National Aeronautics and Space Administration

Detector Coatings for UV Imaging and Spectroscopy

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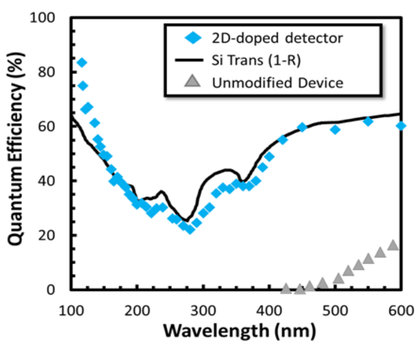
Delta-doped Silicon Detector Performance



JPL's delta-doped (2D-doped) Si detectors exhibit near 100% internal QE for reflection-limited response

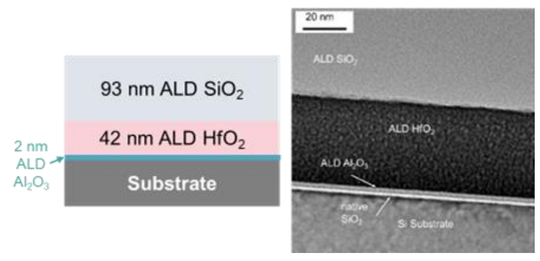
Response can be optimized with antireflection coatings. UV bandpass filters are also used for bandpass tailoring and optimization.

Atomic Layer Deposition for UV Coatings

Detector response is tailored/optimized for specific applications with AR coatings and UV bandpass filters

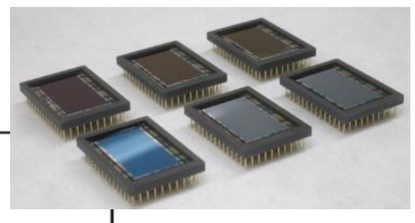
ALD is ideal for UV/optical film preparation owing to distinct advantages:

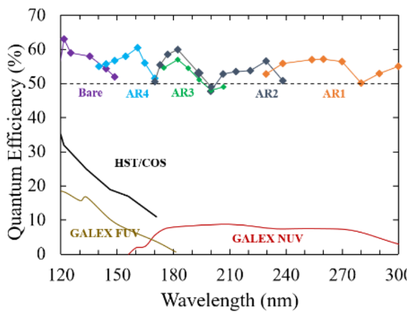
- Nanometer-scale control of film thickness
- Films are conformal and uniform
- Interfaces are sharp/well-defined



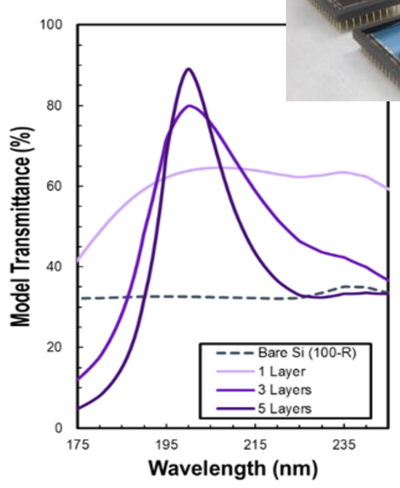
Antireflection Coatings

Specified wavelengths or bands for targeted applications can be optimized depending on coating materials and overall design

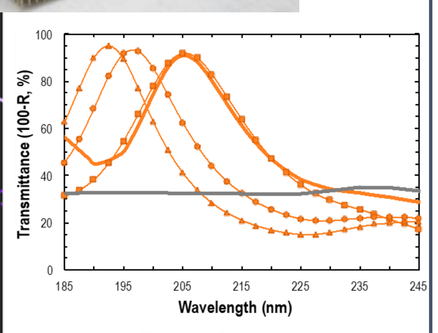




Simple, single layer coatings



More complex, multi-layer coatings

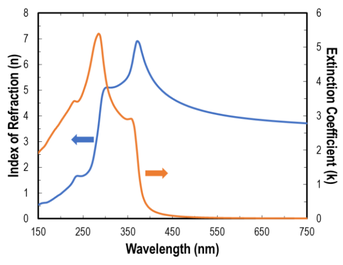


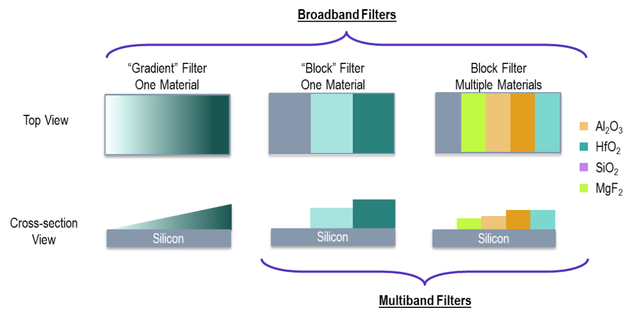
Tunable Bandpass

Nikzad, *et al.*, *Applied Optics*, **51** (2012) 365
Hamden et al., *JATIS* **2** (2016) 036003
Jewell et al., *Proc SPIE* **9601** (2015) 96010N

Coating Techniques for Spectroscopy Applications

The index of refraction of Si is highly variable in the UV; targeting different bandpasses requires different coatings

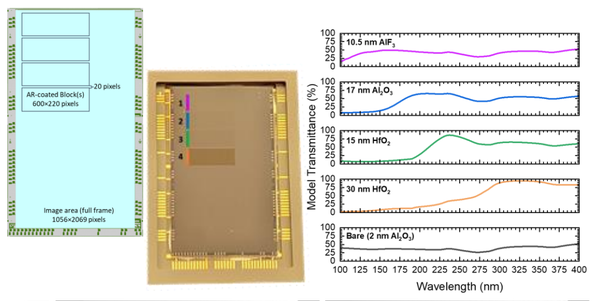


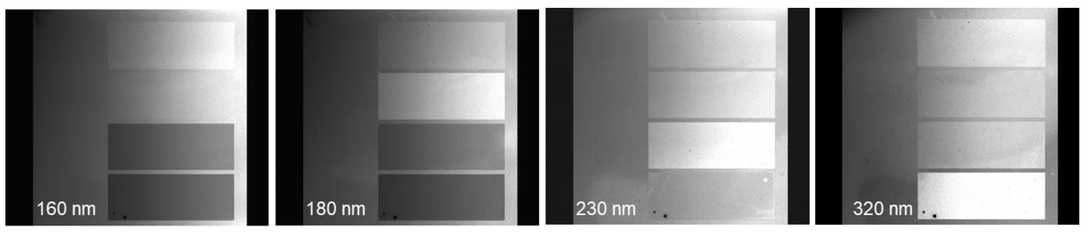


We have developed new coatings methods for preparing silicon detectors with patterned AR coatings for a spatially varying response spanning the ultraviolet (UV) and visible wavelength ranges.

Block Pattern –Prototype

- Four regions each with a unique AR coating
- The contrast/sensitivity of the individual AR coated regions varies as a function of wavelength
- The edges of the patterned regions look sharp/well-defined

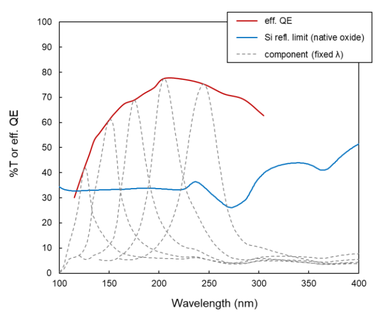




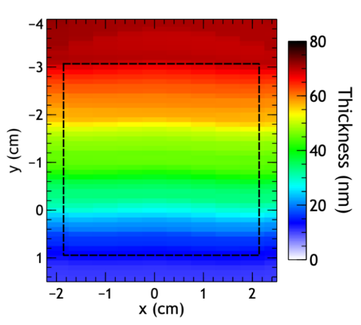
New Technology Report Number 52422; July 20, 2022

Gradient Thickness Coating

- A continuously graded thickness ALD layer can be achieved by deposition into a lateral cavity
- Can be combined with a metal-dielectric structure to create a variable wavelength optical cavity on a detector
- Can provide red rejection and order-sorting while preserving throughput
- Baselined for UVEX long slit spectrograph instrument



Model QE for FUV gradient thickness



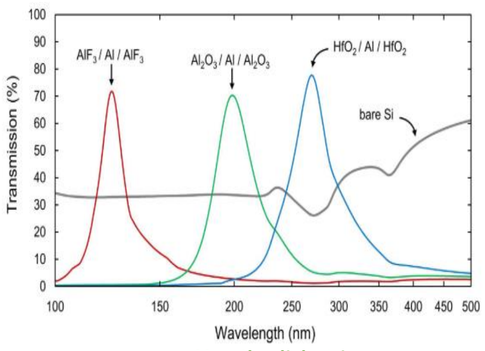
Measured thickness of a graded ALD AlF_3 coating (dashed line is 4x4 cm target area for UVEX detectors)

Device-Integrated UV Bandpass Filters

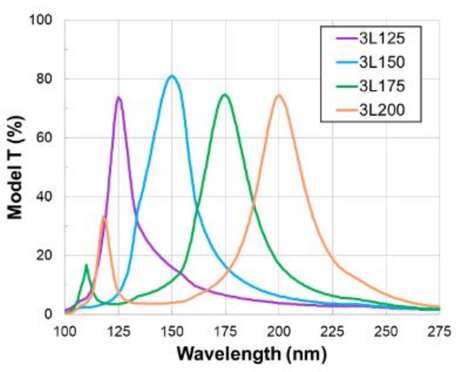
High UV throughput combined with out-of-band suppression, solar-blind UV detector with visible light rejection ratios >10^3

Tailorable bandpass selection

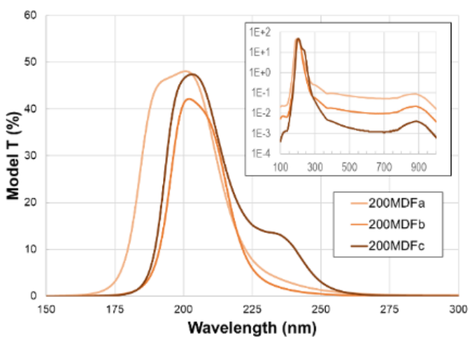
Eliminates the need for a separate filter element (T=30-40% for commercial UV filters)



Vary the dielectric



Vary only dielectric thickness



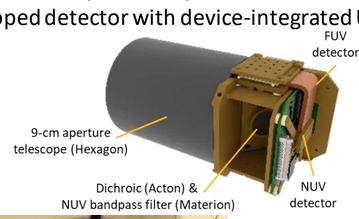
Vary number of layers and Al thickness

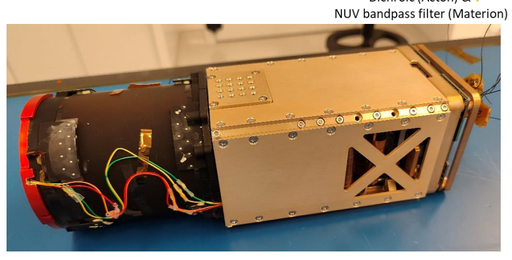
Hennessy et al., *Applied Optics* **54** (2015) 3507
Hennessy et al., *Proc SPIE* **10639** (2018) 106391P

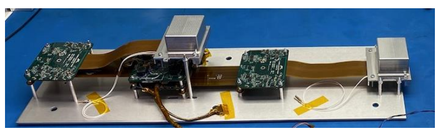
Recent Deliveries – SPARCS

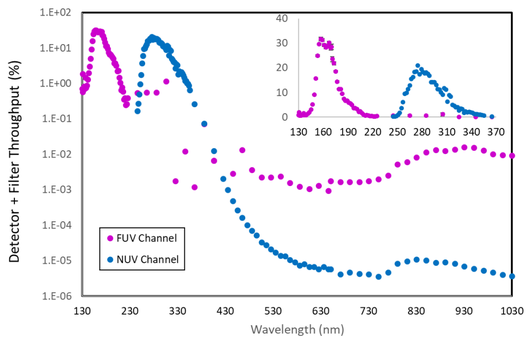
Star-Planet Activity Research CubeSat

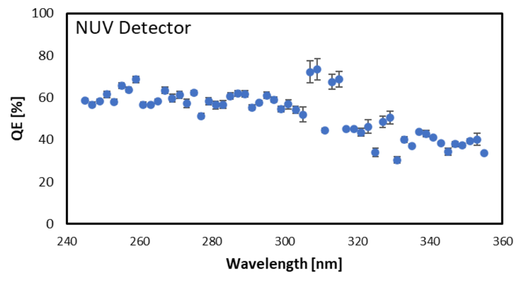
- NASA/APRA funded CubeSat, PI Evgenya Shkolnik (ASU)
- In October, JPL delivered SPARCam: two UV detectors optimized for SPARCS near UV (NUV) and far UV (FUV) bandpasses, along with readout electroncis
  - NUV Channel: delta-doped detector with AR coating; commercial UV bandpass filter (Materion)
  - FUV Channel: delta-doped detector with device-integrated UV bandpass filter (JPL)





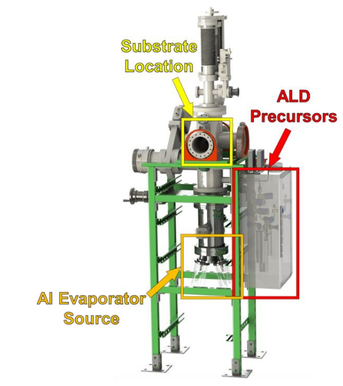






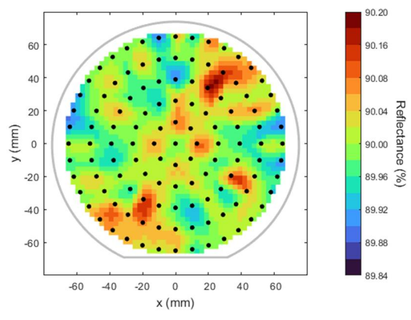
Coatings for Reflective Optics

- ALD MgF_2 has been used as an encapsulation layer for eLiF/Al mirror coatings
  - Recently implemented on optics for the SPRITE CubeSat and Aspera SmallSat missions
- ALD can also be used to deposit LiF, test samples meet the LUVOIR absolute reflectance requirements
- Provides an alternative coating route to conventional methods with relevance to HWO should uniformity requirements prove difficult to meet
- The use of atomic layer etching (ALE) allows independent optimization of the Al mirror coating and the fluoride protection layer
- ALD fluoride processes are being investigated at the meter-class via collaboration with UC Santa Cruz



Custom JPL tool for ALD and Al evaporation in the same vacuum chamber

- Reflectance map on 150 mm diameter substrate for ALD MgF_2/Al coating
- Mean reflectance at 450 nm = 90.0 %
- Uniformity (1σ) = 0.054 %



SPRITE CubeSat primary mirror 16 x 18 x 5 cm in the JPL ALD chamber

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