Efficient and stable Al-based multilayer reflecting coatings for SR, FEL and astronomy

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Multilayer optics for extreme ultraviolet (EUV) range

Applications:

- Synchrotron Radiation (SR)
- Free Electron Lasers (FEL)
- High Harmonics Generation (HHG) sources
- Astronomy - (EUV telescopes of space missions)

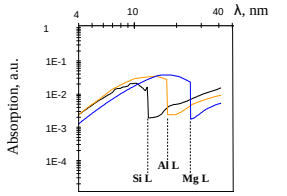
Performance required:

- High peak reflectance at one or more wavelengths
- Efficient attenuation of unwanted emissions
- Appropriate bandwidth
- Long-term stability of reflective multilayer coatings

To be launched in 2017

Selection of materials for EUV multilayers coatings

Choice of low-absorbing materials in the EUV range



> 12.4 nm → Si > 17 nm → Al > 25 nm → Mg

High reflectance multilayers (R > 50 %) at near-normal incidence

1985	Mo/Si	13 nm	Barbee et al.
1995	Mo/Be	11 nm	Skulina et al.
1998	Sc/Si	46 nm	Uspenskii et al.
2009	Mg/Sc/SiC	28 nm	Aquila et al.
2010	Al/Mo/SiC	17 nm	Meltchakov et al.
2013	La/B_4C/C	6.8 nm	Chkhalo et al.

Problem of Al-based MLs high interfacial roughness

⬇

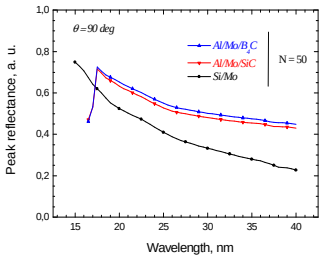
low performance and long-term stability

Solutions:

❖ optimization of Al deposition (Ar pressure, dc/rf power, use of targets doped with Si, Cu…)

❖ use more than two materials in the multilayer structure design

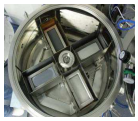
Peak theoretical EUV reflectance of Al-based tri-component multilayers



Deposition and characterization techniques

MAGNETRON SPUTTERING SYSTEM

Uniformity: 0.5% on Ø190mm



2 *rf* and 2 *dc* magnetrons

4 targets: 80×200 mm²

Gas: Ar, Ar + O_2, Ar + N_2

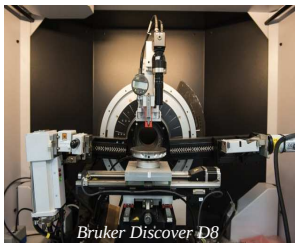
P = 0.1 ÷ 0.27 Pa

STRUCTURAL AND PHYSICO-CHEMICAL ANALYSIS :

- Grazing x-ray reflectometry at RT and upon heating
- Access to AFM, TEM, XES, RBS…

At-wavelength characterization:

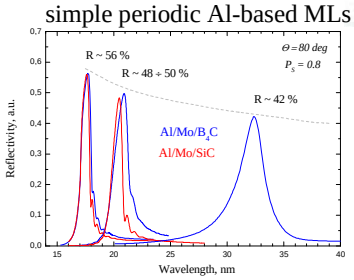
- EUV reflectometer: laser plasma source (4 – 50 nm)
- Measurements with SR: Elettra, BESSY/PTB, Soleil…



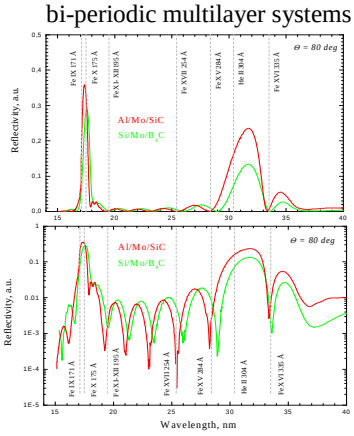
High reflectivity and stability of Al-based multilayer coatings

EUV reflectivity measurements (*Bear@Elettra*)

simple periodic Al-based MLs



bi-periodic multilayer systems

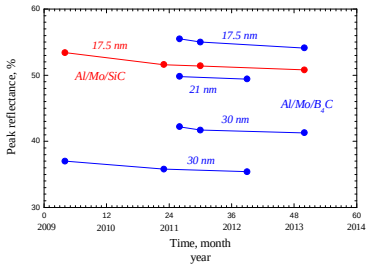


Improved efficiency of Al-based multilayers: Al/Mo/SiC vs Si/Mo/B_4C

(dashed lines are intense emissions in the solar EUV spectrum)

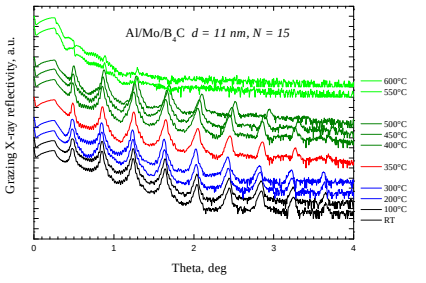
Long-term stability

- no changes of parameters of multilayers stored in air were detected during the period of observation (> 4 years)
- EUV reflectance decreases slightly (2 to 5 % of initial value) soon after deposition due to formation of surface oxide layer
- if capping layer (SiC or B_4C) is thick enough (~ 3 nm), then peak reflectance is stable for several months (and even years)



Thermal stability

- periodic structure of multilayers is generally stable up to 500 °C
- samples annealed at 100 °C in air during several weeks do not manifest any significant changes of parameters apart of the surface oxidation
- multilayer parameters do not change upon heating to 300 °C (observed a slight increase in multilayer period ~ 0.07 nm due to thermal expansion)
- structural phase transition occurs between 300 and 500 °C, most likely in aluminum layers (the multilayer period is decreasing)
- periodic structure of samples heated to more than 500 °C is irreversibly lost



Summary

- ❑ Simple- and multi-channel Al-based multilayer reflecting coatings for EUV have been developed and characterized
- ❑ High theoretical and measured peak EUV reflectance is achieved with multilayers containing Al
- ❑ New multilayers have good temporal and thermal stability of structural and optical parameters

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