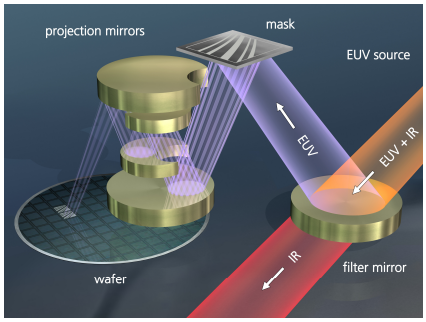
Motivation

Current laser produced plasma (LPP) EUV sources for high volume manufacturing are operated with powerful CO_2 lasers using tin droplets as targets for the emission. In addition to the 10.6 µm wavelength from the laser and the desired EUV wavelength of 13.5 nm, a large amount of non-EUV, known as out-of-band radiation, is created. Spectral filtering and transportation of this unwanted energy out of the EUV optical system is necessary to avoid any deterioration of the optics and resist exposure. Various spectral filter designs have been proposed, including thin foils, grids and reflective gratings. All of them have specific pros and cons concerning efficiency, persistency, manufacturing requirements and costs.

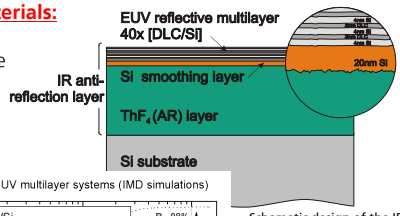
We developed a **new type of spectral EUV filter** based on **EUV reflective** and **IR transparent multilayer coatings**, that can be applied directly to one of the first reflecting elements of the EUV beam path, e.g. the collector mirror.



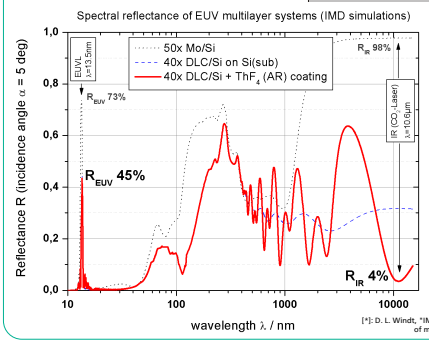
Mirror Layout and Spectral Design

IR transparent materials:

- DLC (diamond-like carbon)
- Si
- ThF_4



Schematic design of the IR-transparent EUV mirror

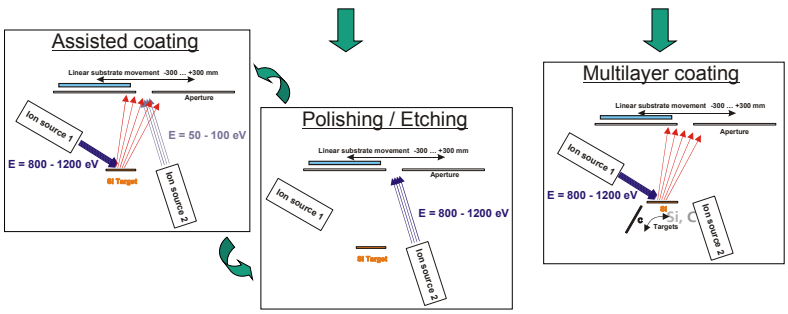


IMD[*] simulation of the spectral response if the proposed EUV filter coating in comparison to other ML systems

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

Multilayer Fabrication

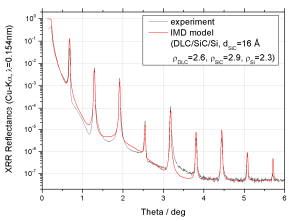
- Pre-coating of an **IR antireflection layer** (ThF_4) on an adequate substrate (e. g. silicon)
- Deposition of the **Si smoothing layer** by alternating (assisted) deposition and etching steps
- Deposition of the **DLC/Si multilayer**



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

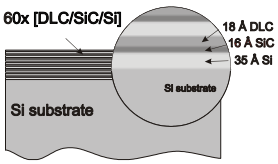
Results and Characterization

DLC/Si multilayer structure

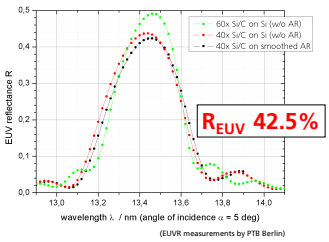


Top: Simulated (red) and measured (black) XRR spectra of a 60x[DLC/Si] multilayer on a super-polished Si substrate.

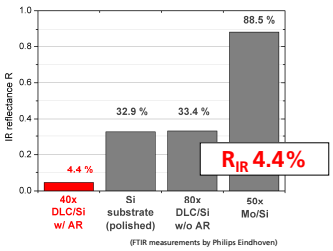
Bottom: Best-fit **3-layer model DLC/SiC/Si:**



EUV and IR optical behavior

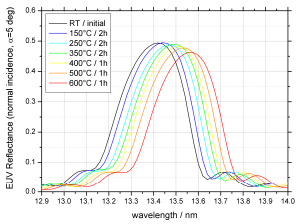


(EUVR measurements by PTB Berlin)



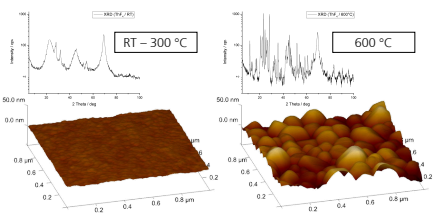
(FTIR measurements by Philips Eindhoven)

Thermal stability



Mechanisms: - Relaxation of DLC layer (~ 0.2% per 100 °C)
- Thickness growth of SiC layer (> 350 °C)

Re-crystallization of ThF_4 AR layer > 300 °C



AFM images of ThF_4 surface (bottom) and corresponding XRD pattern (top)

Chemical stability

Cleaning behavior under H* radicals:

H* etching time [sec]	Sn thickness (XRF) [nm]	EUV ΔR_{MAX} [%]	Peak-shift [%]
Before Sn dep.	-	(41.6)	-
0	6.1	-25.9	-0.1
10	4.6	-6.0	0.0
20	<0.02	-0.2	0.0
50	<0.02	-0.3	-0.1
300	<0.02	-1.2	+0.2

-> almost complete recovery of the EUVR performance

-> still after 300 sec H* etching all 40 periods are detectable (high res. XRR)

-> loss of R_{MAX} due to roughening / degradation of DLC top-layer ?

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