Improved Lyman Ultraviolet Astronomy Capabilities through Enhanced Coatings

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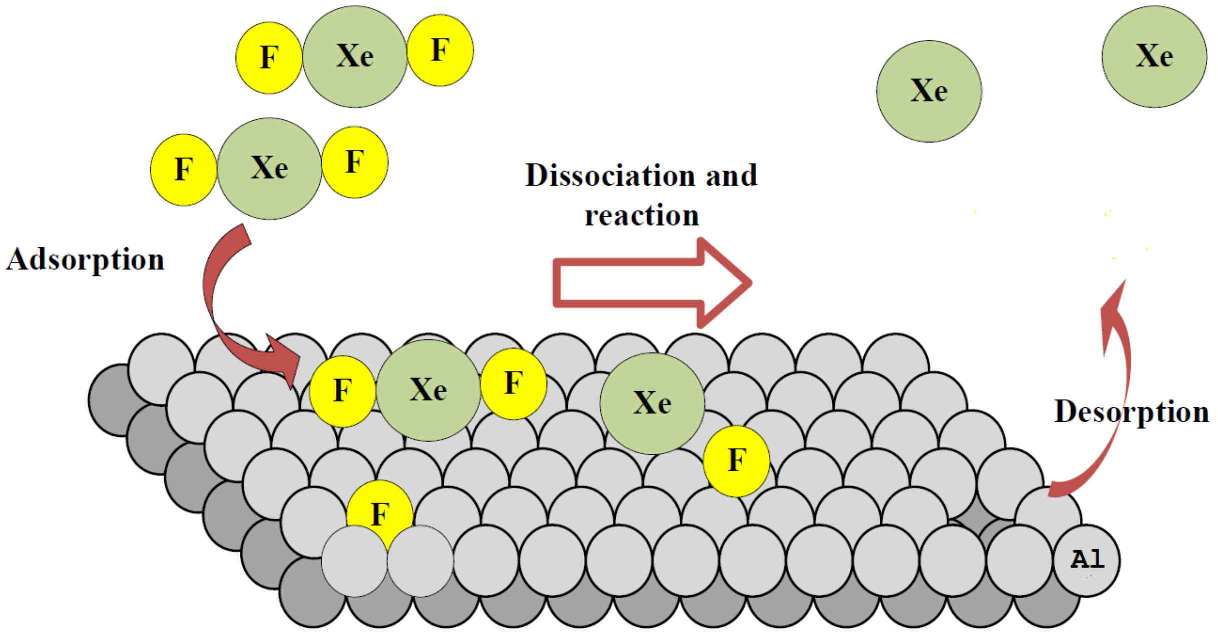
Outline

- Overview & Objectives
- Experimental details
- Results
- Conclusions

Overview and Objectives

- Summarized Task Description
  - Deposit high performance UV to FIR optical broadband coatings by designing/constructing hybrid thin film deposition/ fluorination chamber capable of depositing aluminum under ultra-high vacuum with the capability of adding a precursor gas to fluorinate the surface and form a thin layer of AlF_3 to protect the metal from oxidation.
- Driver / Need
  - High-performance broadband coatings (90-10,000 nm) have been identified as an “Essential Goal” in the technology needs for the Large UV/Optical/IR (LUVOIR) Surveyor observatory.
  - Low reflectivity and transmission of coatings in the Lyman Ultraviolet (LUV) range of 90-130 nm is one of the biggest constraints on FUV telescope and spectrograph design.
- Benefits
  - By demonstrating new low-absorbing materials which can be used at a broadband, the technology will enable the merging astrophysics, solar physics, atmosphere physics, and optical exoplanet sciences with a shared telescope providing high throughput and signal-to-noise ratio (SNR) in the entire spectral range.

Hybrid PVD Passivation/Fluorination chamber



Reactive fluorine compound with low bond energy used (e.g. XeF_2 with 133.9 kJ/Mole)

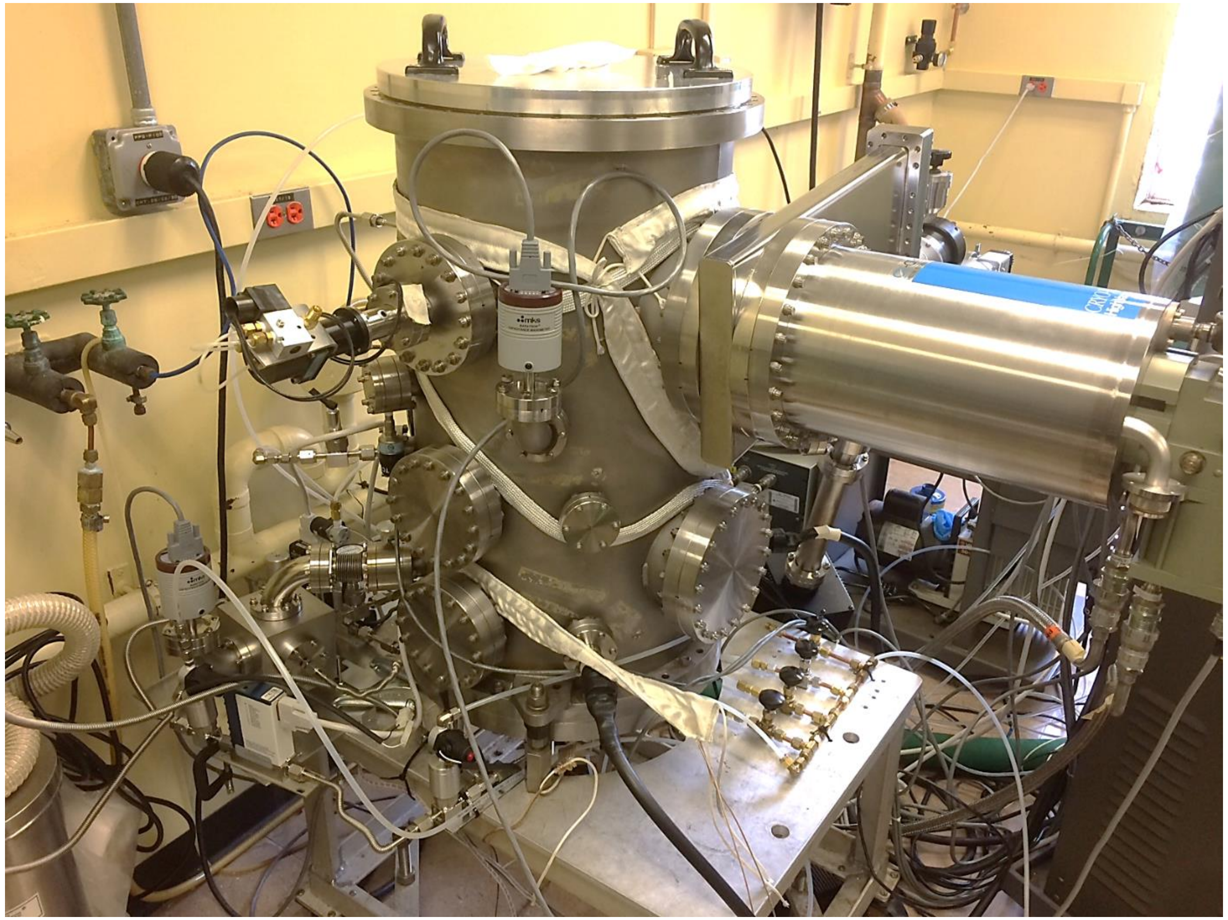
Heating will also be used if compound is not sufficiently reactive for increased selectivity.

XeF_2 is a dry-vacuum based method of reaction and requires no plasma or other activation minimizing damage to substrate.

Objective: Oxide-Free Aluminum Mirrors

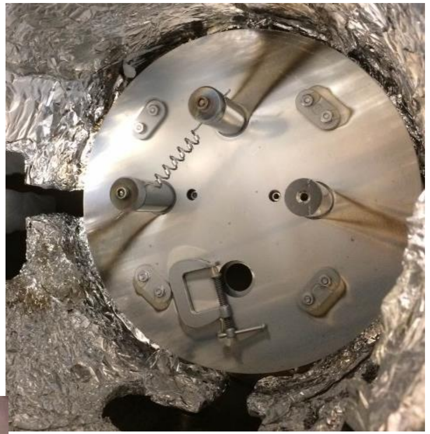
We propose to develop isotropic/homogenuous protected Aluminum broadband mirror coatings with high performance that will extend from the Far-Ultraviolet (FUV) through the far-infrared wavelengths (90-10,000 nm).

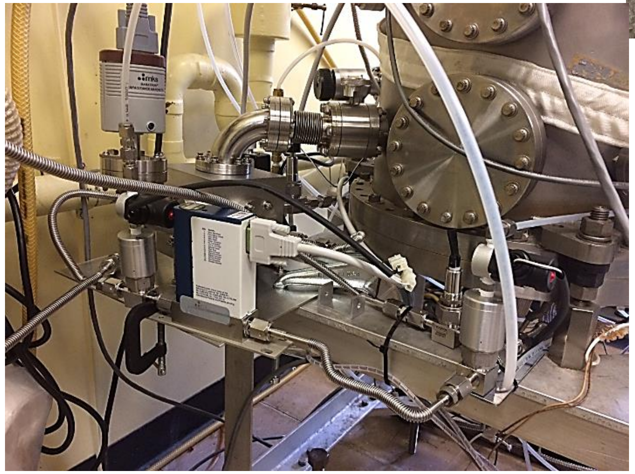
Assembled Research Chamber



UHV Research Chamber capable of thin film physical vapor deposition (PVD) and passivation.

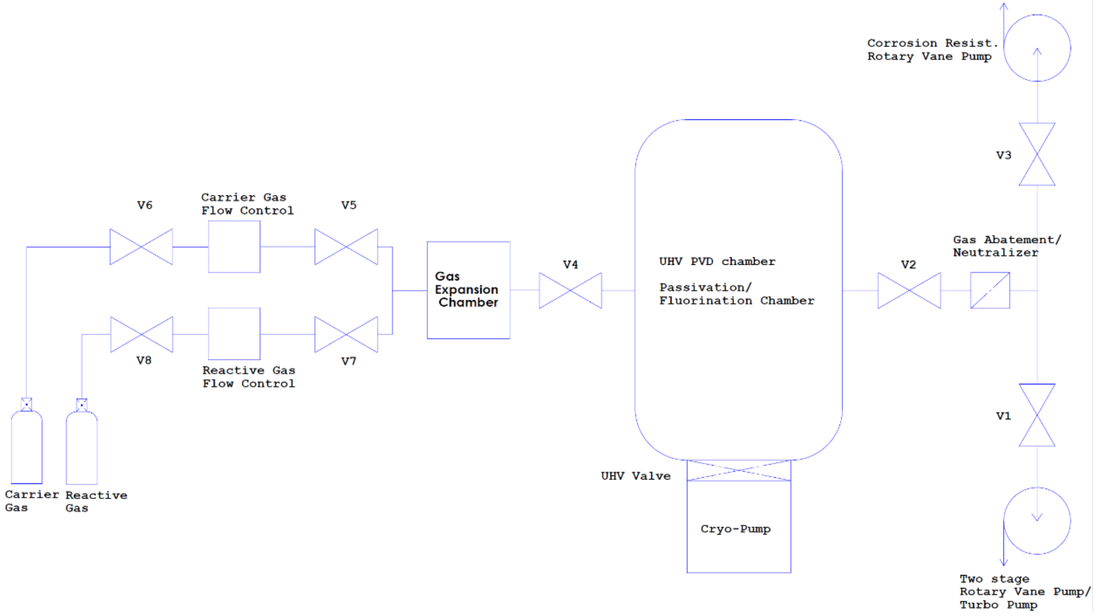
Inside of chamber PVD components.





Gas feed components capable of continuous flow or pulsed flow.

Research Chamber Schematics

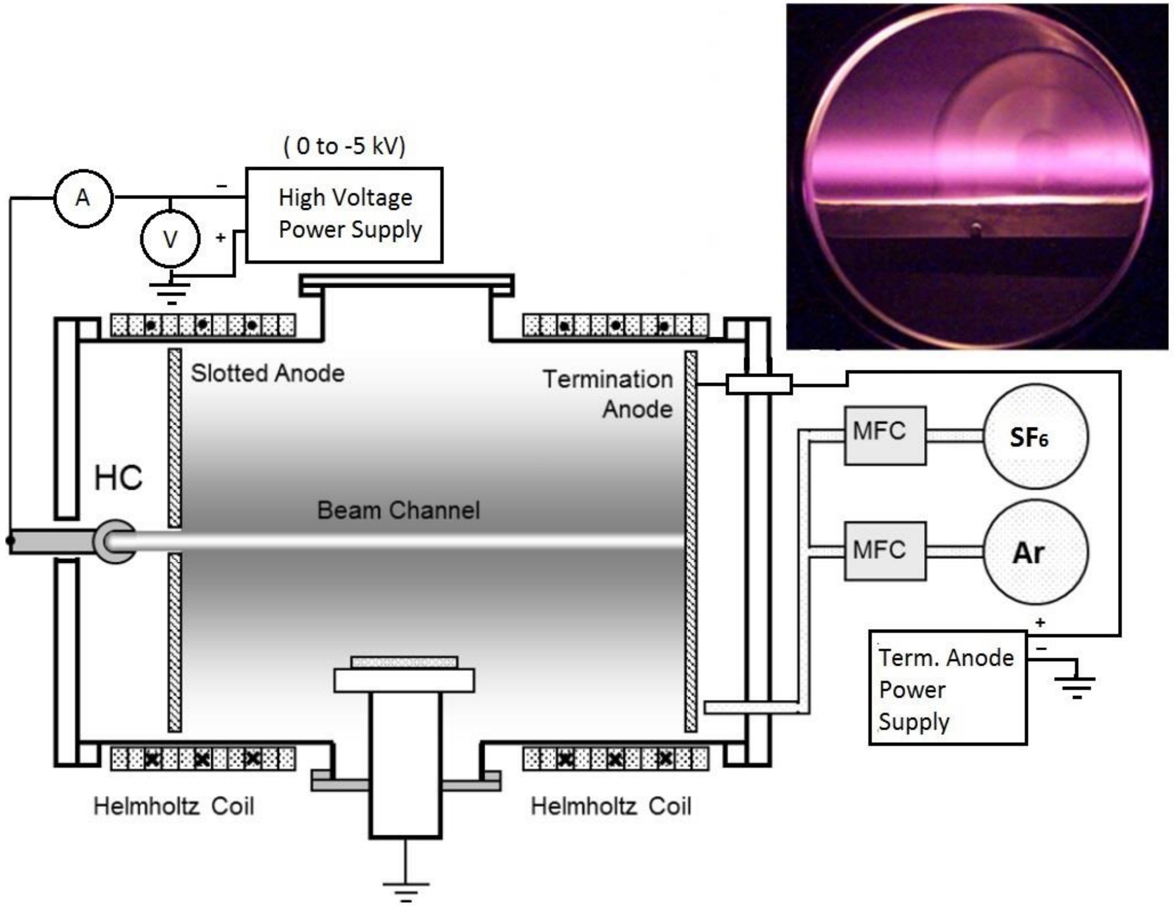


Research Chamber for in-situ thermal evaporation and fluorination

Rack-mounted control/monitor components.

LAPPS Reactor at NRL

- The US Naval Research Laboratory's Large Area Plasma Processing System (LAPPS), which employs an electron beam generated plasma for etching and fluorination of Al samples.
- The schematic diagram illustrates the processing reactor use din this work, whereas the image on the upper right corner is a view of the plasma through a 6 inch port.



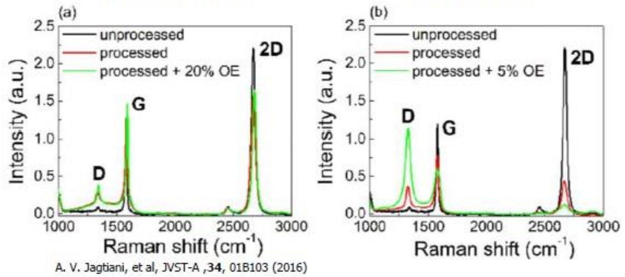
Motivation for e-Beam Etching

- Electron beam generated plasmas have demonstrated the ability to chemically modify2-D materials while maintaining their unique characteristics.
- Electron beam generated plasmas have shown promise as a low damage etch source. Particularly in processing devices with integrated 2-Dmaterials.
- They have also demonstrated selective, highly directional, low damage etching in SiN without pattern dependent etch characteristics in fluorine based chemistries.
- To understand these results it is important to understand the unique attributes of electron beam generated plasmas.

NRL PPD

SiN Etch Stop on Graphene – IBM/NRL

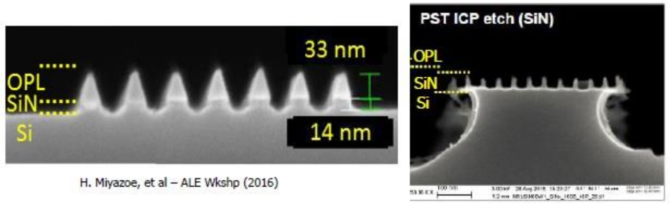
E-Beam Plasma　　　　Low Power ICP



A. V. Jagtiani, et al, JVST-A ,34, 01B103 (2016)

Low Damage SiN Etching – IBM/NRL

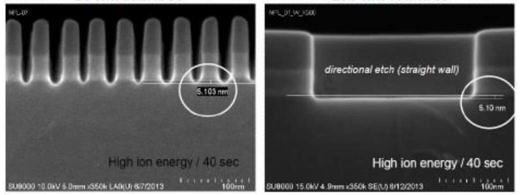
E-Beam Plasma　　　　Low Power ICP



H. Miyazoe, et al – ALE Wkshp (2016)

Low Damage SiN Etching – Applied Materials

20 nm features　　　　230 nm features

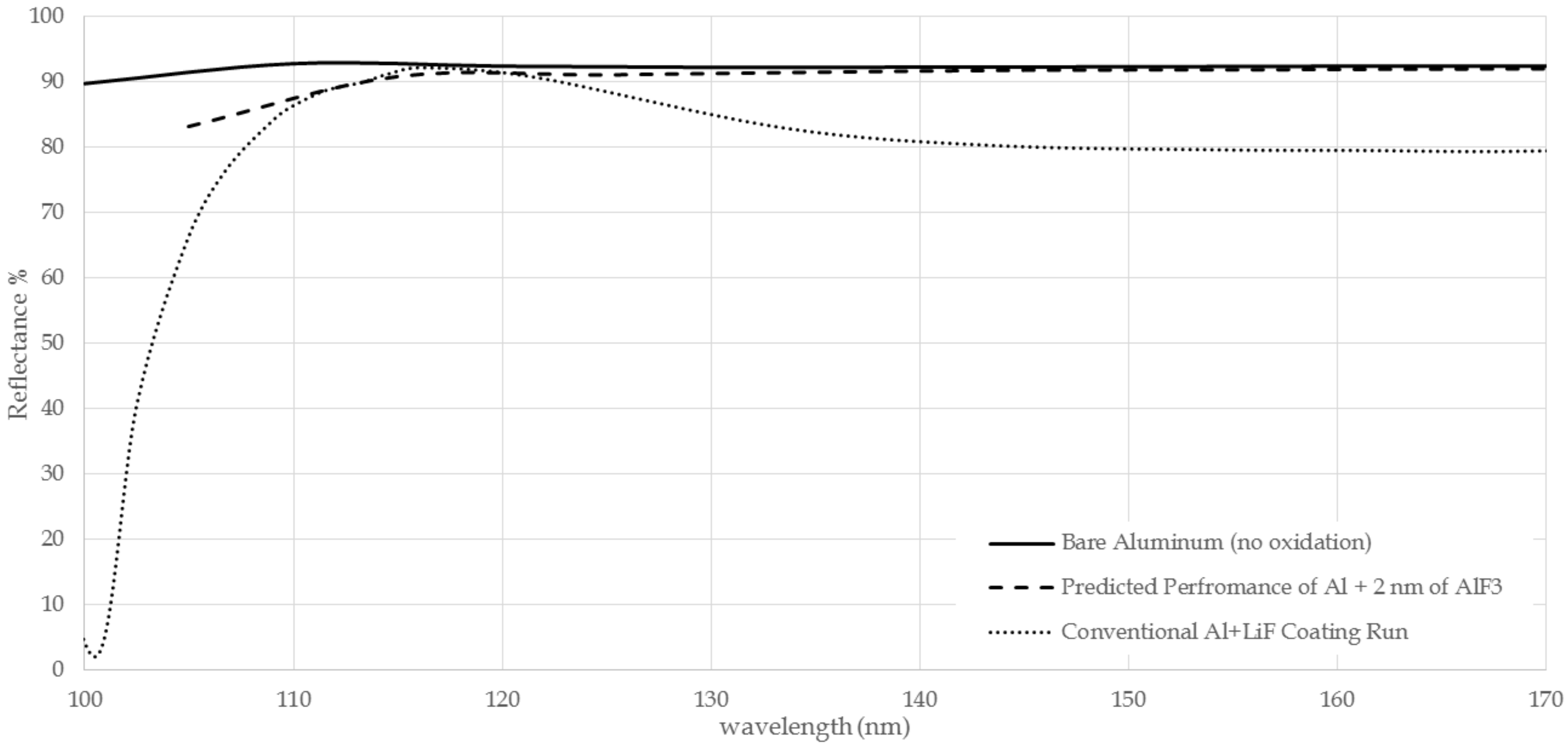


L. Dorf, et al – AVS Symp. (2014)

How are e-beam generated?

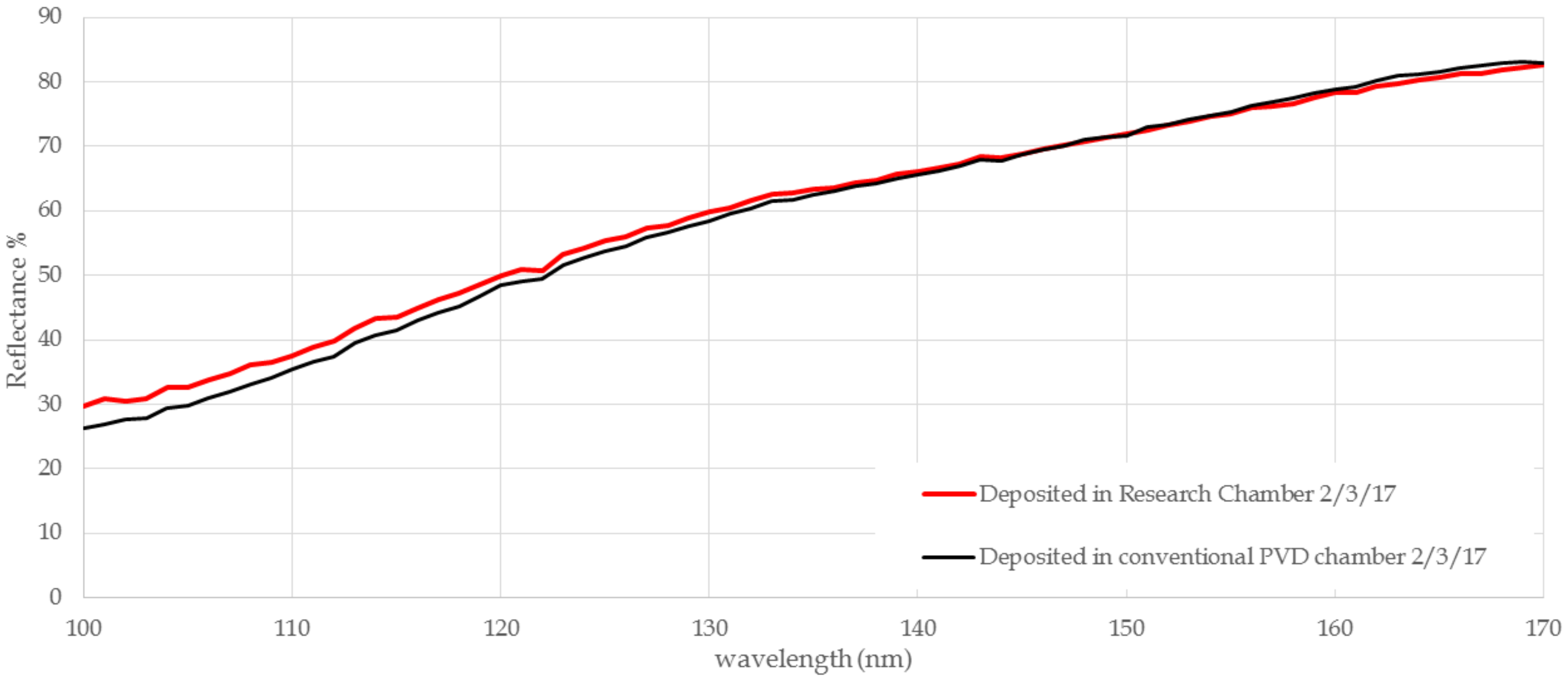
- The injection of a 2 keVbeam into the background gas will directly ionize and dissociate the gas.
- Beam energy well above ionization threshold
- higher beam energy = more efficient ionization

Predicted Performance Comparison

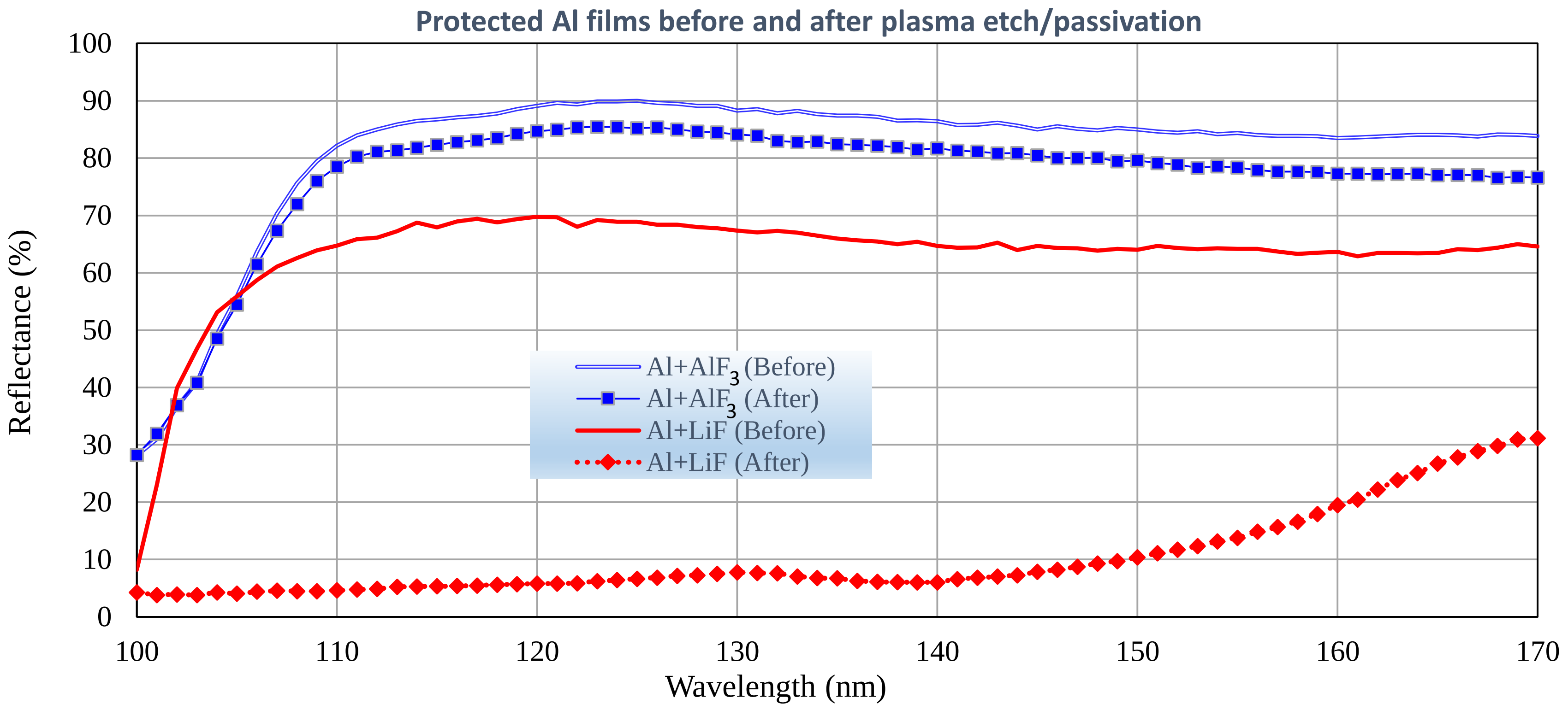


Predicted fluorinated Aluminum should surpass performance of conventional Protective Aluminum coatings

High Performance Aluminum Deposited in Research Chamber

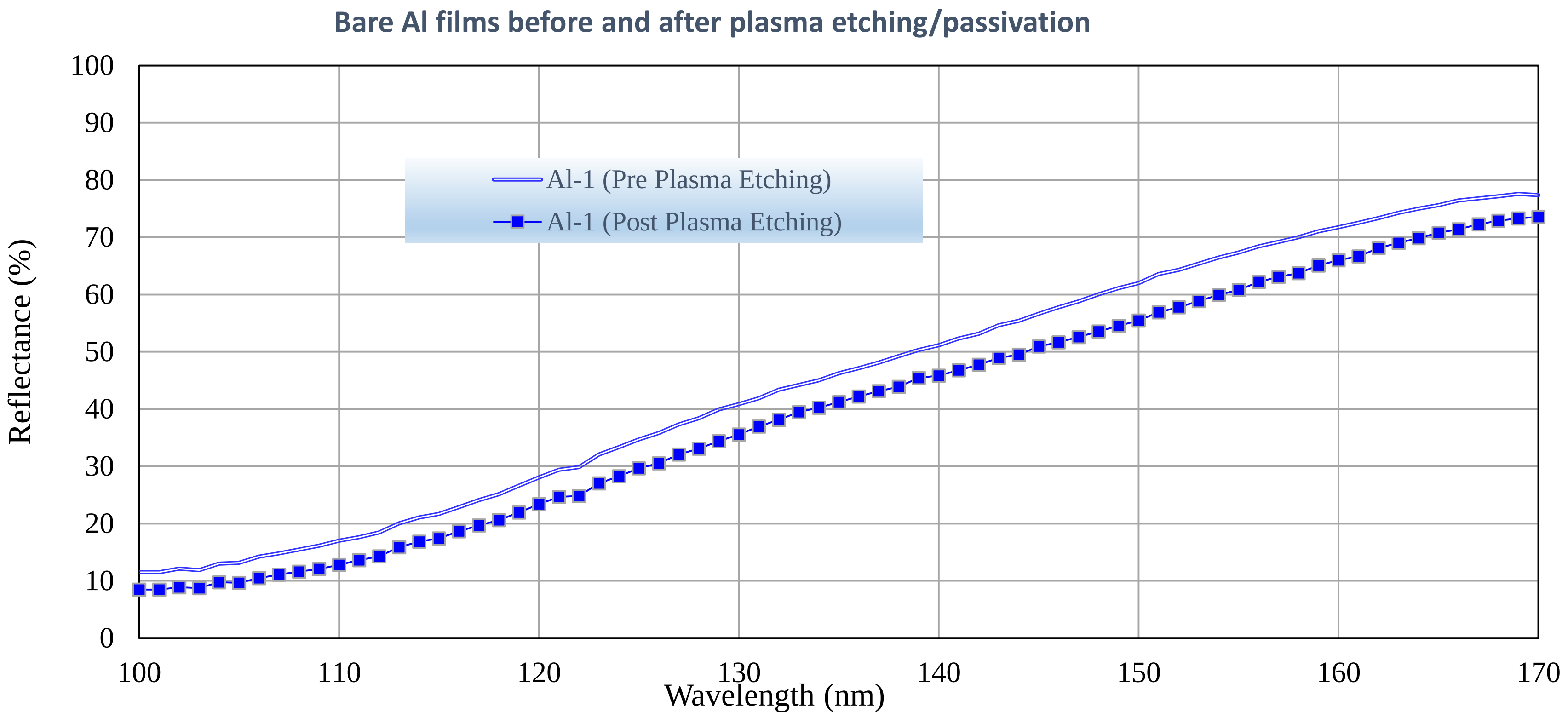


LAPPS E-Beam Results



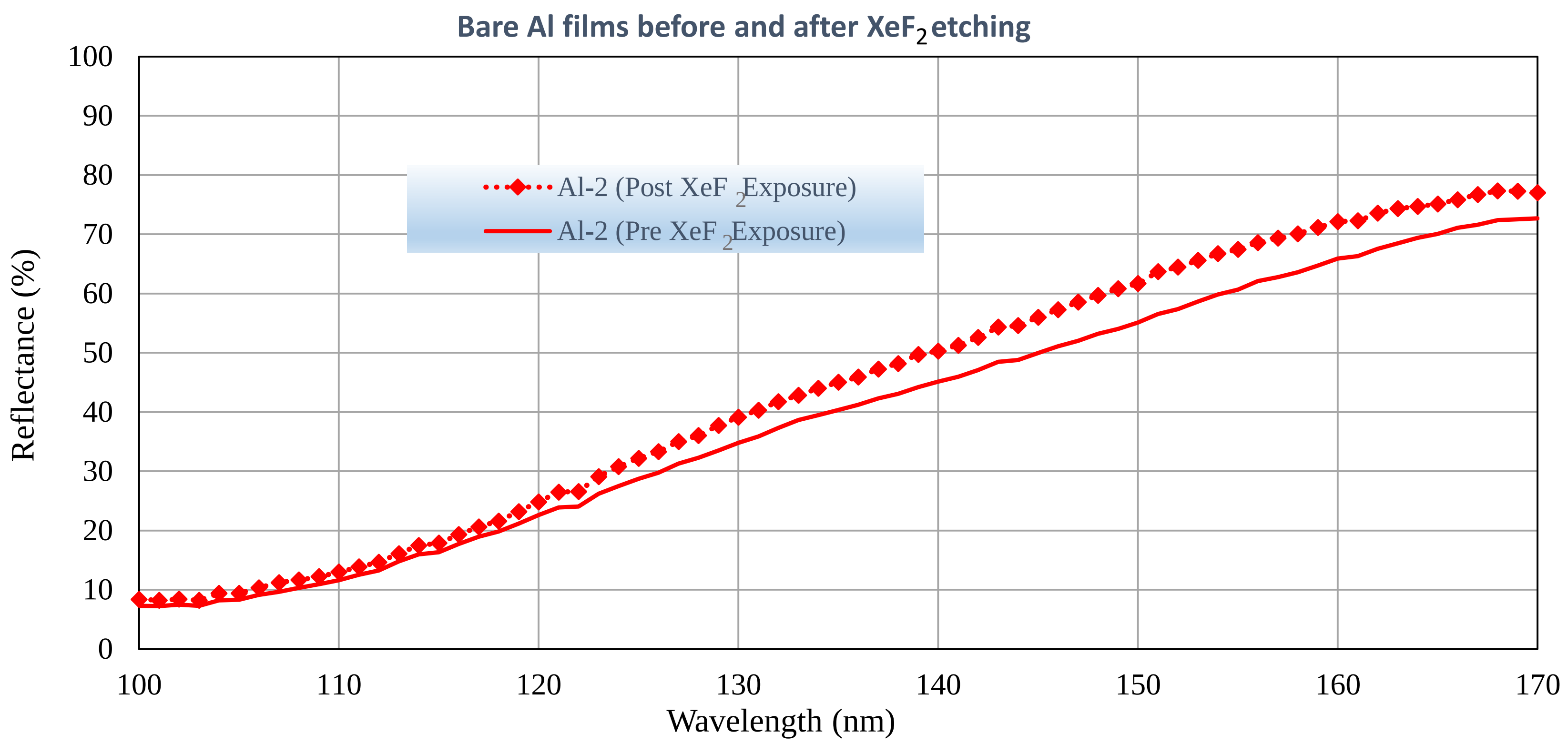
Reflectance results of Al+AlF_3 and Al+LiF samples before and after treatment in the LAPPS reactor at NRL.

Bare Al e-Beam Etching



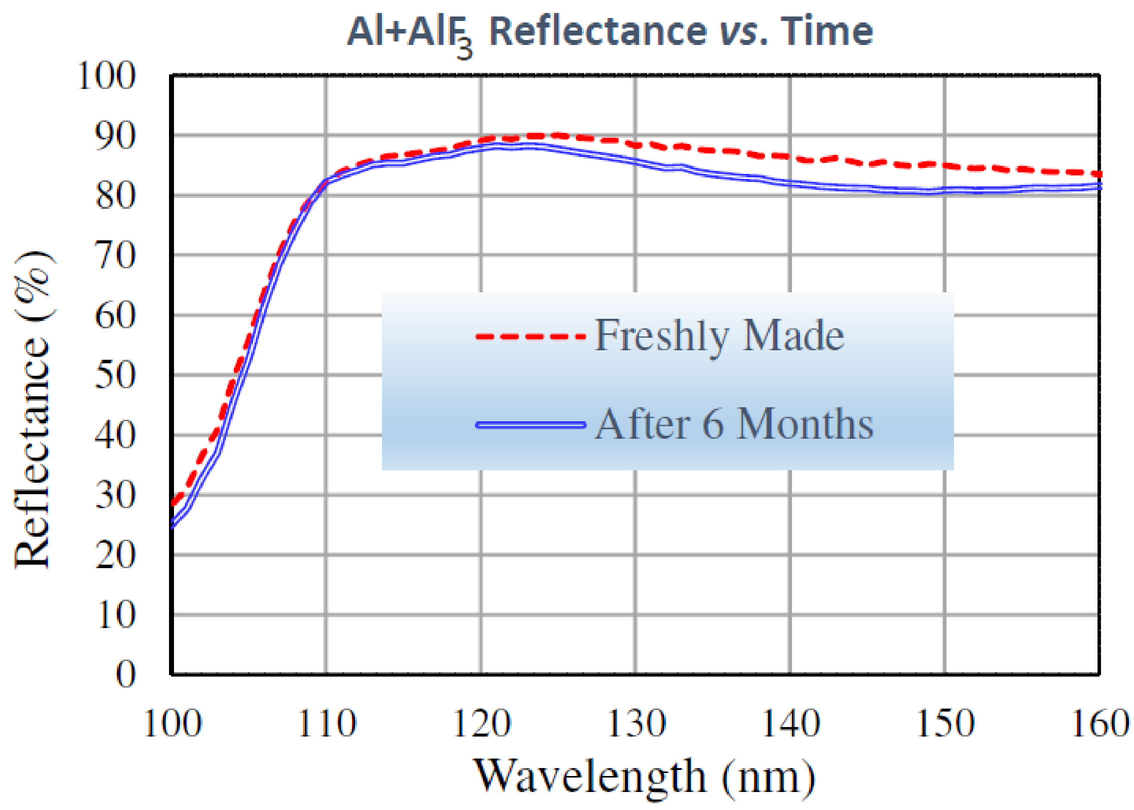
Reflectance results of bare Al sample with native oxide layer before and after treatment in the LAPPS reactor at NRL.

Bare Al Before & After XeF2 Treatment



Reflectance results of bare Al sample with native oxide layer before and after treatment in the XeF_2 reactor locate din the Detector Branch (Code 553) at GSFC.

AlF_3 as Aluminum mirror Overcoat



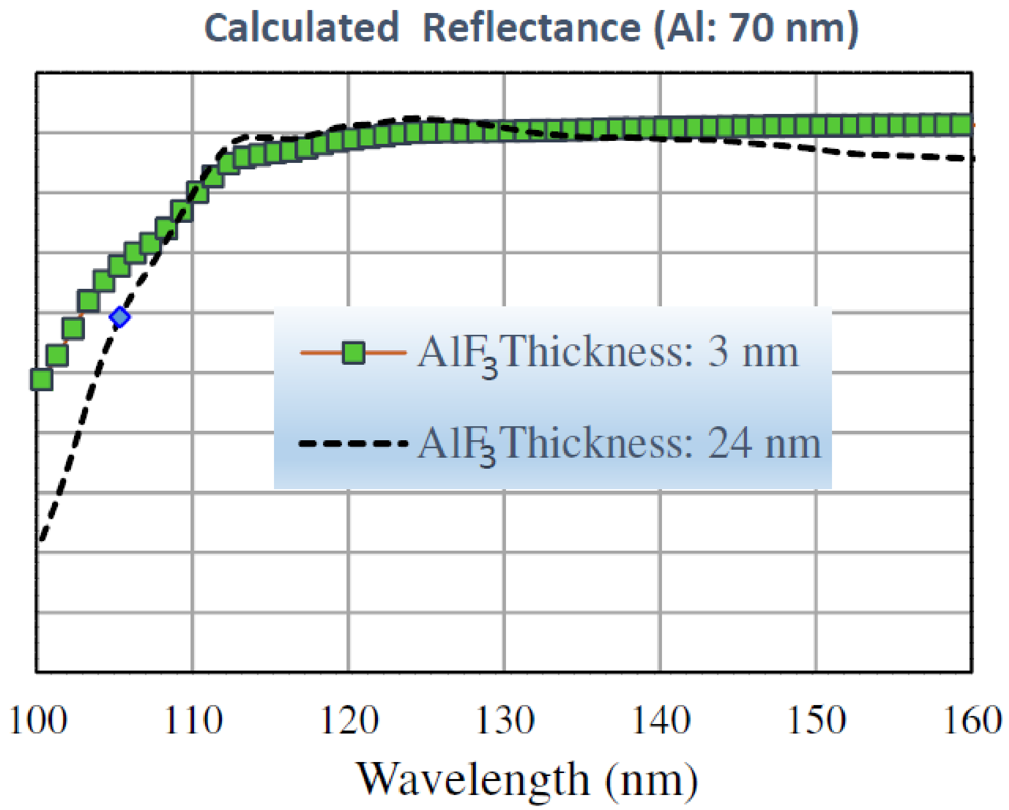


Figure on the left shows the stability in the reflectance of an Al+AlF_3 sample after it was freshly coated and 6 months later.

The figure on the right shows the predicted reflectance performance for a sample with coating parameters as result shown in figure on the left (Al:70 nm; AlF_3: 24 nm) in comparison with a much thinner AlF_3 overcoat (3 nm), which will the AlF_3 thickness for a successfully fluorinated Al sample.

Conclusions

- We studied the feasibility of using the LAPPS reactor (developed at NRL) that employs a low energy- e-beam to etch away the native oxide layer from Al samples as well as thinning the AlF_3 and LiF layers for Al protected with these dielectrics.
- Results indicate no improvement in reflectance performance which may indicate a more aggressive ion or chemical etching would be required for successful native oxide layer removal.
- A second experiment of etching a bare Al smaple in a XeF_2 recator produced a sample with a slight improvement in reflectance in the FUV spectral range.
- Chemical analysis would be conducted in the near future to determine composition of a sample before and after XeF_2 treatment.
- Predicted reflectance performance for a fluorinated Al mirror would produce a sample with reflectance close to 50% at 100 nm and over 90% at wavelengths longer than 110 nm.
- An aluminum sample coated with an AlF_3 overcoat shows a stable reflectance after being kept in a normal laboratory environment (40-50% relatibe humidity) fo ra period of 6 months.