Highly reflective and stable aluminum-based multilayer mirrors for EUV range

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Multilayer optics for extreme ultraviolet range (EUV)

Performance required:

- high reflecting power at the working wavelength
- precise centering of the peak reflectance
- appropriate bandwidth
- stability (temporal, thermal, chemical, resistance to radiation flux)

Applications:

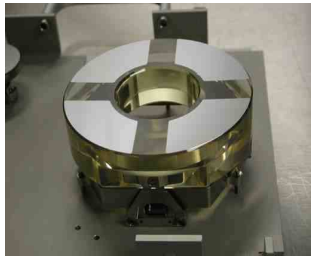
- solar imaging (EUV telescopes)
- optics for synchrotron radiation, FEL and HHG
- plasma diagnostics
- metrology, etc…

Highly reflective multilayers (R > 50 %)

- Mo/Si (1985, Barbee et al.)
- Mo/Be (1995, Skulina et al.)
- Sc/Si (1998, Uspenskii et al.)
- Mg/Sc/SiC (2009, Aquila et al.)
- Al/Mo/SiC (2010, Meltchakov et al.)

Many publications on periodic ML in the EUV range (from 10 to 50 nm) over the last 30 years

EUV telescope and coronagraph



Mirror primaire Ø105 mm pour télescope EUVI de la mission STEREO. Mo/Si multicouches (4 quadrants): λ = 17.1, 19.5, 28.4 et 30.4 nm

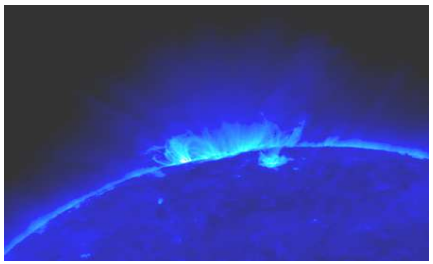
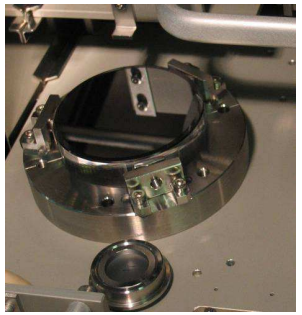
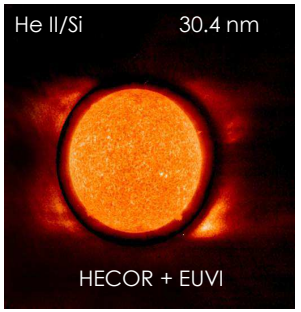


Image of the sun at 17,1 nm from STEREO mission (December 2006)





NRL Herschel rocket. HElium II CORonograph HECOR - Si/Mo/B_4C (Septembre 2009)

Deposition and characterization techniques

CEMOX (*Centrale d'élaboration et de Métrologie des Optiques X*)

Plassys MP800

Combined rf/dc magnetron sputtering system:

4 targets: 80×200 mm^2 (2 *rf* and 2 *dc*)

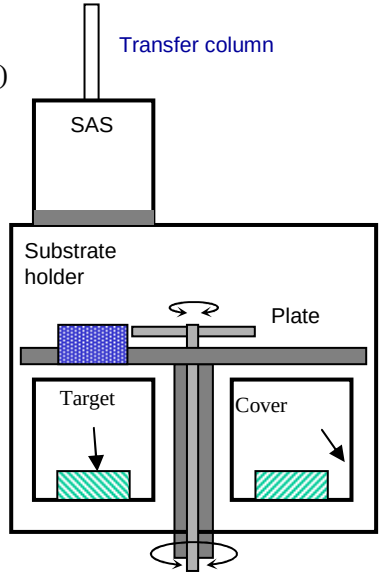
Gas: Ar, Ar + O_2, Ar + N_2

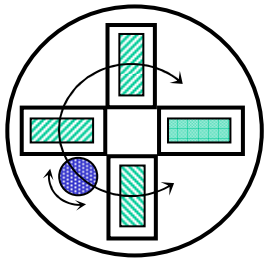
P = 0.1 ÷ 0.27 Pa

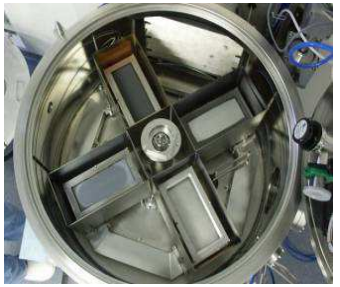
Coating uniformity:

0.5% on a wafer

of Ø 190 mm

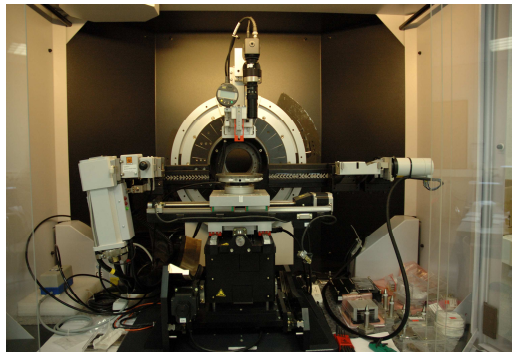






DISCOVER D8 (Bruker)

Grazing x-ray (GXR) reflectivity measurements



EUV reflectivity

- EUV reflectometer at CEMOX

  source: laser plasma (532 nm, 400 mJ, 5ns, 1 Hz),
  spectral range from 4 to 50 nm

- Synchrotron radiation facilities:

  Elettra, BESSY/PTB, ALS, Soleil...

Use of aluminum as a low absorbing materials for multilayers design in the range from 17 to 40 nm

Problem of Al-based multilayers:

high roughness (surface and **interfacial**) in the order of 2 nm

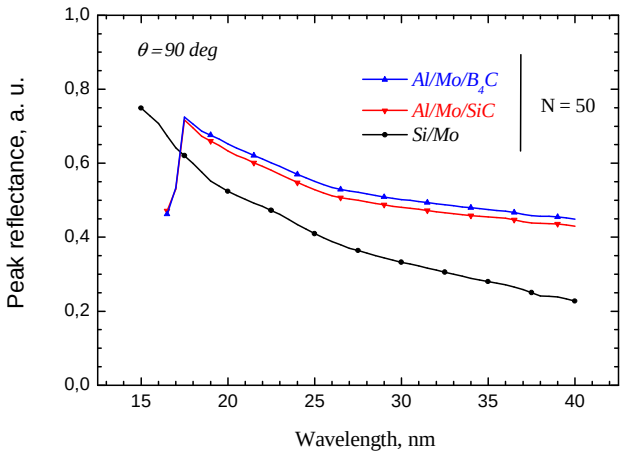
→ measured reflectance is low

$$R = R_0 \exp(-\frac{4\pi^2\sigma^2}{d^2})$$

Proposed solutions :

- use of Al target doped with other elements (Si, Cu, …) to interfere crystallization
- optimization of deposition parameters (working gas pressure, cathode power, etc…)
- introduction of barrier layers
- use of more than two materials in the multilayer structure design

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



POSTER SESSION

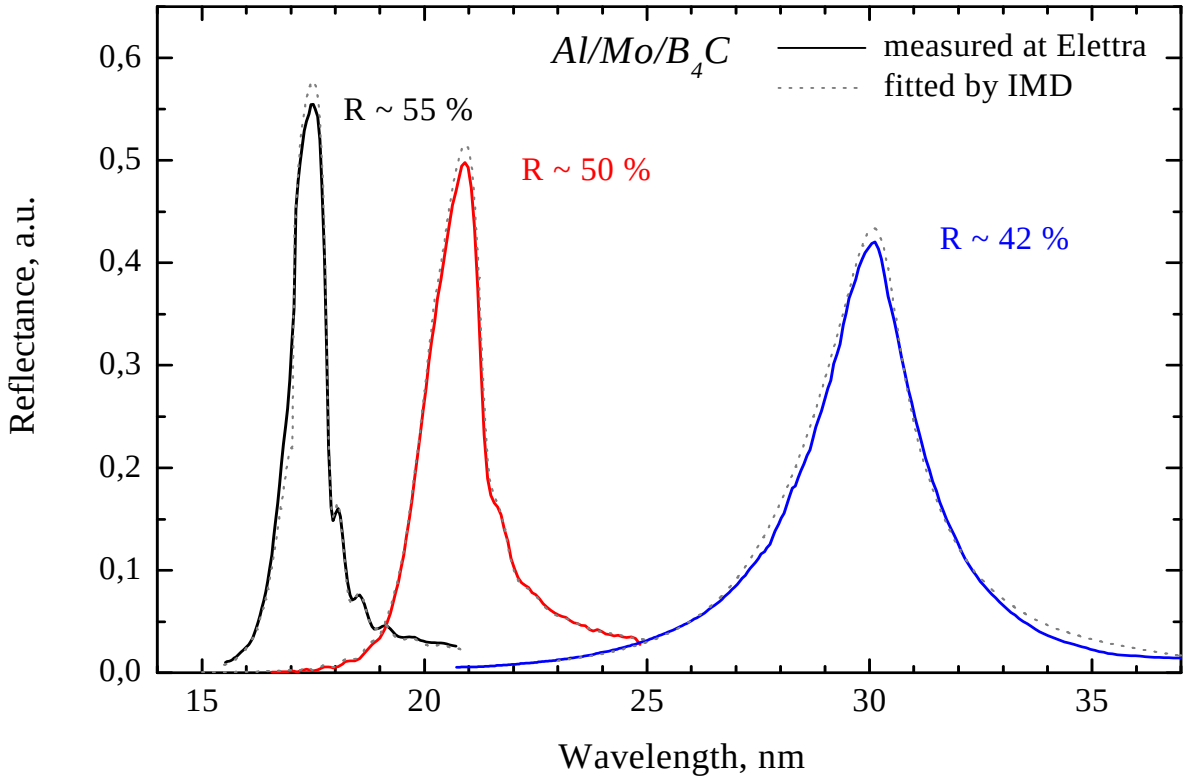
✓ EUV reflectivity of simple and bi-band multilayer mirrors

✓ Temporal stability

✓ Thermal stability

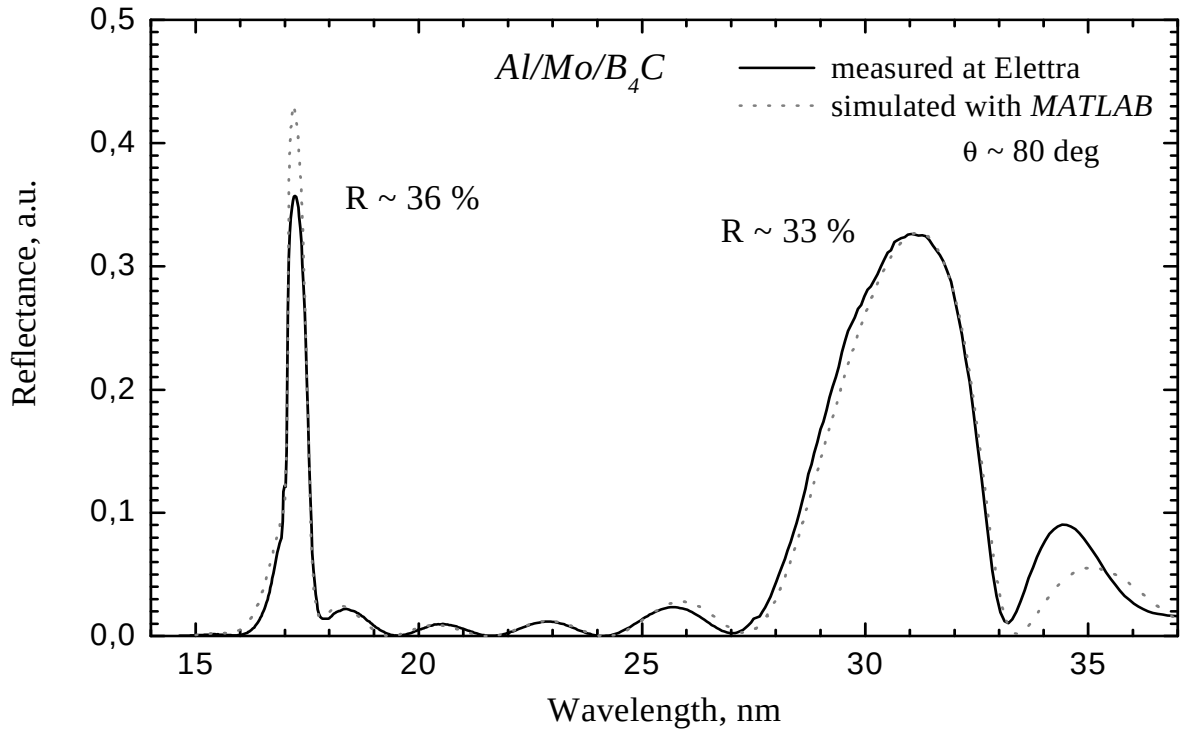
We invite you to see and discuss experimental results on EUV reflectivity and stability of tri-component Al-based MLs

EUV reflectivity of tri-component Al-based multilayers



Reflectivity in the range from 15 to 35 nm of simple band Al/Mo/B_4C multilayers measured at BEAR beamline of Elettra synchrotron

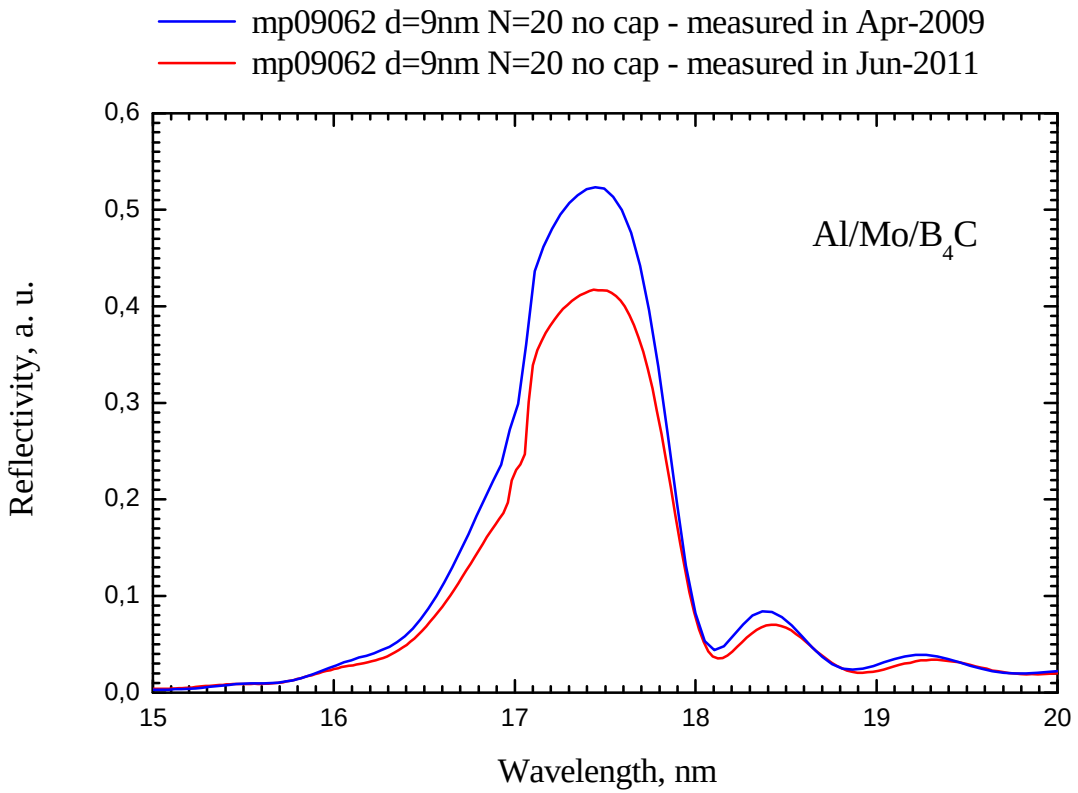
EUV reflectivity of tri-component Al-based multilayers



Reflectivity of bi-band Al/Mo/B_4C multilayer designed for 17 and 30 nm measured at BEAR beamline of Elettra synchrotron

Temporal stability of Al-based multilayers

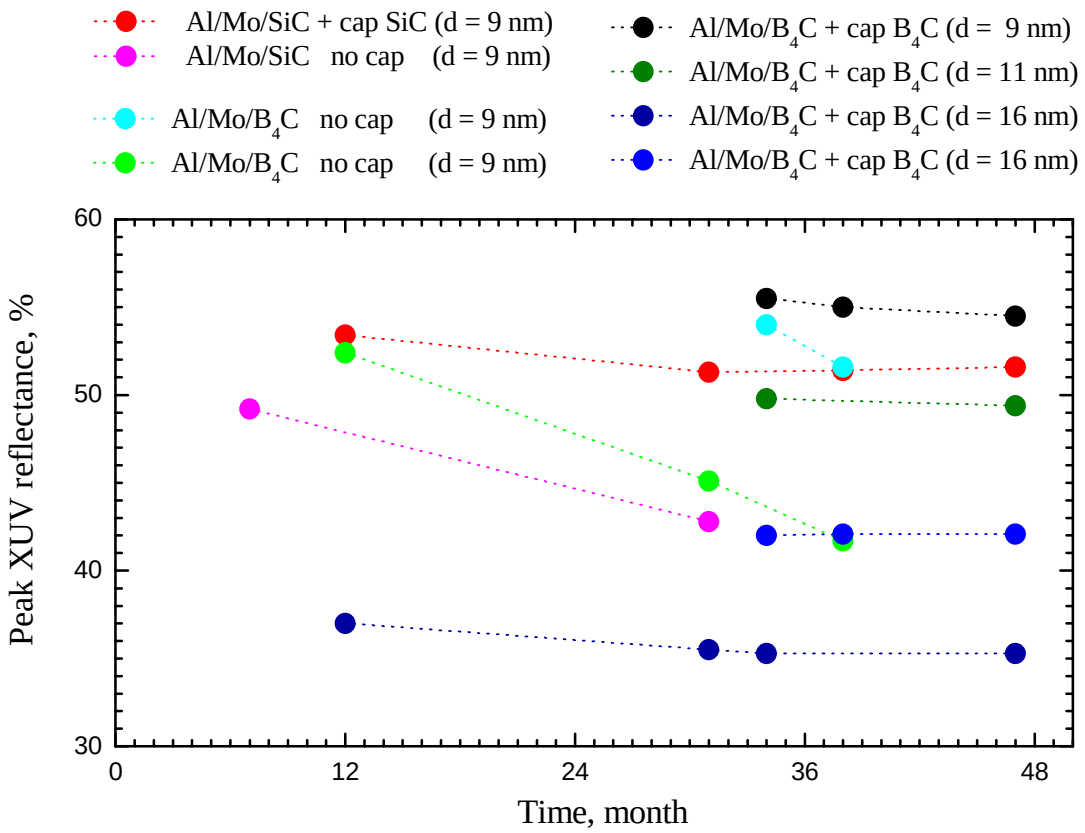
EUV reflectivity measurements of Al/Mo/B_4C multilayers



Significant reflectivity loss observed for the multilayer without protective layer stored during 2 years in air at room temperature

Temporal stability of Al-based multilayers

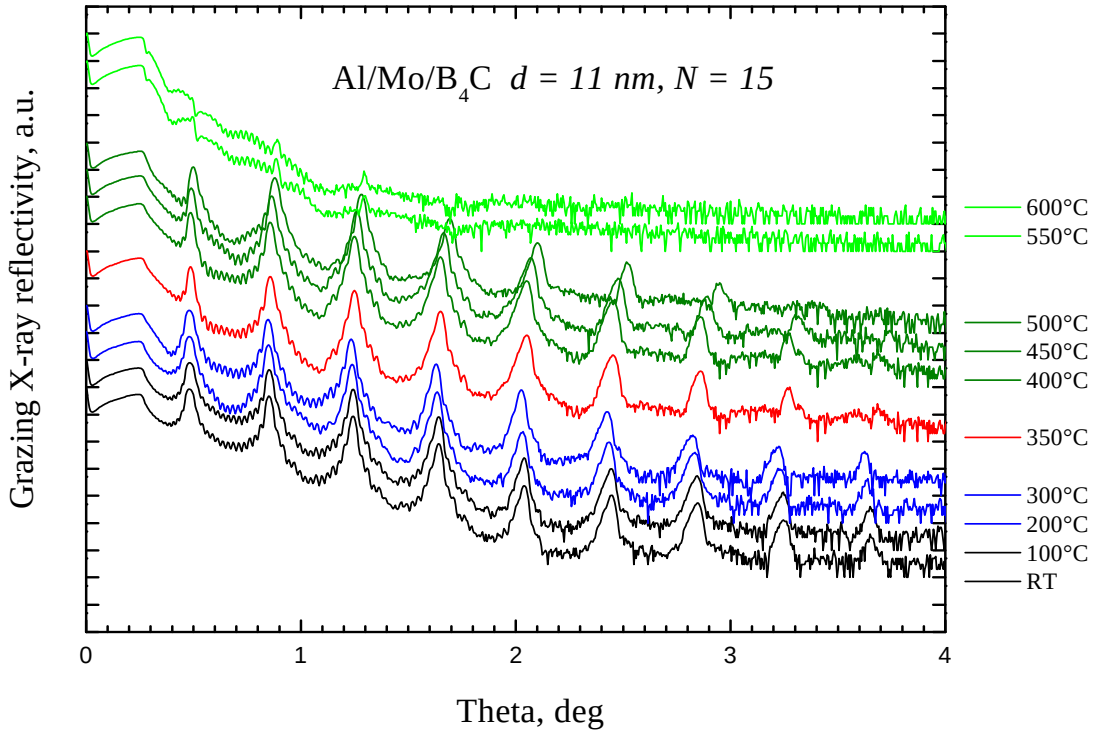
EUV peak reflectance of Al/Mo/B_4C multilayers stored in air



A good temporal stability of optical characteristics **o**f the multilayers with protective layer

Thermal stability of multilayers

GXR measurements of Al/Mo/B_4C multilayers undergone a thermal treatment in air



A good thermal stability of structural parameters **o**f the multilayers upon heating to 300°C

Summary

- New Al-based multilayer optics were realized and characterized with X-rays and EUV radiation
- High theoretical and measured peak EUV reflectance is obtained with tri-component multilayers containing aluminum
- New multilayers have good temporal and thermal stability of structural and optical characteristics
- Further studies are needed in order to assess the resistance of Al-based multilayers to high fluences of EUV radiation

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