

The characterization of optical components using the Cary Deep UV spectrophotometer and 'VW' specular reflectance accessory

Application Note

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Abstract

Deep UV spectra of magnesium fluoride coated optical components have been acquired using a Cary Deep UV spectrophotometer and 'VW' specular reflectance accessory. Measurements were made in an inert atmosphere using a nitrogen-purged glovebox. Samples were characterized over the wavelength range 140 to 250 nm, with significant differences observed between samples produced using different coating methods. The ability of the Deep UV spectrophotometer to acquire high quality UV spectra down to 140 nm is clearly demonstrated.

Introduction

The 'conventional' UV-Vis spectral range incorporates the UV and visible portions of the electromagnetic spectrum from 190 to 900 nm. The short wavelength limit of conventional instruments is defined by the absorption of ultraviolet wavelengths below 190 nm by atmospheric gases. Purging such instruments with dry nitrogen will extend this limit to 175 nm. Working below this wavelength has traditionally required the use of vacuum based techniques.¹

By combining instrument inert gas purging with an appropriate source, optics and detector, the useful working range of UV-Vis spectrophotometers can be extended into the deep UV (DUV; < 175 nm) without the need for vacuum based systems. In this way, DUV research and metrology requiring high performance spectrophotometers can be performed in a relatively straightforward manner, without the additional complexity and expense of vacuum systems.



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The Cary Deep UV is based on the standard high performance Cary spectrophotometer series. However, to allow measurements below 175 nm, a number of important changes and modifications are made.

These include:

- Magnesium fluoride coated optics
- Magnesium fluoride windowed deuterium lamp and solar blind detector
- Dual 1200 line/mm gratings (blazed at 150 nm)

The spectrophotometer is situated in an inert atmosphere chamber or glovebox (Figure 1) capable of maintaining less than 1 ppm oxygen and moisture, allowing measurements down to 140 nm to be routinely made. These can be simple absorbance/transmittance measurements, or more complex reflectance based measurements. Using an absolute 'VW' Specular Reflectance Accessory (SRA), this study aimed to acquire and compare spectra of magnesium fluoride coated optical components supplied by different manufacturers.

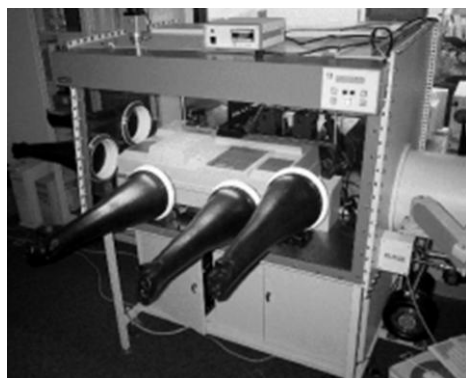


Figure 1. The Cary Deep UV and nitrogen-purged glovebox

Theory

The 'VW' absolute SRA is designed to measure 'mirror-like' reflectance from a sample surface. In addition to absolute measurements, samples can be placed in both beams, allowing comparative measurements. The accessory uses a modification of the 'VW' configuration first described by Strong.² This method calculates absolute specular reflectance by using a pair of matched mirrors as comparison mirrors to perform the calibration and measure the sample reflectance. Whereas this method relies upon a perfectly matched pair of reference mirrors, the Cary 'VW' absolute SRA uses one mirror on a movable 3-pin mount for both the calibration and sample reflectance measurements (Figure 2). This eliminates the need for expensive, perfectly matched reference mirrors.

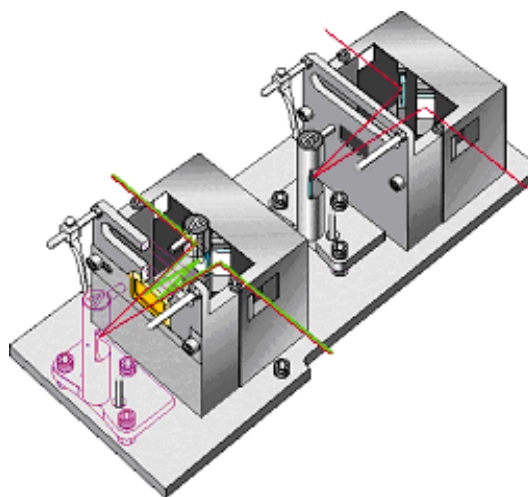


Figure 2. Optical diagram of the Cary 'VW' Absolute Specular Reflectance Accessory

The SRA features a dual 'VW' configuration, with one spherical mirror, and two toroidal mirrors per beam. The movable mounting of the spherical mirrors allows them to be used for both calibration and sample measurement. Hence, the same optical components are in the light path during both calibration and measurement. When a sample is mounted, the only change in the system is due to the reflectivity of the sample, and an absolute value of the reflectance is obtained. The dual 'VW' configuration also permits direct comparison measurements. A reference sample may be placed in the rear position and an unknown sample in the front position. In this manner, the sample can also be directly compared to the reference.

Materials and methods

(For part numbers please see Reference 3)

Equipment

- Cary Deep UV Spectrophotometer
- 'VW' Absolute Specular Reflectance Accessory
- Cary 400/500 Extended Sample Compartment
- IT purged glovebox (Innovative Technology, Massachusetts USA)

Protocol

The 'VW' SRA was installed into the Cary Deep UV and aligned.⁴ The 'Scan' software was opened and the appropriate operating parameters set in the 'Cary' window (Figure 4). In addition, the 'SBW' (spectral bandwidth; nm), 'Beam mode', 'Slit height' and 'Source' were set to '5.000', 'Double', 'Reduced' and 'UV' respectively in the 'Options' window. Finally, 'Zero SRA' correction was selected in the 'Baseline' window.



Figure 3. Instrumental parameters for optical coating measurement

Spectra of three magnesium fluoride coated optical components were acquired in duplicate. In each case, the samples were positioned using the sample clip supplied with the 'VW' accessory. The 'Zero SRA' correction was performed prior to the acquisition of sample spectra in order to set 0 and 100 %T values.

Results and Discussion

Magnesium fluoride (MgF_2) has a number of properties that make it ideal for use as a coating in optical components. These include its hardness, and resistance to mechanical and thermal shock. MgF_2 has a useful transmission range of 0.11-7.5 μm (110-7500 nm) so, not surprisingly, is used for optical components in the ultraviolet and infrared. For the manufacture of coated optical components, the reflectance properties of the final product are of obvious importance. In particular, the optimum wavelength and useful wavelength range of the coating are vital.

Absolute specular reflectance spectra of the three optical components investigated can be seen in Figure 4. All three samples are magnesium fluoride coated but obvious differences in the reflectance spectra exist. This is most probably attributable to the particular coating process involved in each case.

Of note is the different reflectance properties exhibited by mirrors 1 and 2, both supplied by the same manufacturer but having almost opposite reflectance properties in the regions of 164 and 225 nm respectively. Mirror 3 shows a much smoother reflectance profile than mirrors 1 and 2. The excellent reproducibility obtained for duplicate scans of each sample demonstrates the exceptional performance of the Cary 'VW' absolute SRA.

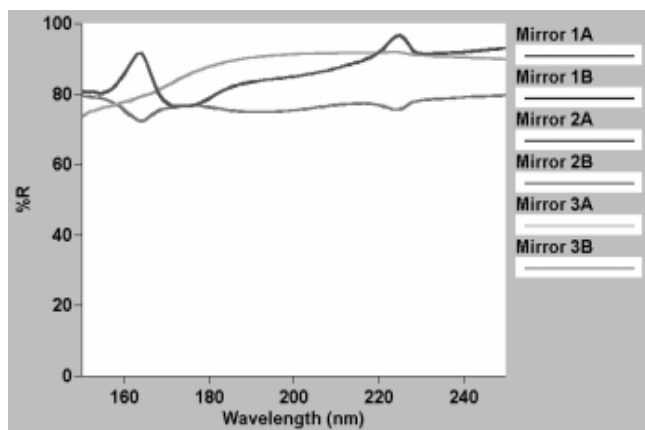


Figure 4. Absolute specular reflectance spectra of the three optical components investigated.

Conclusion

Using a Cary Deep UV spectrophotometer, 'VW' specular reflectance accessory, and nitrogen-purged glovebox, the reflectance properties of three magnesium fluoride coated optical components were investigated.

Samples were characterized over the wavelength range 140 to 250 nm, with significant differences observed between samples produced using different coating methods. The ability of the Cary Deep UV to acquire high quality spectra down to 140 nm also makes it ideal for use in the investigation and characterization of next-generation microlithography and semiconductor components and processes.⁵

References

1. Perkampus, H-H., 'Encyclopedia of Spectroscopy', VCH, **1995** (ISBN 3-527-29281).
2. Strong, J., 'Procedures in Experimental Physics', 1st Ed., Prentice-Hall, Inc., New York, **1938**, 376.
3. Part Numbers:

| Product | Part Number |
|--|--------------|
| Cary Deep UV Spectrophotometer | 00 100783 00 |
| 'VW' Absolute Specular Reflectance Accessory | 00 100438 00 |
| Cary 400/500 Extended Sample Compartment | 00 100466 00 |

4. Cary WinUV Scan Software, 'Cary Help', Version 2.0
5. Hind, A.R., 'R&D at the deep end', *Chemistry in Australia*, 68(4) **2001** 12.

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