How unique optical coatings boost performance in the DUV and VUV

Grant Decastro & David Cook

Spectrum Scientific, Inc.

Introduction

The UV region covers the wavelength range from 100-400 nm sitting in the electromagnetic spectrum between the visible region and X-rays.

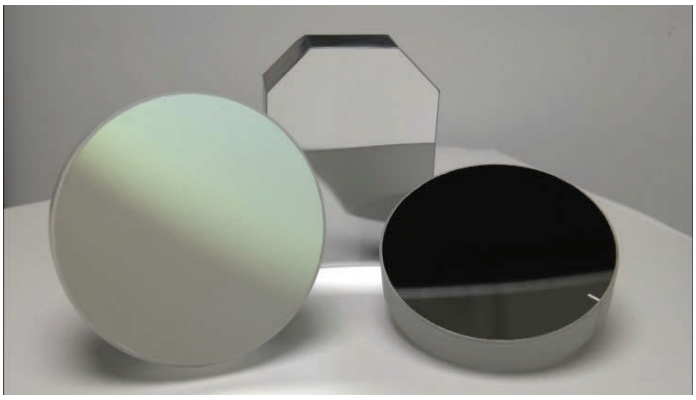
In physics, the UV range is generally split into four distinct regions: the near UV (400-300 nm), the middle UV (300-200 nm), the far UV (200-100) nm and extreme UV (below 100 nm).

For this white paper we are interested in the UV regions defined as the deep UV or DUV (200-280 nm) and the vacuum UV or VUV (100-200 nm).

DUV and VUV optics are used in many applications and although spectroscopy is one of the primary applications, they are also used in the study of electronic circuits, in high resolution microscopy and selective molecular imaging.

In June 2022, researchers reported using a label-free method of deep UV microscopy to monitor prostate cancer aggressiveness[1] and selective molecular imaging is now being used not just on Earth but to identify novel compounds and specific mineral elements in remote locations, including our Sun and far-flung stars and planets.

On August 31 of this year, NASA's MAVEN and the United Arab Emirates' EMM missions released joint observations of dynamic proton aurora events on Mars. The Imaging Ultraviolet Spectrograph (IUVS) observed Lyman α (121.6 nm) and Lyman β (120.6 nm) to discover proton aurora on Mars [2].



For a number of years, Spectrum Scientific, Inc (SSI) has manufactured high efficiency diffraction gratings, which using our proprietary blazing technique, offer high efficiency in the UV, as well as lower stray light compared to conventional ion etched gratings. We have also traditionally supplied a range of aspheric mirrors (off-axis parabolic, elliptical and freeform) operating down to 200nm.

However, in recent years with the advent of UV LEDs and miniaturised sensor technology driving applications further into the UV, we have been asked to provide mirrors that can operate successfully in the DUV and VUV regions. Initially, we outsourced our DUV and VUV coatings but as applications became more demanding, we struggled to find suitable coatings to meet the high reflectivity and throughput requirements that our customers were demanding, and started to develop DUV and VUV coatings in-house to meet this need.

[1] Soltani, S., Ojaghi, A., Qiao, H. et al. Prostate cancer histopathology using label-free multispectral deep-UV microscopy quantifies phenotypes of tumor aggressiveness and enables multiple diagnostic virtual stains. Sci Rep **12**, 9329 (2022).

[2] MAVEN and EMM Make First Observations of Patchy Proton Aurora at Mars (nasa.gov)

How unique optical coatings boost performance in the DUV and VUV

Spectrum Scientific, Inc.

Introduction cont...

After extensive development, we created a range of DUV and VUV coatings that exhibit around 10% higher reflectivity compared to other coatings available in today's market, leading to superior throughput and higher sensitivity for our customers.

This white paper provides more details on our range of VUV and DUV optical coatings.

Current technology

DUV and VUV lasers allow for advanced imaging capabilities. When coupled with improved sensor technology, they have led to increased interest in the DUV and VUV regions in a number of applications.

Many DUV and VUV optical systems are prone to suffering from low overall throughput. To overcome this issue, the sensitivity of the optical systems must be improved, requiring optical components with high-reflectivity coatings to provide the required level of sensitivity and mitigate any losses.

These optical coatings are comprised of a combination of thin material layers and are used to enhance specific properties of an optical component. The composition of an optical coating affects its performance where the number of layers, layer thicknesses, and refractive indices all have an effect.

The right optical coating is not always available in the DUV and VUV regions. There are a limited number of potential coating materials capable of transmitting or reflecting short DUV wavelengths. Metal oxide compounds are a popular choice, with SiO_2 and Al_2O_3 both transmitting at around 225 nm.

But as we move to shorter wavelengths, absorption limits the transparency and laser damage-resistance of oxide coatings.

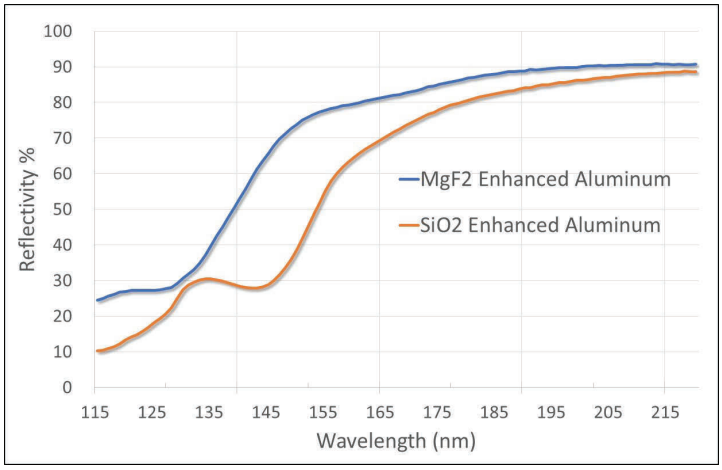


Fig 1: DUV Reflectivity Curves for Enhanced Aluminum with MgF_2 and SiO_2 overcoat

At the sub-200 nm VUV range, the choice and capabilities of optical coatings further reduces. Users struggle to find coating processes and products with the required level of cost effectiveness, fidelity and agility to work across a wide range of optical surface geometries, sizes and dimensions.

How unique optical coatings boost performance in the DUV and VUV

Spectrum Scientific, Inc.

Our solution

Spectrum Scientific, Inc (SSI) has recently launched a range of optical coatings to meet the market need for increased reflectivity and sensitivity in the DUV and VUV, allowing users to unlock new applications in these spectral regions.

Our VUV optical coatings are available from 120 to 200 nm. They are predominantly used in the field of spectroscopy and analytical instrumentation, chemical analysis and space astronomy but can be used wherever high DUV or VUV sensitivity is required.

In an optical system, **throughput** = R^n where **R** is mirror reflectivity and **n** is the number of mirrors in the system, illustrating that the more mirrors there are in an optical system, the higher the overall loss of throughput, leading to a significant loss of photons by the time you reach the sensor for multi-component systems.

Typically our DUV and VUV coatings provide superior reflectivity (figure 2), around 10% higher compared to other optical coatings in the market and as shown in the throughput formula, this increase in reflectivity is critical where high throughput and high sensitivity are required.

With advancing miniaturisation of optical instrumentation, incorporating smaller light sources and detectors, and the hunt for weaker signals, a 10% increase in the reflectivity of each mirror can be critical to successful measurements.

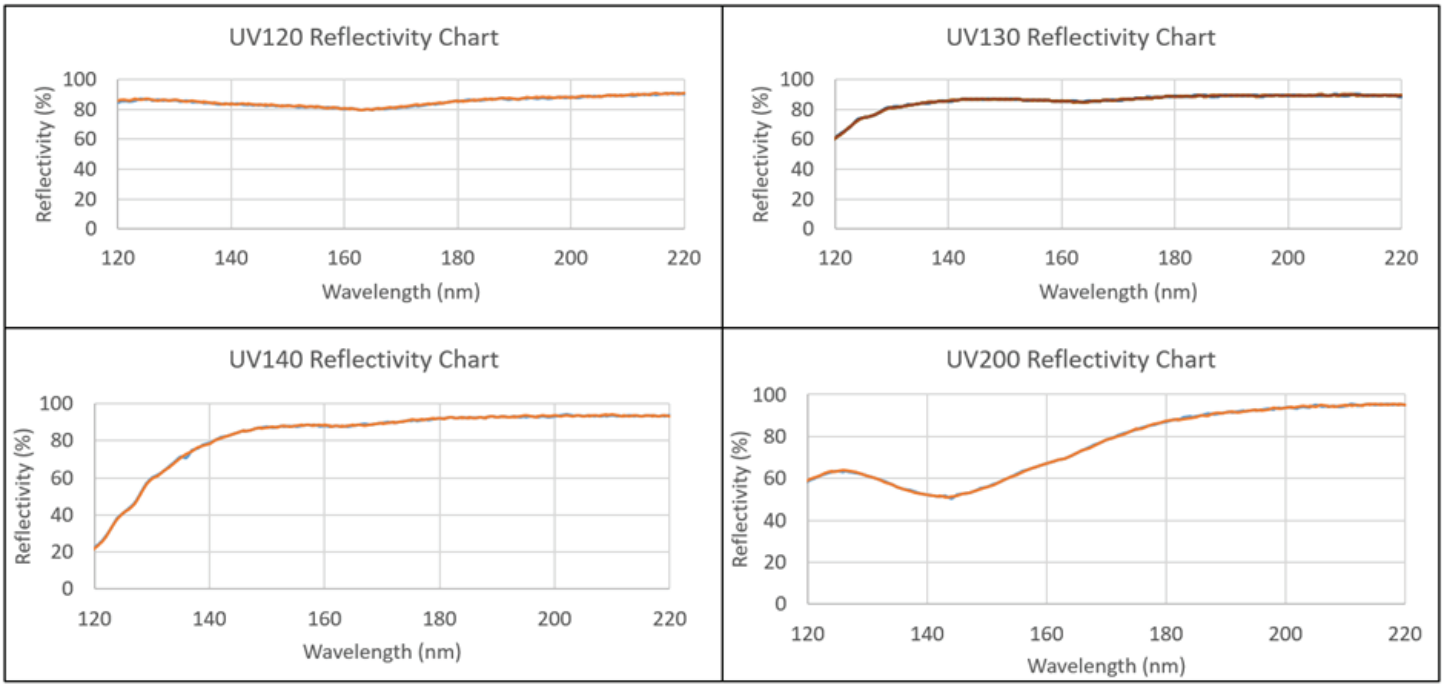


Fig 2: Reflectivity of SSI VUV coatings. Reflectivity data collected from a McPherson VUVAS-1000 Spectrophotometer.

How unique optical coatings boost performance in the DUV and VUV

Conclusion

SSI's DUV and VUV coatings offer a step change in reflectivity, allowing higher throughput in multi-element optical instrumentation, increasing throughput and sensitivity.

In conjunction with our ability to manufacture high volume aspheric mirrors and UV enhanced diffraction gratings, SSI offers a true UV capability to our customers, unmatched by other suppliers.

About Spectrum Scientific

Spectrum Scientific, Inc (SSI) has been manufacturing high volume flat, aspheric and freeform reflective optics, hollow retroreflectors and holographic diffraction gratings since 2004.

We primarily use the optical replication process allowing us to supply high fidelity, high specification precision optics at a lower cost compared to traditional volume manufacturing.

One of our key capabilities is the manufacture of freeform optics, off-axis paraboloids and ellipsoid mirrors with surface figures down to λ/10 or better. We also manufacture plane, concave and convex holographic diffraction gratings, which can be supplied as blazed gratings using our proprietary blazing technique, which not only offers high efficiency in the UV, but lower stray light compared to conventional ion etched gratings.

Spectrum Scientific is ISO 9001:2015 certified and RoHS compliant and our production and test areas are space qualified offering a silicone free production environment where we can replicate reflective optics for space borne telescopes and optical interconnect systems.

Fig 3: SSI Ion Beam Coating System

We have supplied a number of ultra-low stray light gratings for a number of high profile projects, including the Orbiting Carbon Observatory (OCO) and Ozone Mapping Profiler Suite (OMPS).

WP - OC20221025

Spectrum Scientific, Inc
16692 Hale Avenue
Irvine, CA 92606, USA

+(800) 774 0334
+1 949 260 9900

sales@ssioptics.com
ssioptics.com