Specular measurements on high and anti-reflective coated samples with the relative and absolute specular reflectance accessories LAMBDA 800 UV/VIS and LAMBDA900 UV/VIS/NIR spectrometers

Introduction
Radiation reflected from a solid surface can be described in terms of its diffuse or specular characteristics. In this note we will discuss the techniques used to analyze the specular reflected component.

The specular component results from surface reflection, is measured at the angle of incidence, and can be called the “mirror-like” reflected radiation. In fact, the word “specular” originates from speculum, the Latin word for mirror. The specular component of light is of interest since it is a measure of the mirror quality of a reflective surface. For precision optical surfaces the greater the specular reflection component relative to the diffuse component, the higher the degree of polishing of the surface of reflectance.

Specular reflectance measurements provide valuable information regarding the optical material, surface structure and performance. As an example, the specular reflectance component of a polished flat surface is a measure of the uniformity and light-reflecting properties of the optically high reflective and anti-reflective coatings of that flat surface.

The interference pattern generated by the interaction of the front and back surface reflections of thin coatings can be used to determine the actual film thickness of the coating. The thickness of the coating must be on the same order of magnitude as the wavelength of incident radiation and the various angles of incidence you are measuring so the interference pattern can be generated.

The reflectivity of many optically high and low reflective coatings is a function of the angle of incidence of the source light. For this reason specular reflectance measurements are commonly used to characterize the performance of optical components from anti-reflective surfaces, high-flux laser mirrors, solar collectors, thermal insulation, optical films such as multilayer dielectric coatings, and even standard reference mirrors.

These measurements can be difficult for very low reflectance values (of the order of 0.1%) and even with very high reflectance values (of the order of 99%), such as those found in anti-reflective and highly reflective coatings respectively. The precise and accurate measurement of these large flux ratios requires a high sensitivity and wide dynamic range such as the Lambda 800/900 UV/Vis/NIR Spectrometer offers.

The Lambda 800/900 spectrometers and wide a variety of flexible and user-friendly specular reflectance accessories provide the perfect measurement platform. Couple that with the experience of the leader in innovative solutions for the optics industry and you have a new dimension in spectroscopy capabilities.
**Background**

Specular reflectance is defined as the ratio of the reflected radiation to the incident radiation, in which the angle of reflection is equal but opposite to the angle of incidence. In theory, the specular component of radiation can be measured in absolute reflectance, in which case no standard is used or relative reflectance, which is dependent on a reference standard.

Absolute measurements of specular reflectance provide the true "absolute" amount of radiation. The various types of absolute specular reflectance accessories described in this paper are designed to avoid any potential pitfalls of relative methods, such as instability or contamination of the specular reference standard. These types of absolute accessories are different in the optical design, but all have the same theoretical background. They use the identical optical light path and reflectance surfaces (mirrors) in baseline and sample positioning, so that the ratio of these signals gives the sample's absolute specular reflectance.

The following absolute specular reflectance accessories are available for the Lambda 800/900:

- Near Normal Fixed Angle Absolute Specular Reflectance Accessory "VW" Technique (Part Number: PELA-1029)
- Near Normal Fixed Angle Absolute Specular Reflectance Accessory "VN" Technique (Part Number: N101-6008)
- 15° Fixed Angle Absolute Specular Reflectance Accessory "VN" Technique (Part Number: N101-6015)
- 30° Fixed Angle Absolute Specular Reflectance Accessory "VN" Technique (Part Number: N101-6030)
- 45° Fixed Angle Absolute Specular Reflectance Accessory "VN" Technique (Part Number: N101-6045)
- 60° Fixed Angle Absolute Specular Reflectance Accessory "VN" Technique (Part Number: N101-6060)
- Variable Angle Absolute Specular Reflectance Accessory (Part Number: PELA-1030)

The difference between these accessories is in the angle of incidence and their optical design. The angle of incidence is of interest for many applications such as high-reflection laser-flux mirrors or antireflective coatings. Near normal incidence makes the measurement relatively insensitive to instrument polarization effects and to angle of incidence effects of the monochromatic radiation. Higher angles of incidence are very sensitive to the effects of instrument polarization. For this reason, the Lambda 800/900 offers as an option, software-controlled Common Beam Depolarizer, which is used to eliminate such polarization effects.

Figure 1 shows a schematic of the optical layout of the Near Normal Fixed Angle Absolute Specular Reflectance Accessory with the "VW" design by Strong. The difference is in the angle of incidence for this accessory is 7.5°. The baseline correction (or establishment of the 100% line) is performed using the "V" configuration of the accessory.

The specular sample is introduced into the Sample Position and the "V" mirror is moved to the "W" position. The only difference between the optical path of the sample and that of the baseline is two reflections off the sample; thus, the result obtained is the square of the reflectance of the sample. This is related to a disadvantage for this optical layout from the signal-to-noise at low reflectance measurements (<0.3%, Figure 12). The reading converted back to reflectance gives the absolute specular reflectance of the sample.

Figure 2 shows a schematic of the optical layout of the Fixed Angle Absolute Specular Reflectance Accessory with the "VN" design. The angle of incidence for this accessory is 8°. The baseline correction (or establishment of the 100% line) is performed using the "V" configuration of the accessory. The specular sample is introduced on the fixed Sample Position, the last mirror (M3) is turned over to the "N" position and the "V" mirror (M2) is moved to the front "N" position. The advantage of this design is the single bounce on the sample, which results in better signal-to-noise at low and high-reflectance measurements. The minimum size of the sample is 25 mm x 25 mm (1-inch diameter).

![Figure 1. Schematic of optical layout for Near Normal Fixed Angle Absolute Specular Accessory VW design.](image-url)
The direct measurement is the absolute specular reflectance of the sample. No calculations are required as with the VW design.

Figure 3 shows a schematic of the optical layout of the Variable Angle Absolute Specular Reflectance and Variable Angle Transmittance Accessory, which provides absolute reflectance measurements at user-selected incident angles from approximately 10° to 70°. Transmission measurements are possible from 0° to ~60°.

This accessory is designed to measure the absolute reflectance of high and anti-reflective coated surfaces. This design is advantageous for optical research at variable angles of incident light.

The relative method to measure specular reflectance radiation has a direct correlation to the optical performance of the reference standard used. Thus, the measurement gives referenced values rather than absolute values of reflectance. The method is simpler and is correlated to the accuracy of the calibration standards. The relative specular reflectance measurement should be taken under the same condition as the standard calibration values to satisfy the same angle of incidence and polarization effects.

The following relative specular reflectance accessories are available for the Lambda 800/900:
- Near Normal (6°) Fixed Angle Relative Specular Reflectance Accessory (Part Number: B008-6703)
- 45° Fixed Angle Relative Specular Reflectance Accessory (Part Number: PELA-1025)
- 80° Grazing Angle Relative Specular Reflectance Accessory (Part Number: PELA-1026)
- Variable Angle Relative Specular Reflectance Accessory (Part Number: B013-7314)

The 6°, 45°, and 80° Fixed Angle Relative Specular Reflectance Accessories are used to determine the reflectivity of samples relative to a reference standard surface.

Figure 4 shows a picture of the Near Normal Relative Specular Reflectance Accessory. The angle of incidence for this accessory is 6°. The baseline correction (or establishment of the 100% line) is performed using a reference standard. The sample is positioned on an upward viewing port and held in position by gravity. The data obtained with a relative specular reflectance accessory is a function of the standard used in the baseline establishment.

Since a standard NIST (National Institute of Standards and Technology) SRM 2003 mirror is used for baseline calibration, the measured reflectance of the sample is corrected relative to this standard. For reflectance determinations independent of a standard, the absolute specular reflectance should be used. Figure 5 shows a typical surface reflectance curve from a first surface aluminum mirror. The low reflectance at approximately 900 nm is dependent on the aluminum coating of the first surface aluminum mirror on glass (SRM 2003).
If the specular surface is a calibrated standard mirror, then the absolute reflectance of a given sample can be determined by multiplying, point by point, the measured analytical data by the standard mirror data. This should be done with care as described earlier; reflectance is a function of the angle of incidence and the polarization effects. For these types of samples the measurement must be performed under the same conditions as were used when obtaining the standard calibration data. For the SRM 2003 reference mirror noted it is specified at near normal angle of incidence.

References