National Aeronautics and Space Administration

Engineered optical coatings for far ultraviolet spectroscopy

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Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: UV Spectroscopy**

Objectives / Background

Our objectives in the second year of our two-year effort include: studying the thermal compatibility of our ALD mirror coatings processes with candidate polymeric photoresists used in the fabrication of grayscale ebeam diffraction gratings; combining the graded ALD coating approach developed in year one with metal dielectric filter structures; and investigating the performance limits of dielectric narrowband mirror coatings operating in the FUV by comparing commercial efforts with attempts to fabricate the same structures with ALD methods. Combined these elements are synergistic with other technological activities at JPL related to UV spectroscopy.

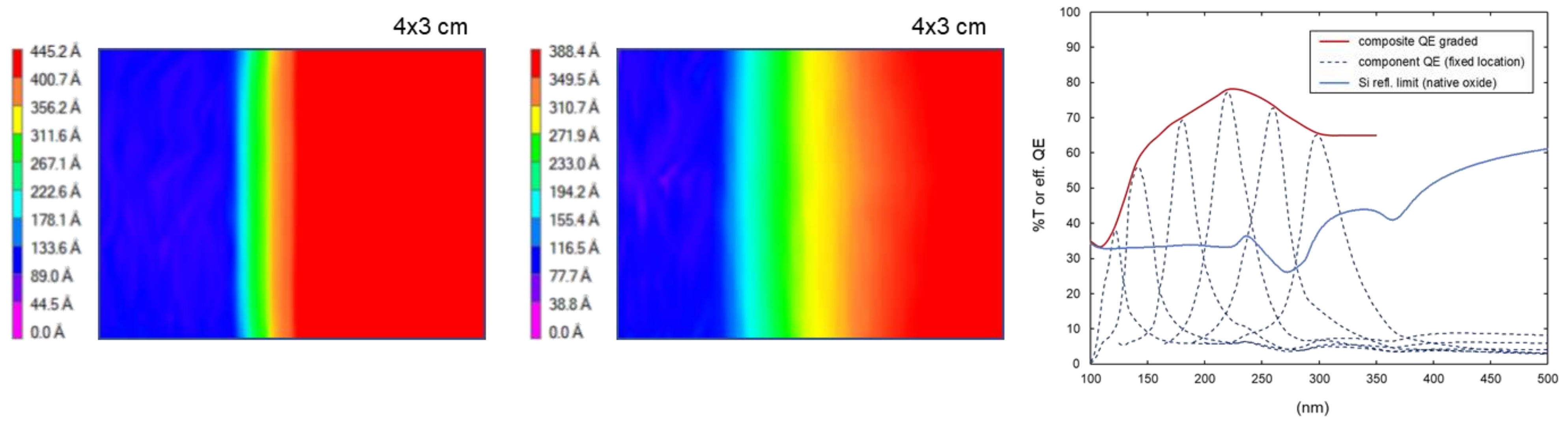
Significance/Benefits to JPL and NASA

Continuing to build complexity in our coating program with new graded techniques and new materials enhances the competitive advantage of UV instrument programs at JPL. The work described here provides enhancing benefits to both the fabrication of reflective diffraction gratings, and also delta-doped detector technology. These approaches are already being incorporated into Astrophysics MIDEX instrument concepts and will result in future UV instruments with improved capabilities. In particular, graded anti-reflection and filter coatings can provide a significant throughput improvement in essentially any spectroscopic instrument operating solid-state sensors in the UV.

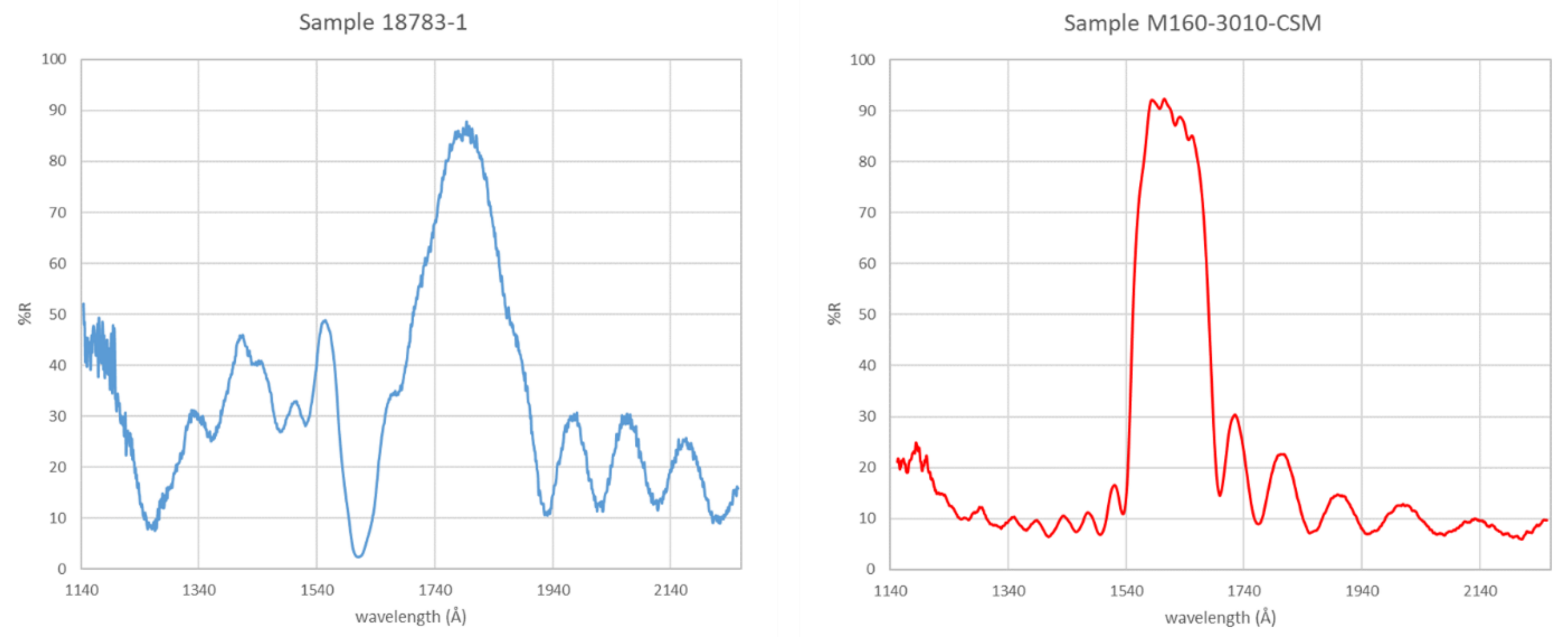
Publications

Hennessy, J., Jewell, A., Hoenk, M. and Nikzad, S., 2021, August. Advances in detector-integrated filter coatings for the far ultraviolet. In UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XXII (Vol. 11821, p. 118211A). International Society for Optics and Photonics.

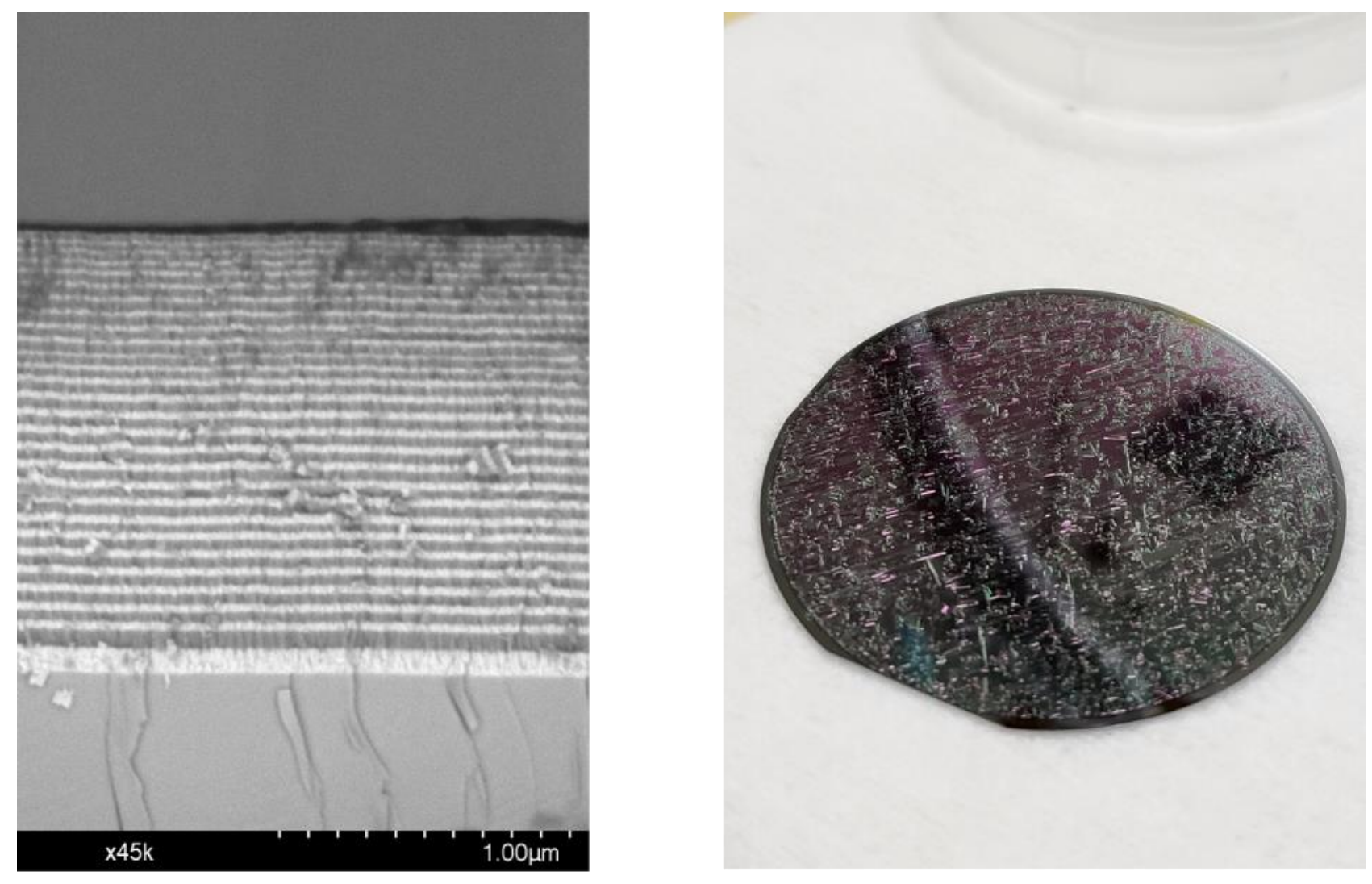
Hennessy, J., Jewell, A.D., Jones, J.P., Crouch, G.M. and Nikzad, S., 2021. Aluminum Precursor Interactions with Alkali Compounds in Thermal Atomic Layer Etching and Deposition Processes. ACS Applied Materials & Interfaces, 13(3), pp.4723-4730.



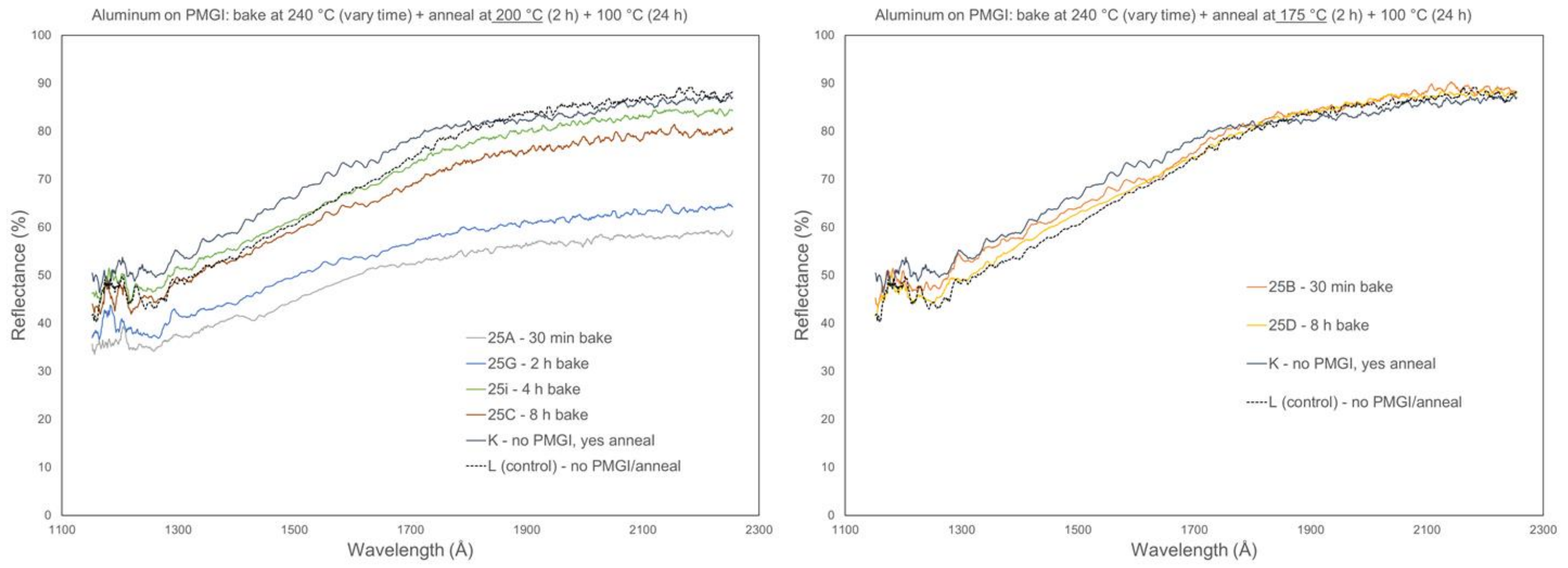
(*left*) Demonstrations of graded thickness AlF_3 were made over larger areas versus the initial attempts in year one. Spatial maps of measured reflectance were used to estimate the variation in AlF_3 film thickness. (*middle*) The gradient slope in film thickness was increased by combining ALD cycles at different working pressures. (*right*) The target for this development is for a FUV spectrometer application with a predicted model QE shown in the red curve realized with a single graded layer of ALF_3 and two additional uniform layers of Al and AlF_3.



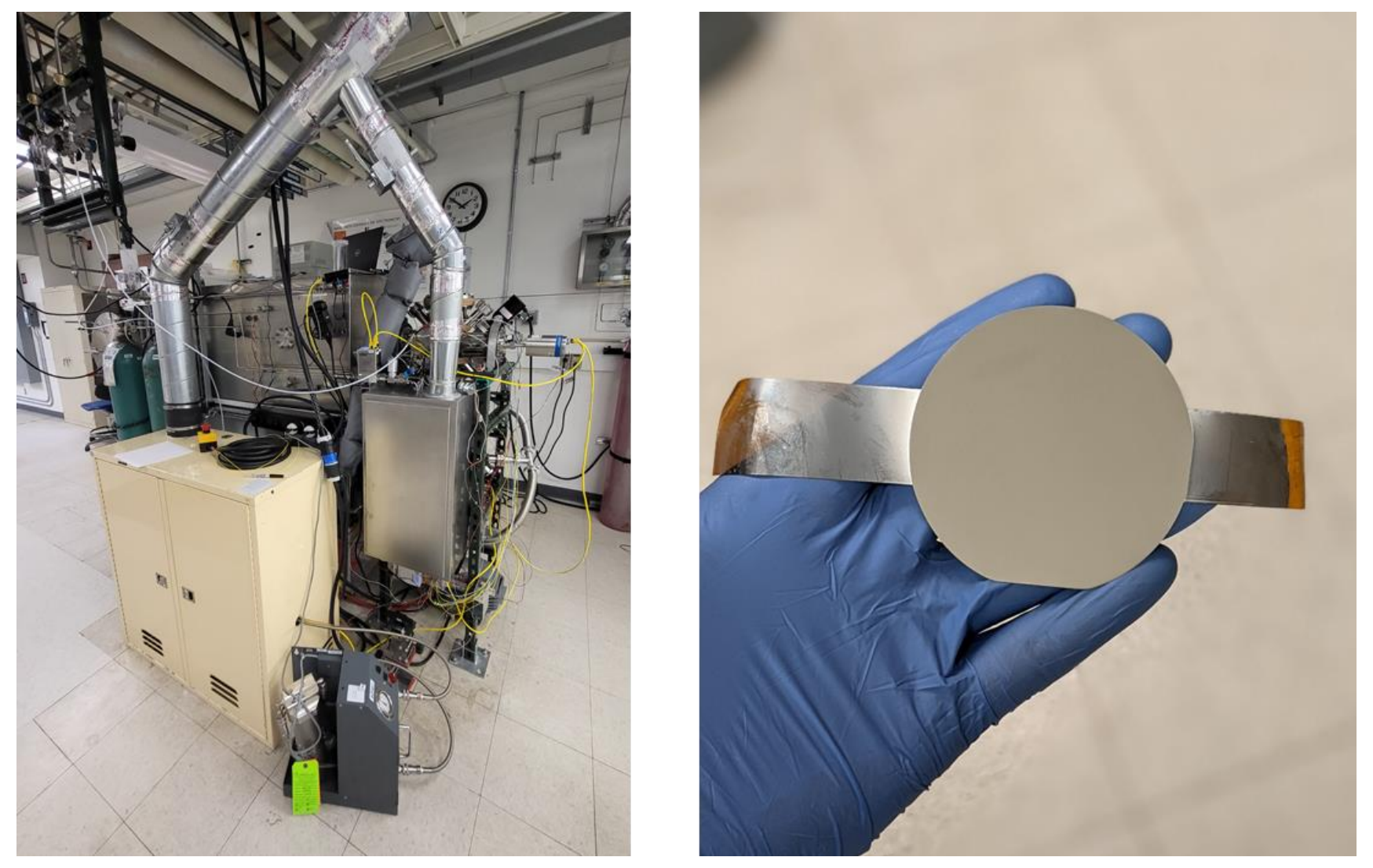
Dielectric mirrors fabricate from two commercial coating vendors, intended target was center wavelength = 160 nm with > 80% R, and < 10% R average out of band. (*left*) Vendor 1 produced a coating with a layer mismatch issue that caused a shift in central wavelength and poor (high) out-of-band R. (*right*) Vendor 2 produced a coating that meets performance specifications but fails upon exposure to typical laboratory air at ~40% RH.



(*left*) Cross-sectional SEM of the multilayer coating fabricated by Vendor 1. The coatings comprises ~27 bilayers, an apparent drift in layer thickness may explain the deviation from the intended performance target. (*right*) A witness coating produced by Vendor 2 on a 50 mm diameter silicon wafer suffered completed mechanical failure shortly (< 5 min) after exposure to laboratory air.



The measured reflectance of aluminum deposited on PMGI coated on Si and baked at 240 °C for a variable amount of time. (*left*) Samples exposed to 200 °C for two hours followed by 100 °C for 24 h to approximate the thermal budget that would be experienced during an ALE + ALD mirror coating process. (*right*) Similar samples but reducing the first annealing temperature to 175 °C.



(*left*) A new combined physical vapor deposition (PVD) and ALD reactor recently completed final installation at the Microdevices Laboratory. The system will combine thermal Al evaporation with JPL ALD metal fluorides processes in the same vacuum chamber. (*right*) The first test Al evaporation coating from this system.

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Clearance Number:
RPC/JPL Task Number: R20028