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EUV multilayer coatings for the Atmospheric Imaging Assembly instrument aboard the Solar Dynamics Observatory

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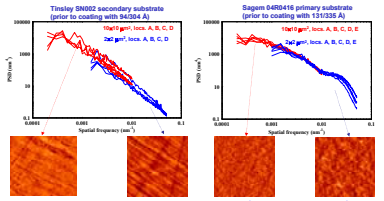
Introduction

- Multilayer coatings for the 7 EUV channels of the AIA have been developed[1] and completed successfully on all AIA flight mirrors. Mo/Si coatings (131, 171, 193.5, 211 Å) were deposited at Lawrence Livermore National Laboratory (LLNL). Mg/SiC (304, 335 Å) and Mo/Y (94 Å) coatings were deposited at Columbia University
- EUV reflectance of the 131 / 335 Å, 171 Å, 193.5 / 211 Å primary and secondary flight mirrors and the 94 / 304 Å secondary flight mirror was measured at beamline 6.3.2. of the Advanced Light Source (ALS) at LBNL
- EUV reflectance of the 94 / 304 Å primary and secondary flight mirrors was measured at beamline X24C of the National Synchrotron Light Source (NSLS) at Brookhaven National Lab. Preliminary EUV reflectance measurements of the 94, 304 and 335 Å coatings were performed with a laser plasma source reflectometer located at Columbia University
- Prior to multilayer coating, Atomic Force Microscopy (AFM) characterization and cleaning of all flight substrates was performed at LLNL

Multilayer-coated AIA flight mirror pair at 335 Å (Mg/SiC, left) and 131 Å (Mo/Si, right)

[1]R. Soufli, D. L. Windt, J. C. Robinson, E. A. Spiller, F. J. Dollar, A. L. Aquila, E. M. Gullikson, B. Kjornrattanawanich, J. F. Seely, L. Golub "Development and testing of EUV multilayer coatings for the atmospheric imaging assembly instrument aboard the Solar Dynamics Observatory", Proc. SPIE 5901, 59010M (2005).

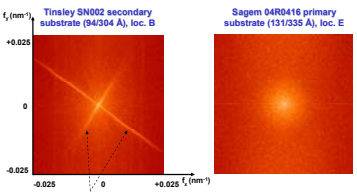
AFM data on flight substrates at LLNL determine surface roughness and reveal morphology associated with specific polishing techniques



$$\sigma^2 = \int_{f_1}^{f_2} 2\pi f S(f)\,df$$

where S(f) ≡ PSD (nm³), $f_1 = 10^{-3}$ nm⁻¹, $f_2 = 5\times10^{-2}$ nm⁻¹

2-dimensional power spectral density of 10x10 μm² AFM images obtained at LLNL on AIA flight substrates



Preferential direction of polishing marks

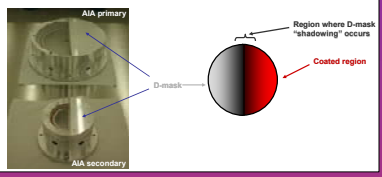
σ = 0.14 nm rms

Isotropic surface finish

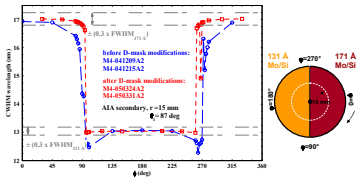
σ = 0.51 nm rms

To maximize mirror performance, multilayer "shadowing" due to coating masks and fixtures needs to be minimized

- "Shadowing" is caused during multilayer deposition by sputtered species bouncing off hardware parts in the vicinity of the substrate, causing the multilayer to miss thickness/wavelength specifications in these areas
- In the case of the AIA optics, the D-shaped mask is of particular concern for shadowing, which occurs around the center line of the optic:
  (1) Within the substrate region that undergoes multilayer deposition
  (2) Underneath the mask, in the region that is expected to remain covered

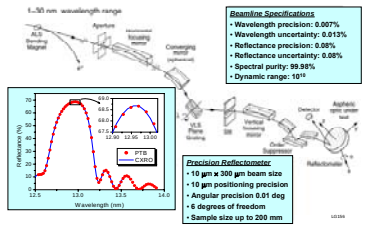


AIA mirrors benefit from D-mask design modifications

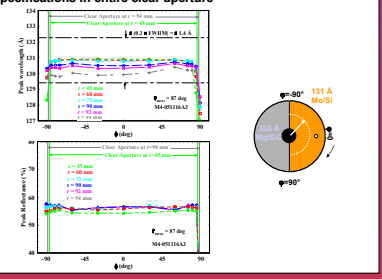


EUV reflectance measurements vs. azimuth angle are performed at r = 15 mm on a test AIA secondary to assess improvements in shadowing due to D-mask modifications

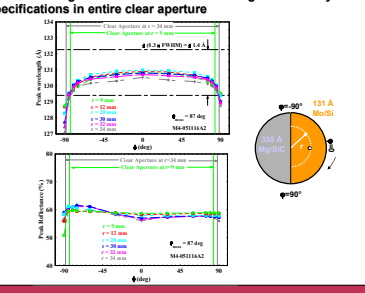
Reflectometry and scattering beamline 6.3.2 (ALS)



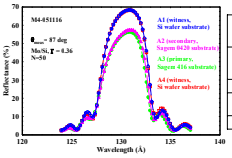
Peak wavelength and reflectance of 131 Å flight primary meet specifications in entire clear aperture



Peak wavelength and reflectance of 131 Å flight secondary meet specifications in entire clear aperture



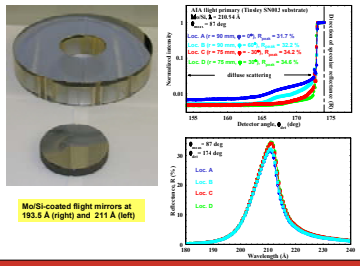
EUV reflectance of flight mirrors is consistent with AFM-measured substrate roughness



Flight mirror	Primary (Sagem 04R0416)	Secondary (Sagem 04R0420)
Substrate roughness (Å rms)	5.0	5.2
R_{max} (%)	56.2	58.8
ΔR* (%, absolute)	8.5	8.4
R_{max} +ΔR	64.7	67.2

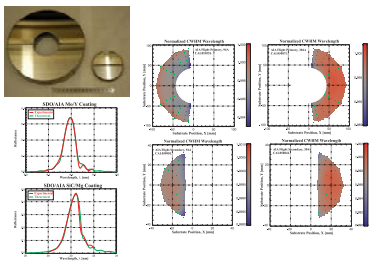
*ΔR = predicted reflectance loss due to high-spatial frequency roughness, based on AFM measurements of the substrate and on a multilayer growth model

Flight substrate topography causes EUV reflectance variations consistent with EUV scattering

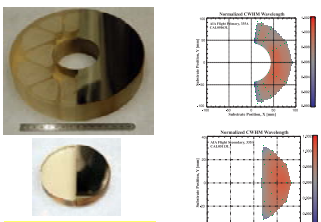


Mo/Si-coated flight mirrors at 193.5 Å (right) and 211 Å (left)

94 Å (Mo/Y) / 304 Å (SiC/Mg) flight coatings



335 Å (SiC/Mg) flight coatings



Flight mirrors are shown after 335 Å SiC/Mg coating is completed (right), prior to deposition of 131 Å Mo/Si coating

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