

# Advance Your Materials

Agilent Cary 7000 universal measurement spectrophotometer



# A More Powerful Approach to Measuring Solid Samples

Do you measure the optical properties of coatings, thin films, optical components, solar cells, or glass?

Do you measure reflectance AND transmission?

Do you want to reduce your cost-per-analysis, and save time and money?

Do you want to measure transmission, reflection, and absorptance at any polarization without moving the sample?

With the Cary 7000 UMS, you can.

Measure virtually any sample; measure absolute reflectance and transmission at any angle; and measure them all unattended.

The revolutionary Agilent Cary 7000 Universal Measurement Spectrophotometer (UMS) will satisfy all your solid sampling needs. Collect hundreds of UV-Vis-NIR spectra overnight, or characterize optical components or thin films in minutes to hours rather than hours to days. Delivering a turnkey solution for research, development and QA/QC in optics, thin films/coatings, solar and glass, the Cary 7000 UMS will advance your materials analysis. Design experiments never before possible, expand your research, and save time and money with the ground-breaking Cary 7000 UMS.

## **Complete sample characterization in a single sequence without moving the sample**

Achieve complete sample characterization, measuring both absolute reflection and transmission in a single sequence—at variable angles and polarization—without moving or disturbing the sample. The Cary 7000 UMS is the first truly universal measurement system, replacing the need for multiple accessories and eliminating accessory changeover or reconfiguration. Its design ensures data quality and prevents sample nonuniformity effects. Spectral inconsistencies that occur when multiple analysis techniques are used to perform a single measurement can also be avoided.

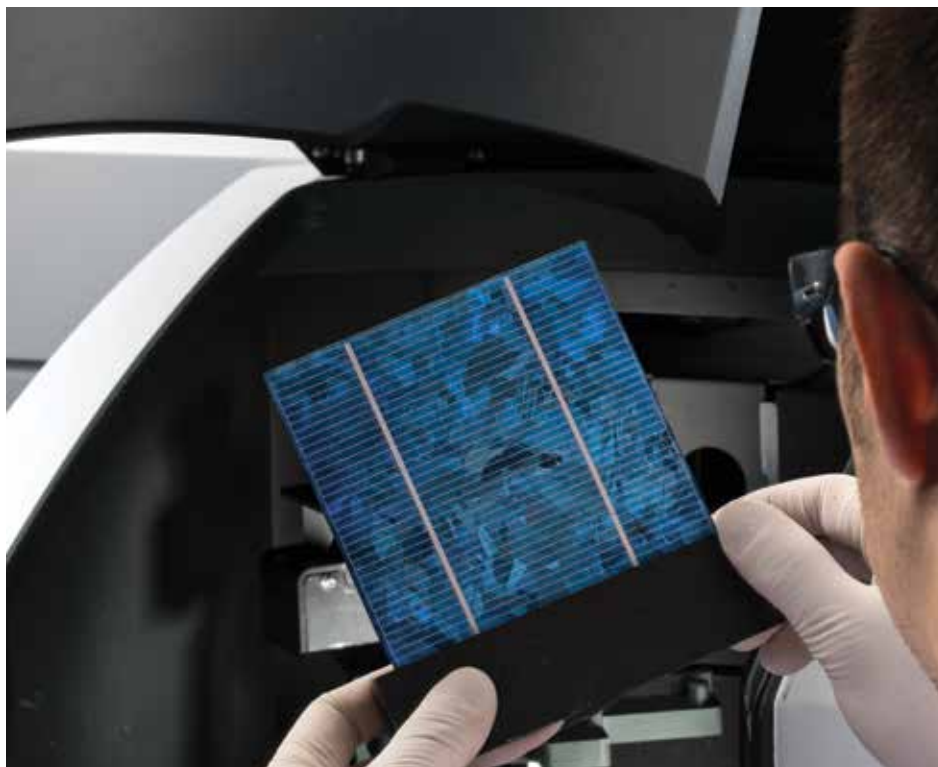
## **Lower cost-per-analysis and improved data quality**

Attain record collection times—reducing your analysis from days to hours or hours to minutes—with direct-view detection and single baseline productivity. The direct-view detection system of the Cary 7000 UMS is do multi-angle, absolute reflection (R), transmission (T), absorptance (A) and scattering measurements through almost 360 degrees, saving time and money. Collecting and processing hundreds of spectra has never been so easy. Just set up your method, collect a single baseline, insert your sample, and walk away. If you have high volume multisample analysis requirements, talk to Agilent about any custom automation needs.

## **New insights into advanced materials with an unprecedented 10 Abs range**

The Cary 7000 UMS featuring the Cary 7000 spectrophotometer provides the highest quality and performance of any UV-Vis-NIR spectrophotometer on the market. With ultralow noise and 10 Abs range, the Cary 7000 UMS delivers high-quality results even with challenging samples such as high optical density filters.

The Cary 7000 UMS provides a more powerful approach to measuring solid samples such as concentrating solar power (CSP) materials and photovoltaics.



## Direct View Optical Design

Advanced capabilities provide you with new insights, faster.

### Superior optical design with Direct View

The Cary 7000 UMS detector has a direct view of the sample. There are no intervening optics such as a light pipe, sphere, or fiber optics—providing the highest light flux and signal-to-noise. This design delivers measurement accuracy, reproducibility, and productivity well beyond anything previously possible. The unique Si/InGaAs detector technology provides the benefit of a UV-Vis-NIR detector in a single sandwich package, ensuring seamless transition from UV to visible to NIR. Coupled with Agilent's high sensitivity PMT and PbSmart detector technology, the Cary 7000 UMS offers the finest UV-Vis and NIR performance optimizing both photometric and spectral range.

Unique wire grid polarizer provides superior energy throughput where required, due to large acceptance angles, while the high contrast ratio provides high quality and control of S and P polarized light.

### Multimodal measurements

- Multimodal measurements—six in total—enable greater depth of information to be obtained quickly, for comprehensive sample characterization.
- Independent control and movement of sample and detector allows absolute reflectance and transmission measurements to be performed without moving the sample.
- New generation high-resolution optical encoder provides positional accuracy with ultra fine angular control down to 0.02 degrees.

The Cary 7000 UMS offers the following measurement modes:

- Absolute specular reflectance
- Direct transmission, reflection, and absorbance—without moving the sample
- Scattered transmission and reflection—by moving the detector independently of the sample and controlling the incoming/outgoing beam geometry

# Save Time, Save Money

Perform multiple measurements on a single system

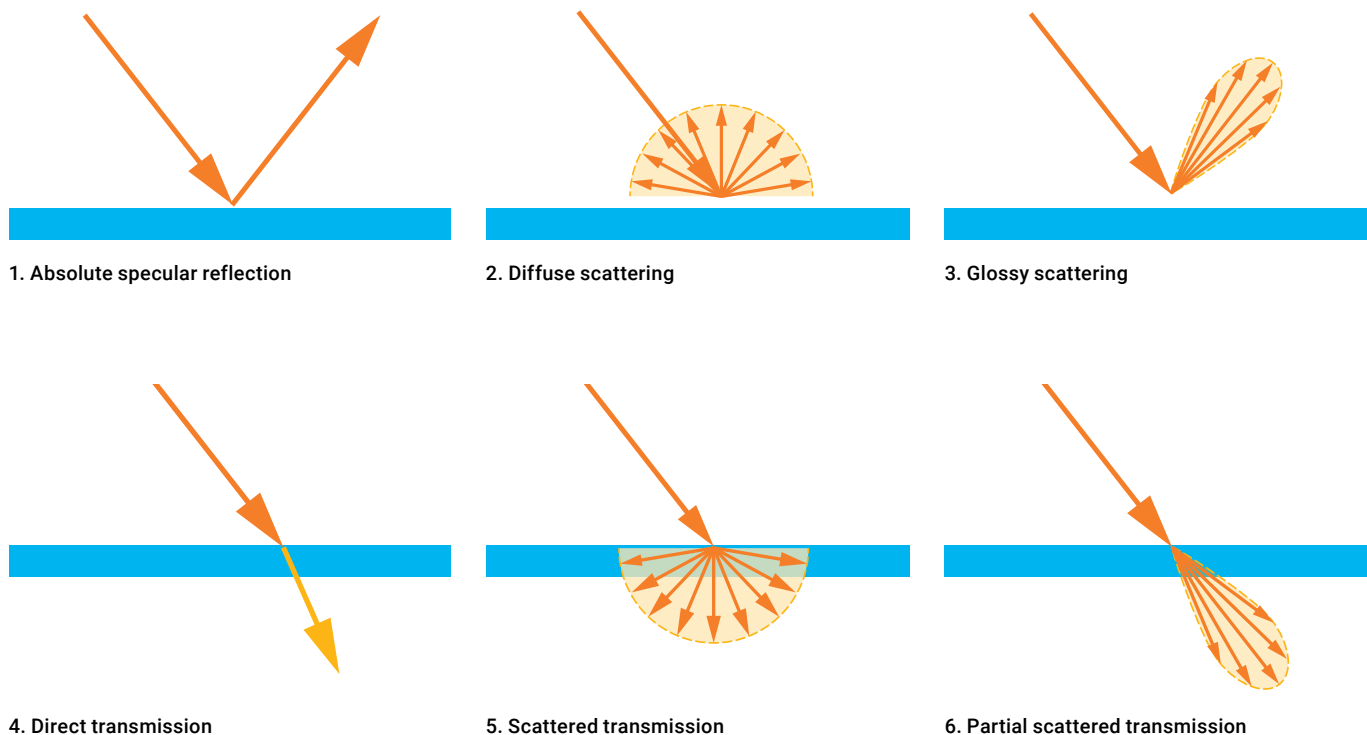
## Replace all your accessories with one system

You no longer need to buy multiple accessories to perform different measurements. The Cary 7000 UMS eliminates accessory changeovers and the need to set up multiple methods or move the sample, which can lead to inconsistencies in acquired spectral data. The Cary 7000 UMS provides accurate, fast, unattended results—beyond the capabilities of other systems.

## Upgrade your existing Cary UV-Vis-NIR

Existing Cary UV-Vis-NIR users can expand your capabilities with the Agilent Universal Measurement Accessory (UMA). The UMA attaches directly to existing Cary 4000, 5000 and 6000i spectrophotometers—the only other requirement is a software upgrade. Experience the same measurement flexibility and productivity as the Cary 7000 UMS on your existing Cary 4000, 5000 or 6000i today.

## 6 Measurements, 1 System



# Distinctly Better Software

Advanced capabilities provide you with new insights, faster.

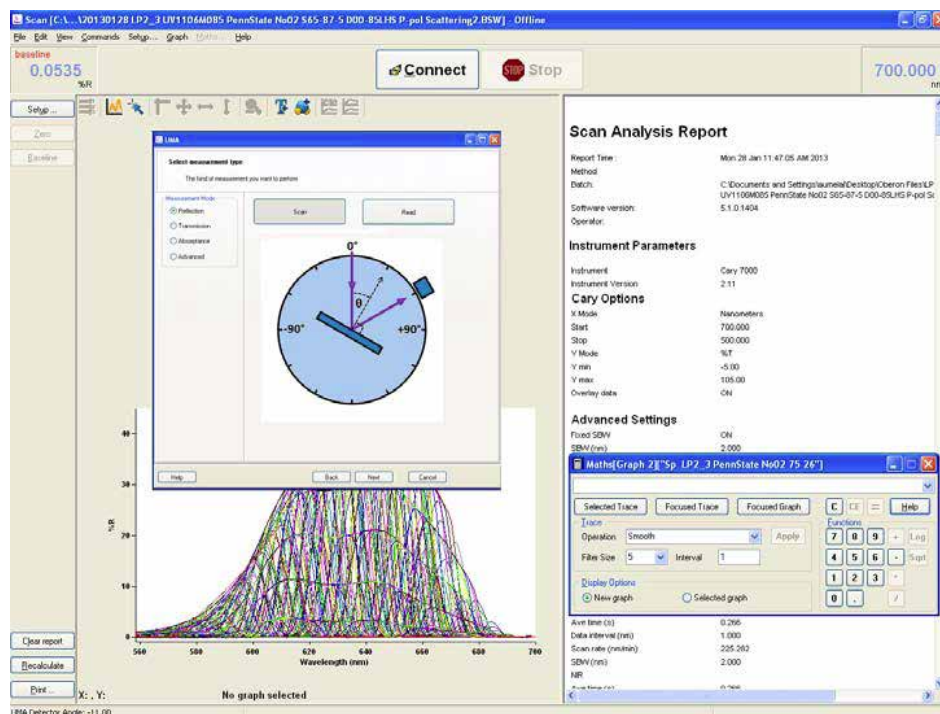
## User-friendly, application-focused software simplifies your workflow

The Cary WinUV software has a modular design that can be tailored to your requirements. Additional capabilities simplify operations, extend data analysis, and boost productivity for every user.

## Method Editor simplifies method setup

The Cary WinUV Method Editor is designed to meet the demands of the automated method sequences of the Cary 7000 UMS. The intuitive interface enables you to set up absolute reflection or transmission measurements, or exactly position the sample and detector.

The Cary WinUV software features a method editor for simple method setup, advanced data processing, and 3D graphics for fast data analysis



# Cary 7000 UMS Applications

Agilent is committed to providing solutions for your application. We have the technology, platforms, and expertise you need to be successful.

| Optics, Thin Films, and Coatings   | Solar  | Glass   | Academic and Industrial Research  |
|--|--|---|---|
| QA/QC coating quality  | QA/QC and Development of parabolic trough and Fresnel reflectors                                 | QA/QC Optical Performance Testing   | Optical constant measurements (refractive index, n, and k)                          |
| Film thickness control   | Photovoltaics – optimizing raw material and module efficiency at various stages of construction. | Conformance to regulatory standards (e.g., EN 410, ISO 9050, EN 13837)  | Film thickness modeling/measurement   |
| Bulk optic performance and characterization  | Coated silicon homogeneity   | Coated/composite properties (construction quality)  | Nanocomposite bandgap measurements  |
| Coating uniformity   | Performance longevity and lowering PM costs under environmental exposure                         | Optical robustness/longevity under environmental testing (e.g., temperature, light exposure, aging, physical abuse) | Characterizing fundamental scattering from Bragg grating surface plasmon polaritons |
| Color/visual appearance  | Optical constant confirmation; purity and surface finish   | Confirmation of final design intent   | Diffuse scattering  |
| Coatings and materials used in fashion eye wear (sunglasses) and safety eye wear (laser/welding goggles) |  |   |   |

## Optics, Thin Films, and Coatings Applications

The Cary 7000 UMS is ideal for optics, thin films and coatings applications. From optimizing your initial design, to monitoring the quality control of raw materials, through to reverse engineering of the end product.

### Reliable and easy-to-interpret

Designers and manufacturers of high-quality multilayer optical coatings require reliable methods to accurately measure optical performance of thin film materials. The Cary 7000 UMS is able to measure %T and %R from the same point, without moving the sample between measurements. This capability eliminates systematic errors often introduced due to small variations in angle of incidence (AOI) when many %R and %T measurement techniques are performed.

- Characterize coatings to a greater level of insight and accuracy than ever before—measure both absolute reflectance and transmission at the same spot on the sample, at angle and polarization.
- Increase productivity and lower cost-per-analysis—the Cary 7000 UMS offers unattended, automated data collection when measuring the quality of end products in manufacturing.

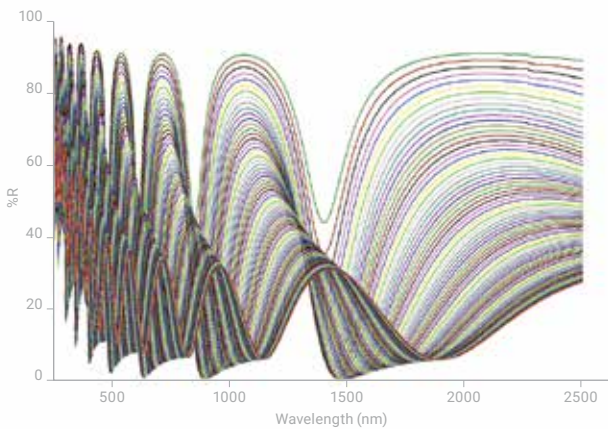


# Optics, Thin Films, and Coatings Applications

## Thin film characterization

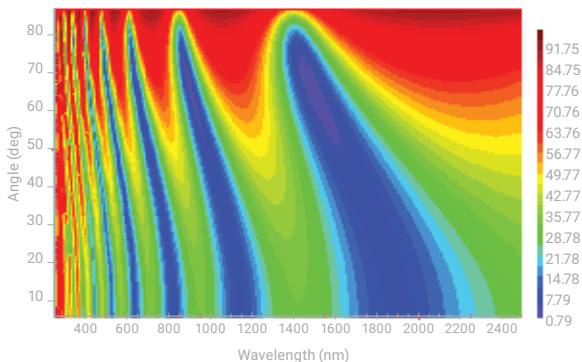
Traditional approaches to thin film characterization have relied on a single angle or a small set of angles, often measured with relative reflectance accessories. Results had to be corrected to absolute values or extrapolated from data from a limited angular set out to the angles of interest to estimate thin film response. Also, the limited or lack of transmission data has resulted in assumptions being made about the end product.

The fine angular control and automation of the Cary 7000 UMS enable you to capture both absolute reflectance and transmission at the angle you want. This removes guess work and allows for precise and detailed assessment of thin film designs. This aids design transfer to production, helping target your QA testing to be more cost effective.



### The power of unattended measurements

Absolute specular reflectance of a coated silicon substrate in the UV-Vis-NIR. Spectra with angles of incidence from 6 to 86° in 1° increments are shown for p-polarized light.



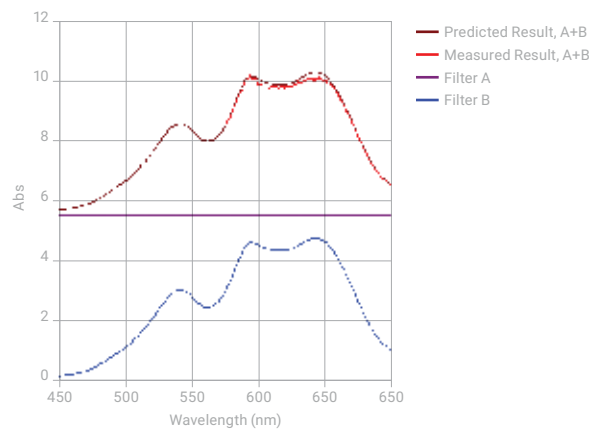
### Visualization tools to gain deeper understandings

A 2D false color plot helps visualize the coating dependence on AOI and wavelength and locate reflection minima and maxima. For example, minimum reflection can be easily identified at 1500 nm with 70 deg AOI.

## High blocking optical filters

High blocking optical filters deliver critical optical control in a wide variety of consumer and industrial products. These filters are used in personal protective equipment, such as laser safety eyewear and welding goggles. They are also used in optical metrology devices where stray light control is critical to system performance.

In the example below, the industry standard “addition of filters” test is used to demonstrate high absorbance measurements beyond 10 absorbance units (Abs). In addition to photometric range, the test requires the spectrophotometer to have strong foundations in linearity and accuracy. Using this technique, photometric range, accuracy and linearity are demonstrated up to 10 Abs.



### Unprecedented photometric range

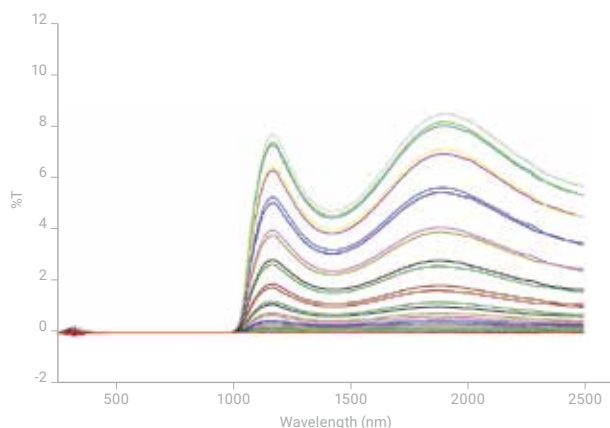
Absorbance spectra of two filters have been measured separately and together on the Cary 7000, demonstrating photometric range and linearity to 10 Abs. The actual and predicted measurements show excellent correlation across the wavelength range measured.

# Solar Applications

Accurately characterize solar cell materials and optimize for efficiency and longevity with the Cary 7000 UMS.

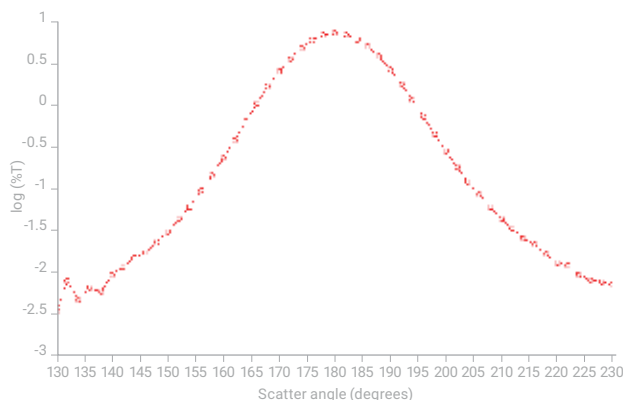
## Solve your analytical challenges in solar applications.

- Accurately characterize solar cell materials such as silicon and thin film coatings
- Determine cell efficiency by measuring the absolute specular reflectance, diffuse scattering and diffuse transmission
- Determine the optical properties of coated and raw materials



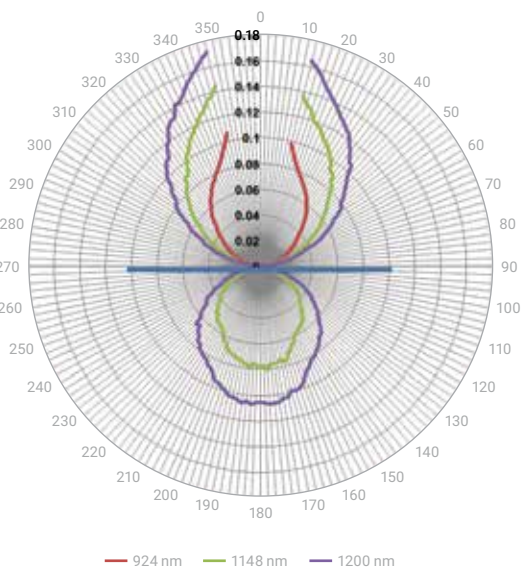
### Independent control of sample rotation and detector position

Diffusely scattered transmission through an AR coated silicon wafer with a polished front surface and unpolished back surface. Each spectrum is measured at a different angle either side of direct transmission, demonstrating the ability of the Cary 7000 UMS to move the detector around the sample.



### High-quality scattered %T spectra from UV-Vis-NIR sandwich detector

Log plot of scattered %T intensity as measured at 1150 nm. The scattering profile is clearly detected out to angles exceeding 45 deg from the direct transmission (180 deg).



### Angular freedom and control at your finger tips

The radial plot shows angular, and wavelength dependent, scattering from an unpolished, uncoated, silicon wafer (125 mm x 125 mm x 0.4 mm). The sample is shown at the center ( $r = 0$ ) and light incident from  $\theta = 0$  deg normal to the sample. Diffusely scattered reflection is observed at three wavelengths (924 nm, 1148 nm, and 1200 nm) and diffuse transmission at only two due to the strong absorptance of silicon at 924 nm.



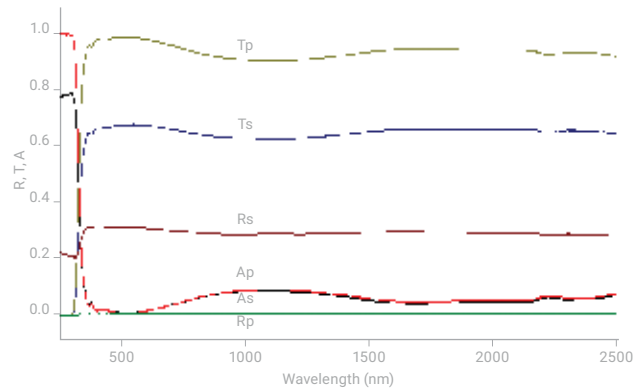
# Glass Applications

Whether you need to determine optical properties, increase the energy efficiency of glass products, or meet regulatory standards, the Cary 7000 UMS delivers.

## Fast, convenient glass measurement and classification

Measure and characterize glass and glass products, including automotive and architectural glazing products.

- Perform absolute reflection and transmission measurements from the same point on the sample without having to move the sample between measurements. This ensures the highest-quality R and T data for QA/QC operation and provides a new level of insight into the research and development of glazing and coated glazing products.
- Obtain fast and convenient spectral data for glass measurement and classification standards such as ISO 9050, EN 410, and ISO 13837.
- Collect a complete set of transmission and reflection data using standard glazing methods supplied with the Cary WinUV software. The methods include CIE damage factor, light reflectance, light transmittance, skin damage factor, total solar energy transmittance (solar factor), and UV transmittance.



### Rapid, comprehensive glass classification

A single 2 mm thick piece of architectural float glass was measured under s-polarized and p-polarized light, as denoted by the s/p subscripts. Measurements were made at both positive and negative angles of incidence,  $\pm 60$  deg, and then averaged. The spectral data was collected in less than 20 minutes and is shown here as Transmittance (T), Reflectance (R), and Absorptance (A).

| Scan Analysis Report   |  |
|--|--|
| Report Time:   | Mon 26 May 24:12:06 R#2013                                     |
| Method:  |  |
| Batch:   | C:\USERS\CHRIS\DESKTOP\ISO9050 3.5 TEST DATA.B5W               |
| Software version:  | 6.0.0.1544   |
| Operator:  |  |
| <b>Sample Name: Rs LP2_2 Glass 2mm 7</b>                                   |  |
| <b>Test Report</b>   | Determination of Luminous and Solar Characteristics of Glazing |
| ISO9050 Glass in Building  | 3_5  |
| Solar direct Transmittance   | 0.874  |
| Solar Direct Reflectance   | 0.080  |
| Direct Solar Absorptance   | 0.053  |
| Secondary Heat Transfer factor of glazing towards inside*, Single Glazing  | 0.014  |
| Secondary Heat Transfer factor of glazing towards outside*, Single Glazing | 0.029  |
| Total Solar Energy of Transmittance (Solar Factor)                         | 0.888  |

### Glass calculation and reporting tool

The Cary WinUV software includes a glass calculation and reporting tool which can be customized or expanded to other in-house QA/QC testing. This is an ISO 9050 test report generated for an architectural glass sample.

# Research Applications

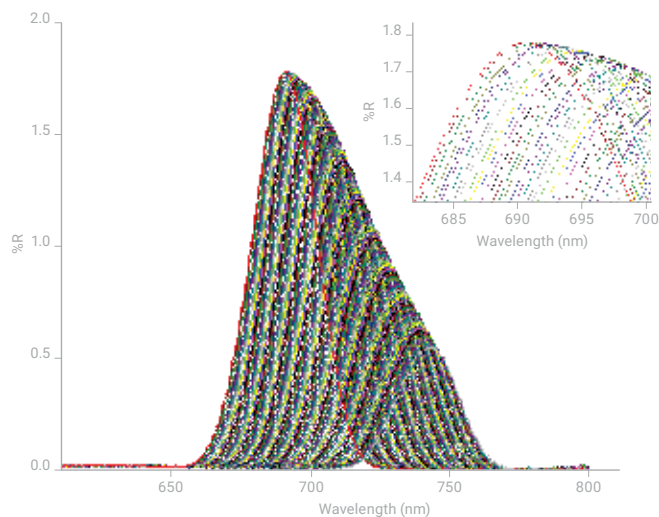
## Gain deeper insights into advanced materials research

For researchers who require the ultimate performance and flexibility, the Cary 7000 UMS can completely characterize any sample with the highest accuracy, reproducibility, and speed. The Cary name has become the standard for researchers wanting to extend the boundaries of spectrophotometric measurement techniques. The Cary 7000 UMS continues this tradition, by offering the widest flexibility, performance, and productivity ever available in a UV-Vis-NIR spectrophotometer:

- Two color sandwich detector provides quality detection from UV through visible to near-infrared wavelengths in a single detector assembly. This eliminates the need to physically change detectors or optical geometry onto the detector over the broad wavelength range.
- High throughput wire grid polarizer ensures maximum signal throughput and polarization quality and extinction. Precise and repeatable motion control of detector and sample is achieved using a high-resolution optical encoder settable to 0.02 degrees.

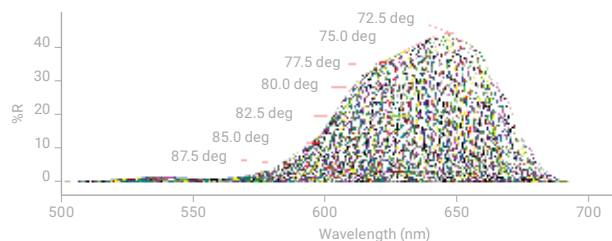
## Metamaterials research

Advanced optical engineering and coating development is driving a new area of research into metamaterials. The Cary 7000 UMS can be used to characterize these metamaterials. Independent control of detector position and sample rotation allows diffuse scattering to be captured over the UV-Vis and near-IR wavelength range for s- and p- polarized incident light.



### Superior positional control

Diffuse scattering from a compact disk. The familiar color changes are captured using angular dependent reflection over a 15 deg arc from 48–63 deg (AOI) at 0.04 deg intervals (375 spectra). Scattered light was detected at 25 deg to the incident light using a 2 deg aperture. The inset shows a magnified view of the diffuse scattering peak of the figure at top. Angular dependent scattering is clearly resolved at 0.04 deg intervals (2 arcmin 24 arcsec) dependence



### Characterization of metamaterials

Spectral data set collected from the sample (provided by Pennsylvania State University, USA, Dept Chemistry). In this example, control over the direction and speed of light pulses is achieved by exploiting a photon-surface coupling phenomena known as Surface Plasmon Polaritons (SPPs). Specialized thin film coatings are applied to a metal substrate to modify its resonant frequency dispersion properties. Scattered reflection for each AOI (labeled) is seen to generate a spectral envelope imprint at differing reflection intensities.

# Related Materials Analysis Solutions From Agilent

Agilent offers a range of UV-Vis and FTIR solutions for materials analysis



### Agilent Cary 5000/6000i UV-Vis-NIR

The Cary 5000 combines PbSmart technology with the unparalleled optical design and performance of all Cary UV-Vis-NIR instruments. It requires only one detector to extend that performance into the NIR, and achieves superior NIR performance to meet your application needs. The Cary 6000i with a high-performance InGaAs detector is optimized for the shortwave NIR, delivering superior resolution in the 1200–1800 nm region. No instrument can match the NIR performance of the Cary 5000 and the Cary 6000i.



### Agilent 4300 handheld FTIR

The 4300 is a lightweight handheld system that is versatile and rugged. It has interchangeable sampling accessories that can be changed in seconds without re-alignment. This capability makes it ideal for the analysis of surfaces, coatings, films and composites, as well as the analysis of bulk materials including powders and granules.



### Agilent Eclipse fluorescence

The Agilent Cary Eclipse with unique xenon flash lamp technology delivers superior sensitivity with fiber optics. It can be combined with a wide range of options including polarization, temperature control and solid sample holders.



### Agilent Cary 630 FTIR

The world smallest benchtop FTIR is ideal for QA/QC of thin films, optics, and polymers. The Cary 630 FTIR is designed for one purpose – to provide you with great results rapidly and reliably, day after day. Offering robust performance in a compact design, the Cary 630 FTIR is available with multiple sampling capabilities such as specular reflectance and Ge and Diamond ATRs.



### Agilent Cary 60 UV-Vis

The Cary 60 with unique xenon flash lamp technology is the world's fastest scanning UV-Vis. With an exceptionally long lifetime of 3 billion flashes, the lamp typically lasts 10 years. It can be fitted with solid sample holders to characterize many sample types, including filters, powders, gels, optical components, and fabrics. A fiber optic reflectance probe and coupler allows the remote measurement of solid samples.



### Agilent 8700 LDIR Chemical Imaging System

The 8700 Laser Direct Infrared (LDIR) uses the latest quantum cascade laser (QCL) technology coupled with rapidly scanning optics to provide fast, clear, high-quality images and spectral data. This technology works with the Agilent Clarity software for rapid and detailed imaging of large sample areas.

## Agilent CrossLab: Real insight, real outcomes

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