Enhanced Fluoride over-coated Al Mirrors for FUV Astronomy

Manuel A. Quijada1, Javier del Hoyó1, Steve Rice1, Felix Threat1

1. NASA-GSFC Code 535, Greenbelt, MD, United States

ABSTRACT

Astronomical observations in the Far Ultraviolet (FUV) spectral region are some of the most challenging due to the very distant and faint objects that are typically searched for in cosmic origin studies such as origin of large structures, the formation, evolution, and age of galaxies and the origin of stellar and planetary systems. These challenges are driving the need to improve the performance of optical coatings over a wide spectral range that would increase reflectance in mirrors and reduced absorption in dielectric filters used in optical telescopes for FUV observations. This paper will present recent advances in reflectance performance for Al-MgF2 mirrors optimized for Lyman-alpha wavelength by performing the deposition of the MgF2 overcoat at elevated substrate temperatures. We will also present optical characterization of little studied rare-earth fluorides such as GdF3 and LuF3 that exhibit high-absorption over a wide wavelength range and could therefore be used as high refractive index alternatives for dielectric coatings at FUV wavelengths.

Description and Objectives:

1. To develop on a large scale (up to 1 meter diameter) coating of mirrors using a Al-MgF2 coating process to enhance performance in the Far-Ultraviolet (FUV) spectral range
2. Study other dielectric fluoride coatings and other deposition technologies such as Ion Beam Sputtering (IBS) that is known to produce the nearest to ideal morphology optical thin film coatings and thus low scatter
3. Optimize deposition process of lanthanide trifluorides as high-index materials that when paired with either MgF2 or LiF will enhance reflectance of Al mirrors at Lyman-alpha

Approach for Objective 1:

Retrived a 2 meter coating chamber with heaters/thermal sleeve to perform coating iterations at a high deposition temperatures (200-300°C) to further improve performance of protected Al mirrors with either MgF2 or LiF overcoats

Tasks Description:

- Design and fabrication of internal heat shield for COS 2 meter Chambers
- Three wall panels were made out of stainless steel and were designed to easily interlace with the existing internal configuration of the chamber
- Optimized cooling parameters for high FUV reflectance in a deposition chamber that is a 5 meter radii.

Approach for Objective 2:

Upgraded Ion Beam Sputtering (IBS) chamber with a two-gas flow controller system. Krypton gas is used in IBS deposition. In addition, Freon (CF4) is used as reactive gas to replenish the targets (MgF2) stoichiometry. Finally, we added heaters to the chamber to improve microcrystalline film properties.

Optimize deposition process of lanthanide trifluorides as high-index materials that when paired with either MgF2 or LiF will enhance reflectance of Al mirrors at Lyman-alpha.

Approach for Objective 3:

Optimize deposition process of lanthanide trifluorides as high-index materials that when paired with either MgF2 or LiF will enhance reflectance of Al mirrors at Lyman-alpha.

Tasks Description for FUV Dielectric Coatings:

- Choose a high-index (H) and low-index (L) pair combination
- Form a pair of (GLL) layers with distributed optical (quarter-wave Optimal thickness at design wavelength)
- Repeat the stack above until desired reflectance is achieved.

Optimization and characterization of MgF2 films using the IBS process did not give satisfactory results (see graphs below)

The data on the graphs above were used to obtain refractive index (n and k) for MgF2, GdF3, and LuF3 films. The results are shown in graph

Al+MgF2 Coating Performance:

3-step coating process:

- Al is coated on the substrate at room temperature to the planned layer thickness
- As soon as possible after the Al deposition, overcoat the Al layer and substrates at room temperature with a thin 0.5 nm-layer of MgF2 in order to protect the Al from oxidation and contamination
- Heat the substrates to 200-300°C and finish the planned heat MgF2 thickness MgF2.

Results:

- Predicted vs. measured reflectance of test Al and Al-MgF2 coatings in the 300-500 nm, MgF2: 200 nm
- Enhanced performance is obtained by heating (~225 °C) substrates during MgF2 deposition
- Reflectance is ~85% even at 1550 nm

Micro-roughness Al+MgF2 Films

The tables above show micro-roughness results on two classes of Al+MgF2 coatings done with the MgF2 layer deposited at ambient (left) and at elevated (right) temperatures. The table on the right shows the average roughness for the elevated MgF2 depositions is 30% smaller.

Conclusions

- Reported gains in FUV reflectivity of Al-MgF2 and Al-LiF mirrors by employing a 3-step process during PVD coating deposition of these materials.
- Successfully demonstrated gain in FUV reflectivity using a large 2-meter chamber that will allow coating up to 1 meter diameter optics.
- Characterization of lanthanide trifluoride material candidates to determine their FUV transparency for development of dielectric coatings.
- Will plan to reduplicate a second 1-meter chamber to perform IBS film deposition of MgF23,4,5 materials.