Advances in detector-integrated filter coatings for the far ultraviolet

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INTEGRATED METAL-DIELECTRIC FILTERS

Multilayer filters of aluminum and dielectric layers are used to create UV bandpass filters. There are significant throughput advantages in integrating these filters directly onto a back-illuminated silicon sensor.[1]

Combining JPL delta-doping with integrated metal-dielectric filters can create solar-blind imaging sensors that maintain high UV efficiency

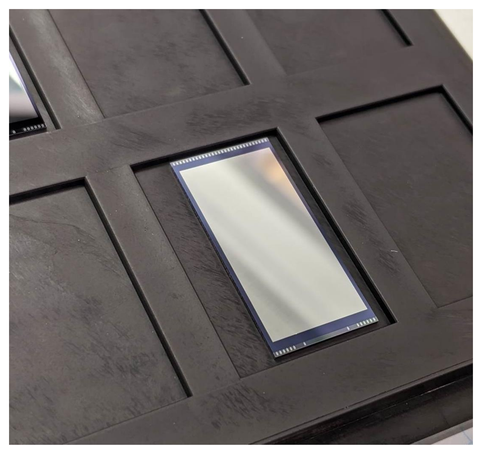

Fig. 1. A delta-doped Teledyne e2v CCD with an integrated metal dielectric bandpass filter. The filter structure combines three Al layers deposited by evaporation with four AlF_3 layers deposited by ALD.

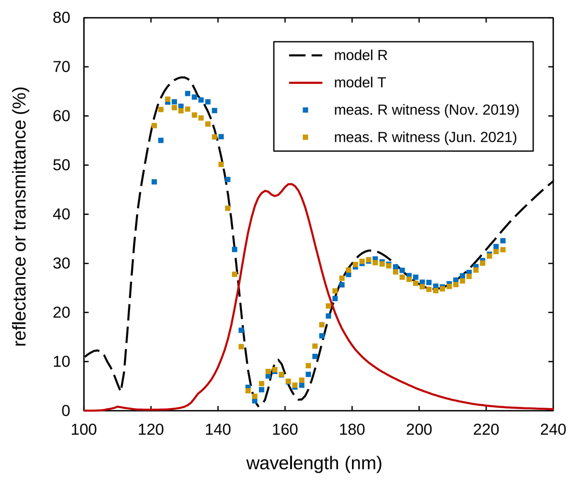

Fig. 2. The measured reflectance of witness samples to the device in Fig. 1 and the model target and predicted transmittance. Little change in witness reflectance is observed for long duration storage.

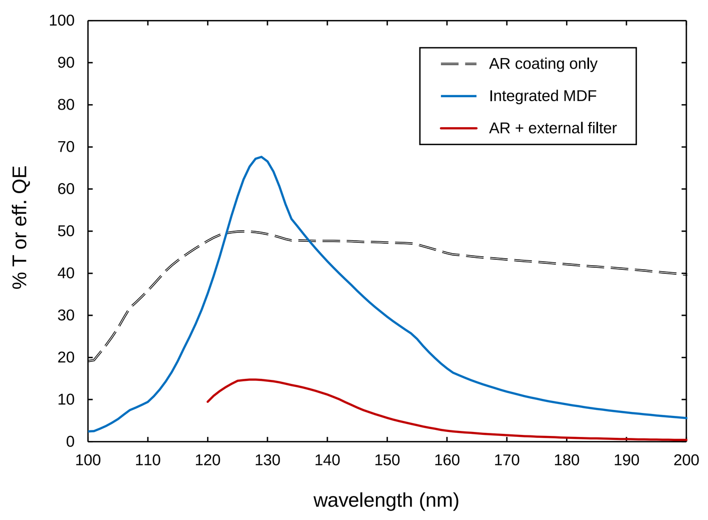

Fig. 3. The modeled performance of a directly integrated metal-dielectric filter (MDF) versus a simple AR coating, and an AR + stand-alone filter optimized for a bandpass near 130 nm.

The filters have been developed at JPL for a number of applications including high energy physics detectors,[2] and astrophysics instruments such as the SPARCS CubeSat.[3] The Al layers in these filters are deposited by evaporation, and the dielectric spacer layers utilize a number of ALD processes developed at JPL[4-6] Custom thin-film vacuum chambers have been developed to optimize the combination of these filters with back-illuminated, delta-doped detectors.

GRADED THICKNESS BY ATOMIC LAYER DEPOSITION

ALD is often utilized to take advantage of properties related to film thickness uniformity. Because ALD is not line-of-sight, physical shuttering or masking of the substrate cannot be used to create thin films with a graded lateral thickness.

Introducing ALD reactants into a constrained volume can force ALD into a non-uniform mode

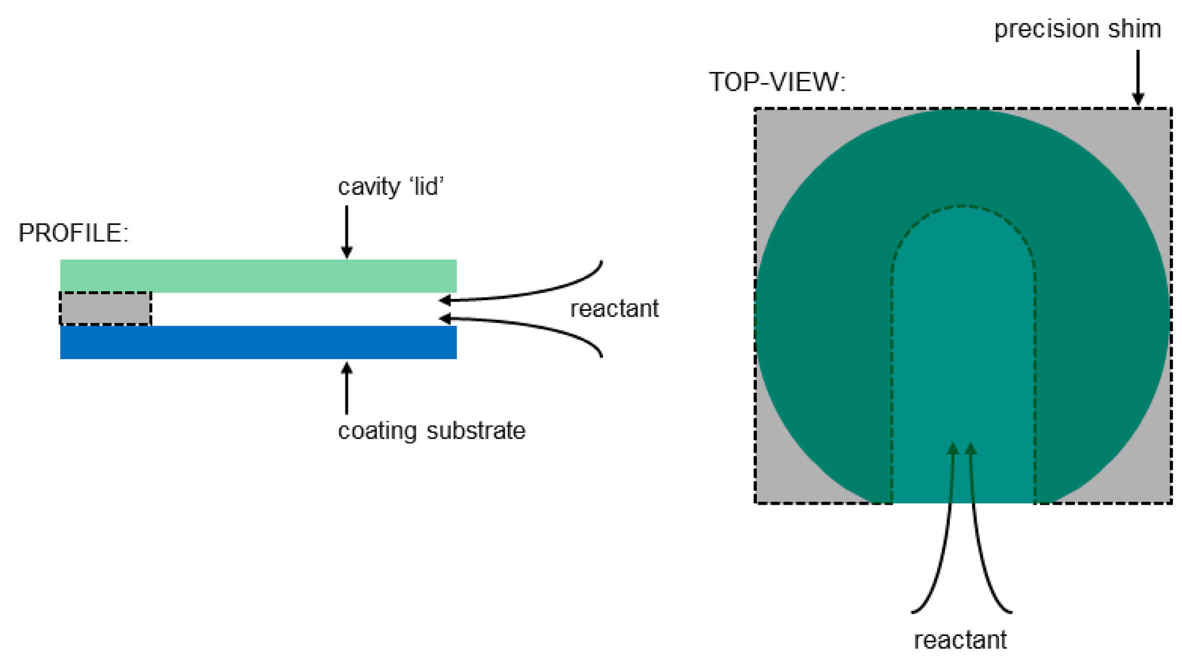

Fig. 4. Deposition into a shallow cavity limits the amount of reactant that can penetrate before the next ALD half cycle begins.

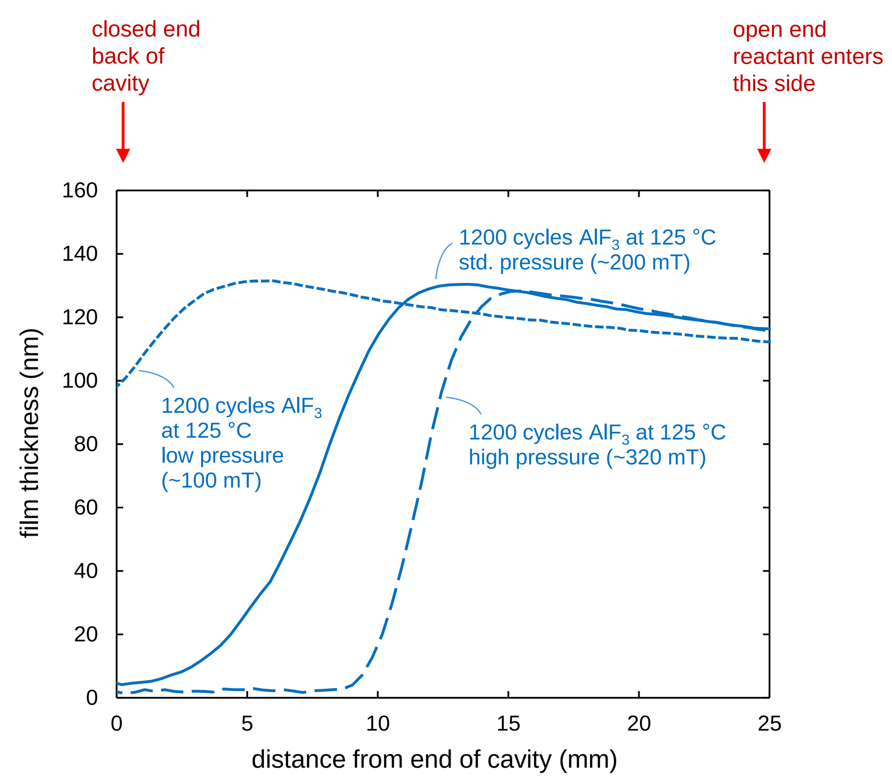

Fig. 5. Measured variation in AlF_3 film thickness as a function of distance into the cavity. The penetration depth can be varied by altering the height of the cavity or the working pressure of the process as shown here. Arbitrary positive slopes can be engineered by combining ALD cycles at different pressures.

We have used this approach for graded thin films of AlF_3 and Al_2O_3 and can extend to any thermal ALD process (e.g. HfO_2, SiO_2, MgF_2, LaF_3…)

IMPROVED THROUGHPUT FOR ULTRAVIOLET SPECTROSCOPY

The use of graded thickness coatings can create a minimum reflectance as a function of lateral position in order to match the spatial response of a detector system to the spectral dispersion of light in a spectrometer.

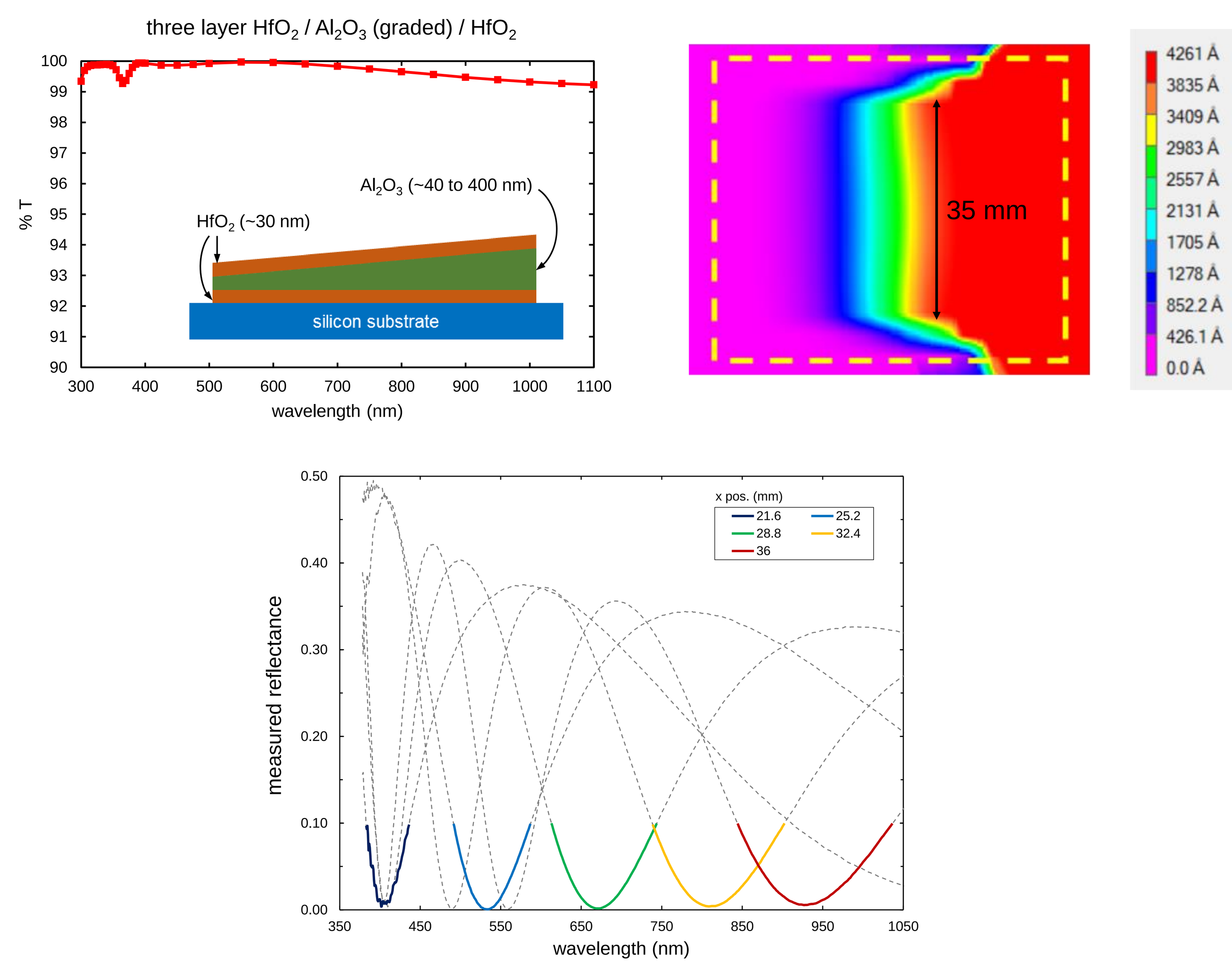

Fig. 6. (*upper left*) The modeled transmission (red curve) of the three layer AR coating on Si shown in the inset. (*upper right*) The measured spatial variation in Al_2O_3 thickness for this three layer coating deposited by the ALD cavity method on a Si wafer. (*bottom*) The measured spectral reflectance of the three-layer stack at various points along the graded direction.

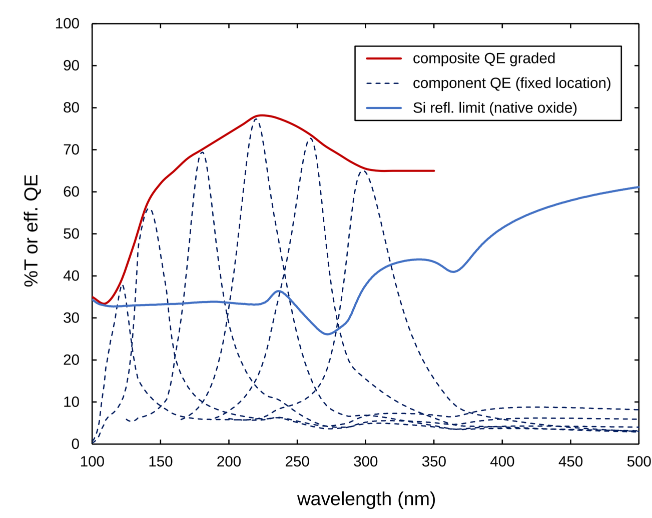

Fig. 7. Metal-dielectric structures that incorporate graded thickness can significantly improve throughput over bare Si devices in the FUV. The modeled QE shown here is for a simple three layer filter with a single graded layer of AlF_3 capped with uniform layers of Al and AlF_3.

REFERENCES

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