Enhanced Fluoride over-coated Al Mirrors for FUV Astronomy

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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 using a wide spectral range that would increase reflectance in mirrors and reduced absorption in dielectric filters used in optical telescope 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 low-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:
Retrival a 2 meter coating chamber with heaters/thermal shroud 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 shields for GSFC 2-meter Chamber.
- Closed wall panels were made out of stainless steel and were designed to easily interface with the existing internal configuration of the chamber.
- Optimized coating parameters for high FUV reflectance performance on substrates of chosen composition and size and not to be >0.5 meter radius.

Approach for Objective 2:
Upgrades Ion Beam Sputtering (IBS) chamber with two gas-flow controller system. Hygroskin gas is used in IBS deposition. In addition, Freon (CF4) is used as reactive gas to etch the targets (MgF2) thin chemistry. Finally, we added heaters to the chamber to improve nanocrystalline film properties.

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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 (H,L) layers with thicknesses equal to a Quarter-Wave Optical thickness at the design wavelength.
- Repeat the cycle until desired reflectance is achieved.

Example of A/R coating design and fabrication:
- A L/2 mirror reflectance of 90% is desired.
- Choose a high-index (H) and low-index (L) pair combination
- Heat the substrate to 200-300 °C and finish the planned final MgF2 thickness MgF2.

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 deposition 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 gains in FUV reflectance using a large 2-meter chamber that will allow coating up to 1 meter diameter optics.
- Characterization of lanthanide tri-fluoride material candidates to determine their FUV transparency for development of dielectric coatings.
- Will plan to refurbish a second 1-meter chamber to perform IBS film deposition of MgF2/LiF materials.