

# Specular Reflectance Accessory Function, Operation and Application

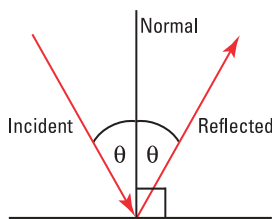
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## Introduction

Specular reflectance is “mirror like” reflectance off a surface. In this kind of reflectance, the reflected beam comes off the mirror at the same angle as the incident beam.

Even metal mirrors are not perfect. There is always some degree of *diffuse* reflectance and some level of absorbance. For example, if you shine a flashlight at a mirror you can see the image of the beam on the mirror surface even though you are not looking into the full force of the reflected beam. What you are seeing is diffusely reflected light. Similarly, while we think of a typical building window as being transparent, we can also see reflections in the window glass if it isn't back-lit. The *transparent* glass has a *specular reflective* component to its optical properties.

In the simplest cases, specular reflectance accessories (SRAs) enable measurements of how good a mirror is at reflecting light at a particular angle and how *bad* a window is about reflecting rather than passing light at a particular angle. Higher level applications involve coatings that may be tuned to reflect certain wavelengths and pass others, or to attenuate some wavelengths while completely reflecting or passing others. Specular reflectance spectra may also be used to calculate the thickness of thin films deposited on surfaces.



## Definitions

**Specular Reflectance** – reflectance off a mirror-like surface

**Diffuse Reflectance** – reflectance off a matte surface

**Relative Reflectance** – most accessories described here measure reflectance *relative* to a standard mirror used to collect a baseline. This means that a measurement of “90%R” means that the sample reflects 90% as much light as the reference, not that it reflects 90% of incident light. It also means that sample measurements of >100%R are reasonable, implying that the sample is *more* reflective than the reference mirror.

**Normal** – the angle 90° to a plane

**Near Normal** – reflection at an angle  $\leq 10^\circ$  from the normal

**Grazing Angle** – reflection at an angle  $\geq 80^\circ$  from the normal – i.e. within 10° of the plane of the surface.

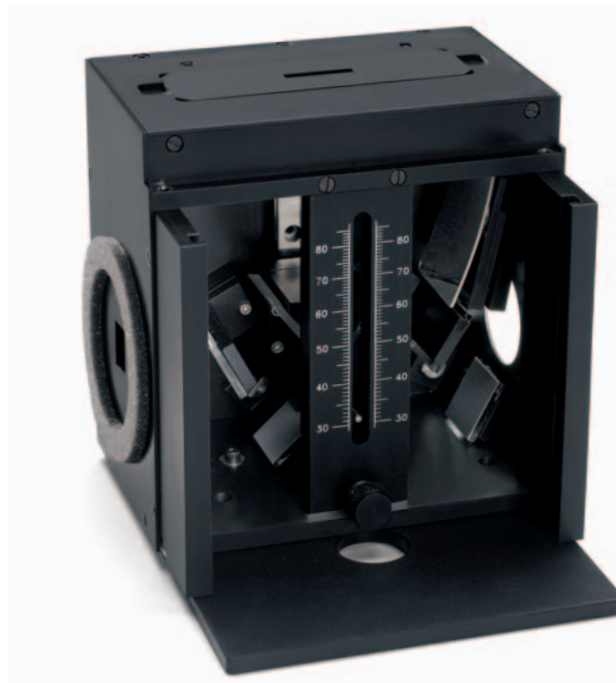


Figure 1: The VeeMAX™ variable angle SRA

For an optical system using mirrors to direct light, light absorbed rather than reflected by the mirror is converted to heat. In high power applications, this can lead to heating and failure of the mirror. Mirror suppliers and purchasers including manufacturers of lasers, spectrophotometers, and lighting reflectors such as vehicle headlights use SRAs to test the efficiency of their mirrors.

## Background

The reflectance of a mirror often varies as a function of both the incident angle of the light beam and the wavelength of the light. For example:

- Gold mirrors, used extensively in the *infrared* industry, are inappropriate to UV-Visible spectrophotometry because they absorb strongly below 600 nm.
- Aluminum mirrors reflect well through the visible region but require a  $MgF_2$  coating to enhance their reflectivity in the UV.
- Dielectric mirror coatings can be manufactured to reflect certain wavelengths at certain angles. For example, at 0° and 45°, dielectric Nd:YAG laser-line mirrors are available with 99.7% reflectivity 50 nm either side of 532 nm and 1064 nm, but no reflectivity at all outside these ranges.

## Key Words

- Grazing Angle
- Low Reflectance
- Mirrors
- Near Normal
- Optics
- Reflectance
- Specular
- SRA
- UV-Visible Spectrophotometry
- Variable Angle

Scientists need accessories that give them access to the angles at which they need to test mirrored surfaces. They can accomplish this by purchasing one or several fixed angle SRAs or, if the angles of interest fall within its 30°- 80° range, the VeeMAX variable angle SRA.

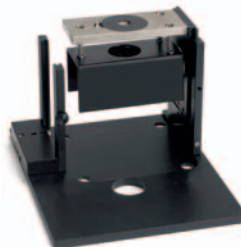
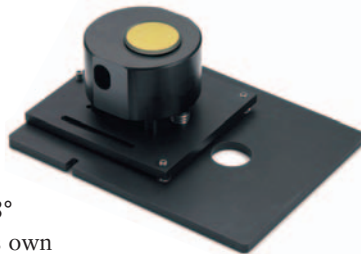
The area of the reflective surface that is analyzed may be varied by choosing one of a series of masks supplied with each accessory. Note, however, that as the incident angle moves from near zero to near 90°, the spot size of the beam on the sample increases. This means that a mask with a larger opening is necessary to pass enough light to achieve good signal to noise or, at grazing angles, to make the measurement at all.

### Fixed Angle SRAs

Thermo Fisher Scientific markets a series of fixed angle *relative reflectance* SRAs in angles ranging from 8° *near normal* to 85° *grazing angle*. The 8° accessory comes with its own Evolution™ 300/600 UV-Visible spectrophotometer baseplate and mounts directly into the kinematic mount of the sample compartment. The sample mounts on top of the accessory as shown in the picture above. It is supported on three small ball-bearings to reduce surface contact and minimize potential for damage to the surface.

Additional Thermo Scientific fixed angle SRAs available in 15°, 20°, 30°, 45°, 60° and 85° angles mount in a solid sample holder inside the sample compartment. Like the 8° SRA, these accessories measure reflectance relative to a reference mirror included with the accessory. They also ship with a series of masks that allow the user to measure different areas of a surface.

A fixed near normal (10°) *absolute specular reflectance accessory*, is also available from Thermo Fisher Scientific for the Evolution 300 spectrophotometer. The VN is designed to keep the light path the same length in both the “V” and the “N” position. A 100%R baseline is collected in the “V” position using all the mirrors in the accessory. Upon switching to the “N” position, the only net change is the addition of the sample mirror to the light path. No change in experimental conditions between the 100%R baseline and the sample scan *other* than inclusion of the sample mirror means that the scan records the absolute reflectance of the test mirror.



### Variable Angle SRA

The VeeMAX SRA (Figure 1) is adjustable from 30° to 80°. Where the fixed angle SRAs use two flat fixed mirrors, the VeeMAX utilizes curved fixed mirrors and movable flat mirrors to allow the user to select the incident light angle. The VeeMAX operates with the sample compartment open.



A light-sealed tube is supplied with the accessory for placement in the reference beam. The VeeMAX fits across the sample compartment between the sample beam port and the detector port. It has an attached Evolution 300/600 baseplate to ensure proper mounting position. A sliding cover on the front of the VeeMAX gives access to the adjustment mechanism and excludes light from the accessory during measurement. VeeMAX allows a choice of three mask sizes and ships with a UV enhanced aluminum reference mirror.

While the VeeMAX allows the user to choose any reflectance angle from 30° to 80°, its longer light path and large number of mirrors mean greater signal attenuation than is found in the fixed angle SRAs. The flexibility to select multiple angles with one accessory must therefore be weighed against performance criteria when choosing among the relative reflectance SRA options.

### Specular Reflectance Applications

Practical applications of *near normal* reflectance measurements include testing laser cavity mirrors. Other dielectric mirrors including bandpass mirrors and lens coatings intended to reflect rather than absorb particular wavelengths might also be tested at near normal angle. Larger volume applications include selective wavelength mirrors such as rear-view mirrors in cars that should not reflect “glare” of following headlights, and anti-reflective coatings in markets such as picture-frame glass and windows for office buildings that should be *hot mirrors*—i.e. they reflect infrared (heat) while passing visible wavelengths.

Specific angle measurements are necessary to qualify mirrors in optical systems for both research and production instruments, and also to test the same kind of coatings mentioned above at a variety of angles.

Specular reflectance measurements yield information on the amount of *gloss* in a paint according to ISO 2813:1994<sup>1</sup> and the degree of polishing of lenses or mirrors.



Thickness calculations on thin surface films are also possible using a SRA. Spectra of films show a sinusoidal wave pattern with a period that increases with wavelength. The equation

$$d = \frac{m}{2D_n \sqrt{(n^2 - \sin^2 \theta)}}$$

where:

- $d$  = film thickness
- $m$  = number of fringes (peaks) in wavenumber region chosen
- $n$  = refractive index of the film
- $\theta$  = angle of incidence
- $D_n$  = wavenumber region used

describes the relationship between film thickness, refractive index and number of fringes over a given wavenumber region. Note the importance of expressing the x-axis in the frequency scale *wavenumber* (cm<sup>-1</sup>) when using this equation.

## Experimental Methods

For all the relative reflectance accessories, a reference mirror is first placed reflective face down over the mask and a baseline spectrum is recorded as 100% reflectance. Depending on the application, measurements may be made at specific wavelengths or as a scan across a wavelength range. The 100%R baseline should be followed by a 0%R baseline recorded with no mirror over the mask opening and a closed sample compartment.

Measure the sample by placing it face down over the mask opening and recording the reflectance spectrum. If a *calibrated* mirror<sup>2</sup> was used to record the 100%R baseline, the calibration factors listed in the calibration certificate supplied with the mirror may be imported into VISION™ software. The software interpolates values between the calibrated wavelengths and adjusts sample data for the calibration constants as it is collected.

## Results

An example reflectance spectrum obtained on the VeeMAX SRA is reproduced in Figure 2. The sample was a *45° cold mirror*. This is a dielectric mirror intended to reflect visible light and pass infrared light at 45°. The VeeMAX data clearly demonstrates this property, showing reflectance starting to cut off at 700 nm to a level consistently below 11% above 750 nm.

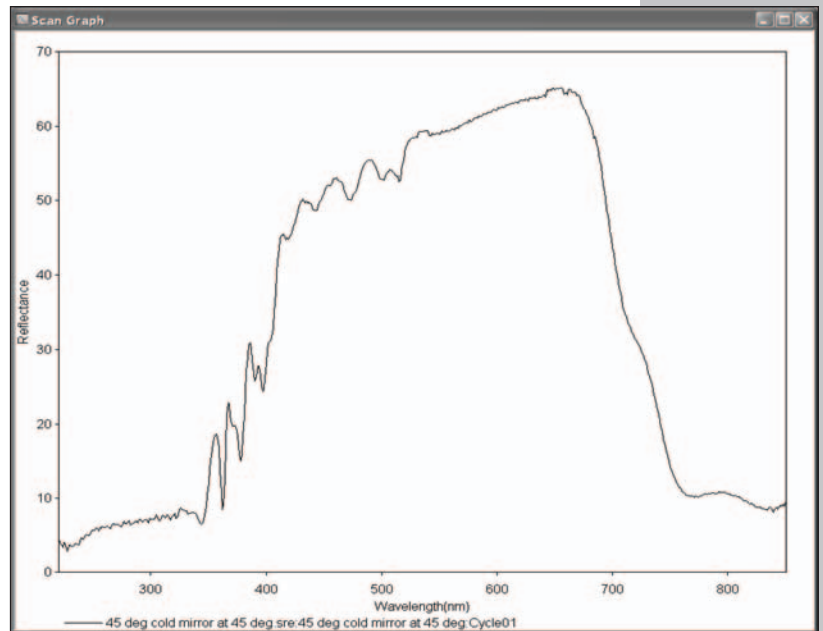


Figure 2: VeeMax spectrum of 45° cold mirror at 45°

## Conclusion

Fixed angle SRAs at 8°, 15°, 20°, 30°, 45°, 60° and 85° and the VeeMAX variable angle (30° to 80°) SRA facilitate collection of relative reflectance data in both the Evolution 300 and Evolution 600 spectrophotometers. The VN absolute SRA is available for both instruments to obtain absolute reflectance data at 10°. Thermo Scientific spectrophotometers and SRAs provide the full range and flexibility required to perform reflectance measurements at important angles and wavelengths from 190 nm to 1100 nm.

## References

1. ISO 2813:1994 specifies a test method for determining the specular gloss of paint films using a reflectometer geometry of 20°, 60° or 85°. The 60° geometry is applicable to all paint films, but for very high gloss and near-matt films 20° or 85° may be more suitable. The 20° geometry is intended to give improved differentiation between high-gloss paint films. The 85° geometry is intended to give improved differentiation between low-gloss paint films. The method is not suitable for the measurement of the gloss of metallic paints.
2. NIST no longer supplies calibrated mirrors as a stock part. Instead, they calibrate customer-supplied mirrors at customer specified angles. Calibration can be performed in the range 250 nm to 2500 nm at a cost of approximately \$4100.  
Certain third party vendors supply calibrated mirrors traceable to NIST calibrated standard mirrors. A list of vendors is available by calling NIST Calibration Services. Up to date contact information may be found at the NIST website.  
<http://ts.nist.gov/MeasurementServices/Calibrations/opticalproperties.cfm> (accessed Sept. 27, 2007).

## Ordering Information

Recommended system for specular reflectance analysis.

Description	Part Number
Evolution 600 PC-controlled spectrophotometer with VISION <sub>pro</sub> ™ Software	10600501
Evolution 300 PC-controlled spectrophotometer with VISION <sub>pro</sub> Software	10300201
Solid Sample Holder (to mount fixed angle SRAs 15° - 85°)	222-217200

### Relative Specular Reflectance Accessories

8° Near Normal specular reflectance accessory	222-244800
15° specular reflectance accessory (requires 222-217200)	222-233500
20° specular reflectance accessory (requires 222-217200)	222-233600
30° specular reflectance accessory (requires 222-217200)	222-219500
45° specular reflectance accessory (requires 222-217200)	222-219600
60° specular reflectance accessory (requires 222-217200)	222-233700
85° specular reflectance accessory (requires 222-217200)	222-233800
VeeMAX variable angle SRA, 30° - 80°	222-239600

### Absolute Specular Reflectance Accessory

VN 10° Near Normal absolute specular reflectance accessory	222-216500
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### Optional Software Packages

VISION <sub>lite</sub> ™ MaterialsCalc Software	869-124500
REPORTER SPX™ Software	869-127400

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