J.A. Woollam Co., Inc.

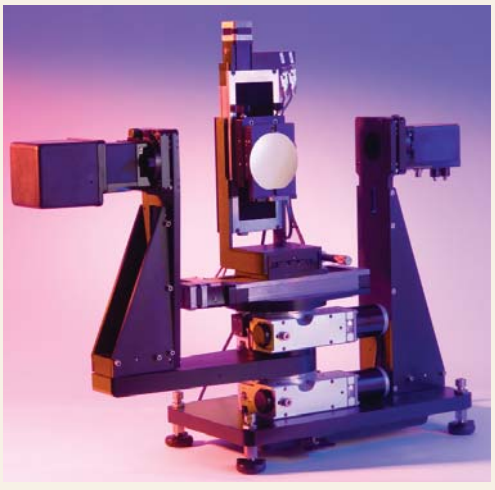
Ellipsometry Solutions

RC2®


Innovative

Capabilities

The RC2® builds on 25 years of ellipsometry experience. It combines the best features of previous instruments with innovative new technology: dual rotating compensators, achromatic compensator design, advanced light source and next-generation spectrometer design. The RC2 is a near-universal solution for the diverse applications of spectroscopic ellipsometry and Mueller matrix ellipsometry.



RC2 on Vertical Base

Why an RC2?

Advanced Measurement Capabilities

The RC2 is the first commercial spectroscopic ellipsometer to collect all 16 elements of the Mueller matrix. Mueller matrix SE allows characterization of the most advanced samples and nanostructures.

Unparalleled Accuracy

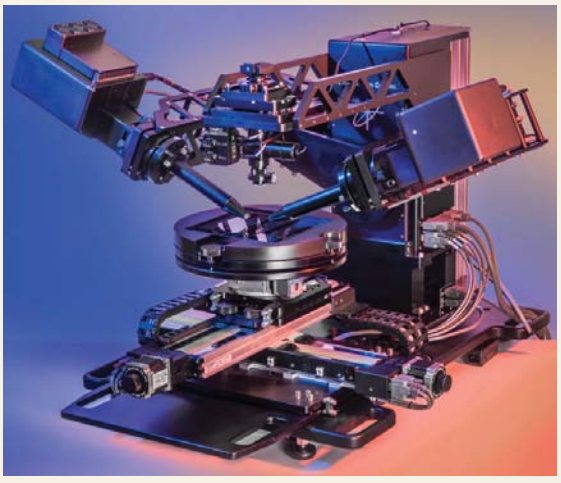
An innovative optical design allows superior data accuracy for standard spectroscopic ellipsometry measurements (SE), generalized ellipsometry measurements (g-SE), and the entire Mueller-matrix (MM-SE).

Wide Spectral Range

Collect over 1000 wavelengths from the ultra-violet to the near infrared - all simultaneously.

Fast Measurement Speed

Synchronous operation of both compensators allows highly accurate data without waiting to "zone-average" over optical elements. Collect the entire spectrum (over 1000 wavelengths) simultaneously in a fraction of a second.



RC2 on Auto Horizontal Base with Focusing

RC2 on Horizontal Fixed Base with Controll Box

Advanced Technology

Dual Rotating Compensators

The RC2 uses synchronous rotation of two compensators (both before and after the sample) to provide high accuracy, fast measurement speed, and advanced measurements including the complete Mueller matrix.

Achromatic Compensator Design

Patented achromatic compensators provide optimized performance over a wide spectral range from the ultraviolet to the near infrared.

Advanced Light Source

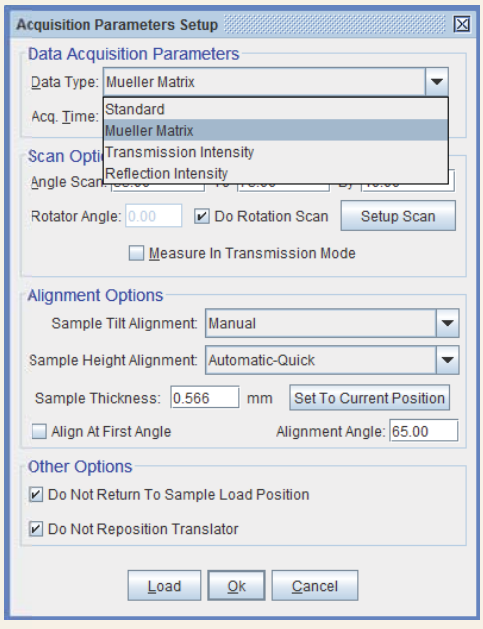
Next-generation light source includes computer-controlled beam intensity to automatically optimize the signal on any sample (low or high reflection).

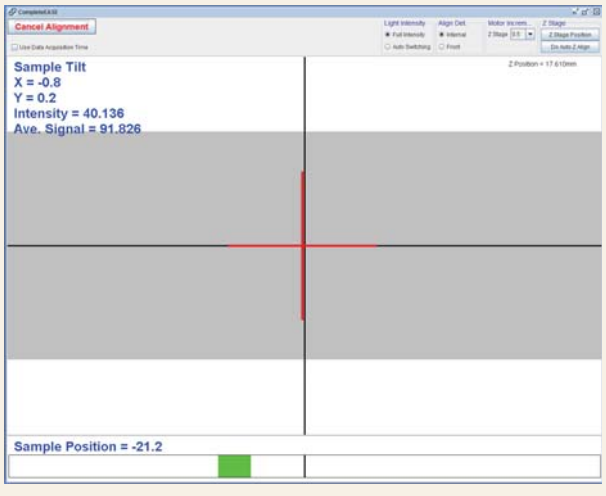
Innovative Spectrometer

Next-generation spectrometer collects over 1000 wavelengths simultaneously. Advanced silicon CCD is combined with an InGaAs diode array - both designed to reduce bandwidth which improves measurement of sharp data features.

Advanced Beam Alignment

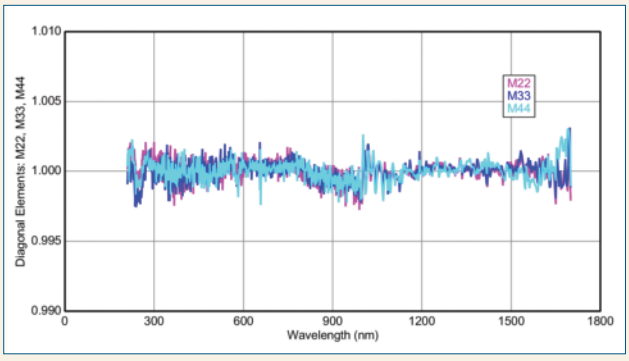
With the RC2, we have "re-thought" how beam alignment should be achieved. Multiple position-sensitive detectors along the beam path help ensure the system (and sample) are always well-aligned for highest data accuracy.

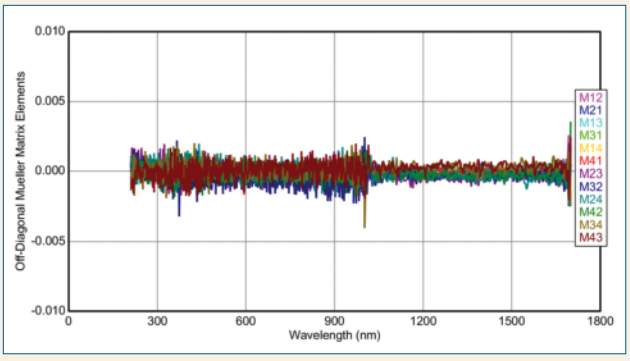




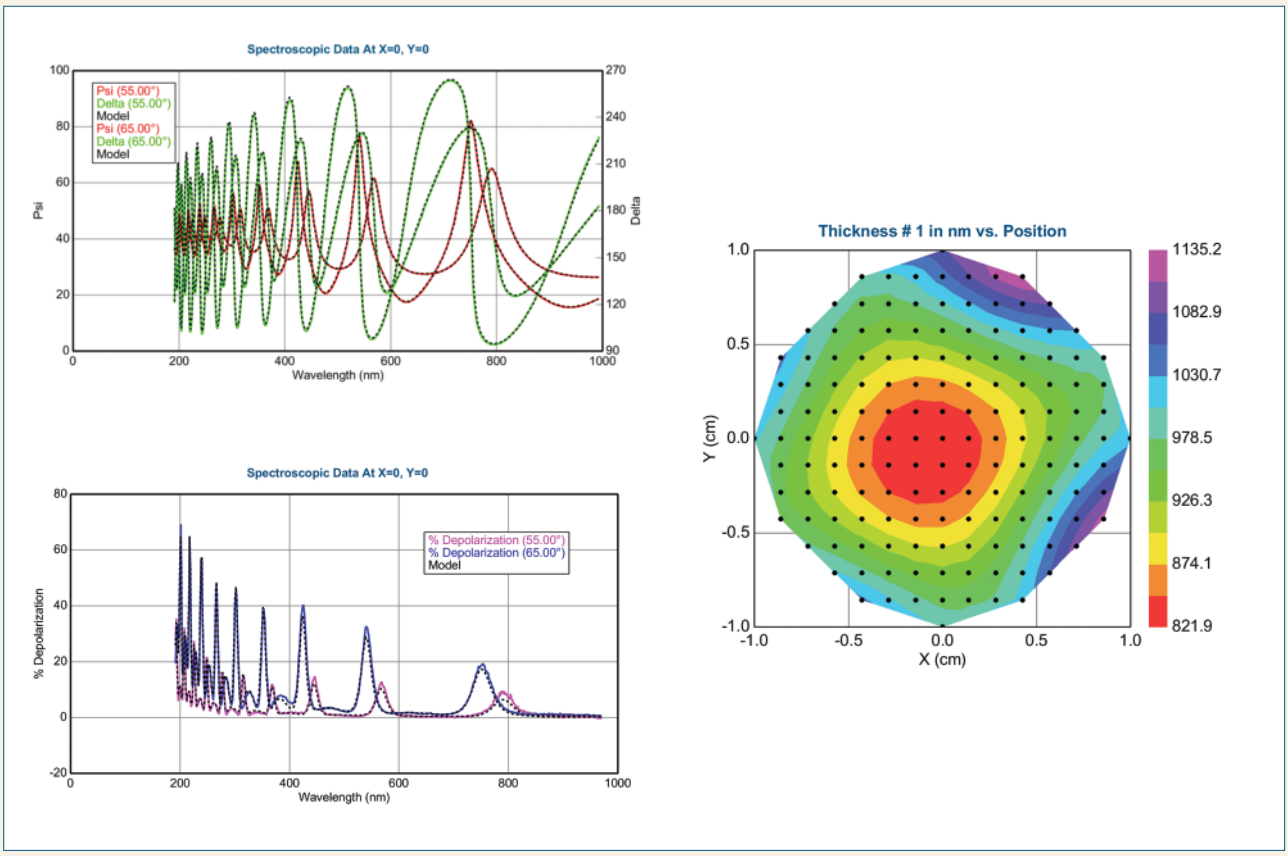
Excellent Data Quality

The advanced RC2 technology provides very high data accuracy. A test measurement of air (straight-through) produces diagonal Mueller matrix values = 1 ± .002 and off-diagonal Mueller matrix values = 0 ± .002.

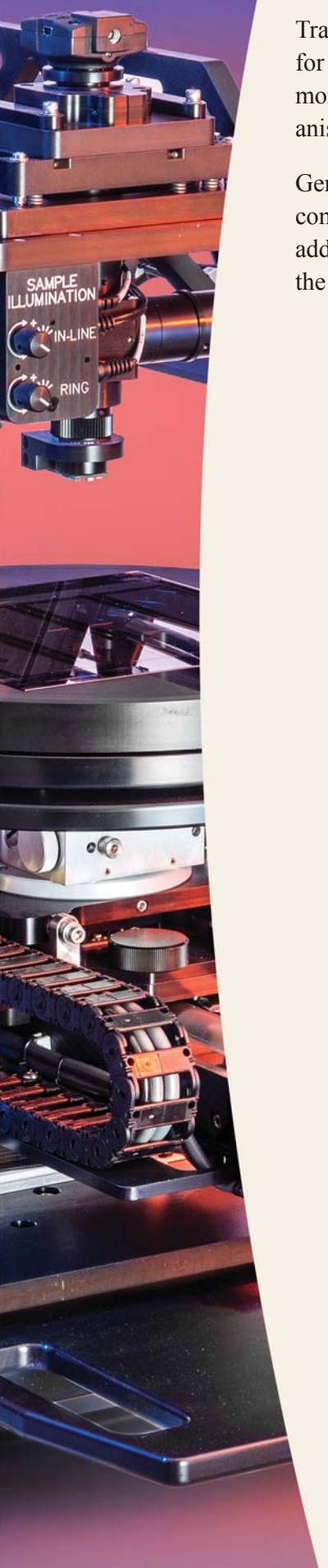




Mueller matrix data accuracy translates to superior Psi-Delta and Depolarization measurements. A uniformity map demonstrates the advantage of highly accurate depolarization data - quantifying and modeling the sample non-idealities - even in a highly non-uniform region of the sample.



Anisotropic Applications



Generalized Ellipsometry

Traditional ellipsometry measurements are ideal for standard thin film characterization. However, more advanced measurements are required for anisotropic materials.

Generalized ellipsometry collects six values compared to the standard two (Ψ, Δ). This additional information completely characterizes the cross-polarization of anisotropic samples.

Jones matrix for anisotropic sample:

$$\begin{bmatrix} r_{pp} & r_{sp} \\ r_{ps} & r_{ss} \end{bmatrix}$$

Generalized ellipsometry measures:

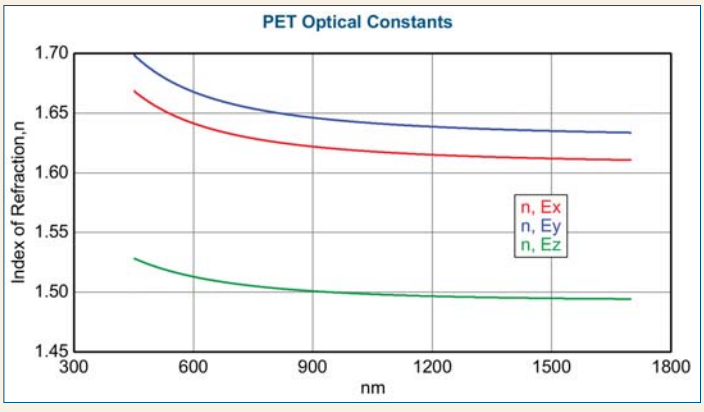
$$\rho = \tan(\Psi)e^{i\Delta} = \frac{r_{pp}}{r_{ss}}$$

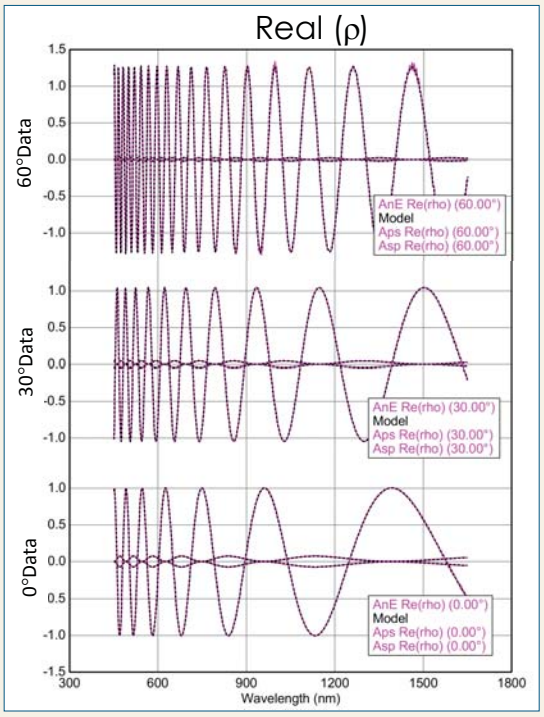
$$\rho_{ps} = \tan(\Psi_{ps})e^{i\Delta_{ps}} = \frac{r_{ps}}{r_{pp}}$$

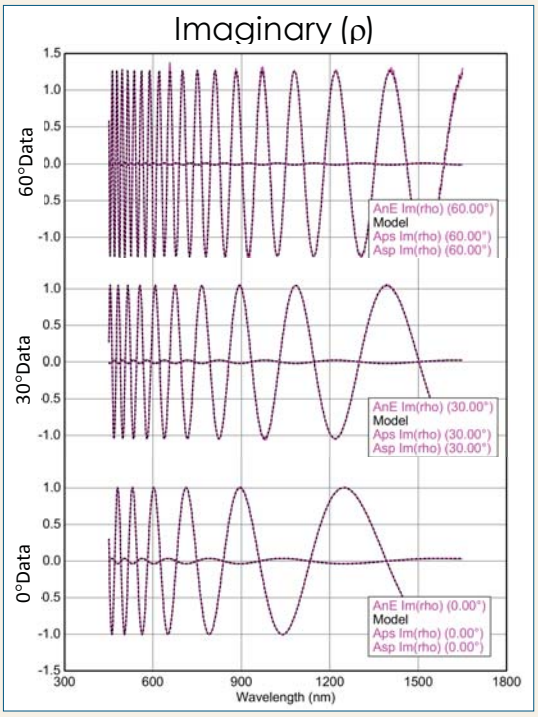
$$\rho_{sp} = \tan(\Psi_{sp})e^{i\Delta_{sp}} = \frac{r_{sp}}{r_{ss}}$$

Anisotropic PET (Polyethylene Terephthalate)

Generalized ellipsometry measurements of the transmitted beam provide high sensitivity to the birefringence in anisotropic PET films.





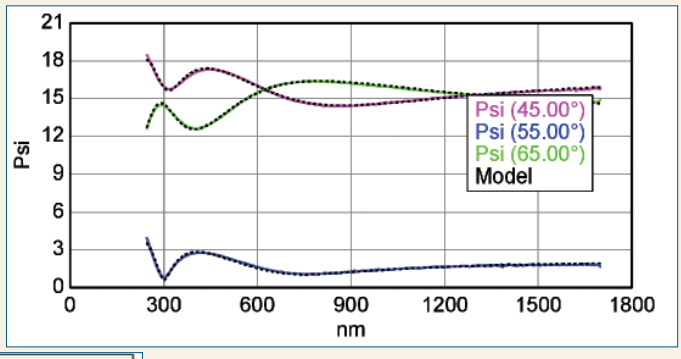


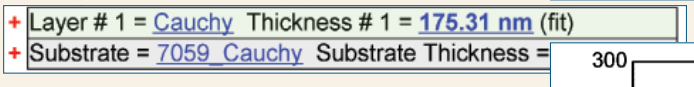
Variable Angle Generalized Ellipsometry was used to fully characterize the biaxial indices ($n_x \neq n_y \neq n_z$) of the PET substrate.

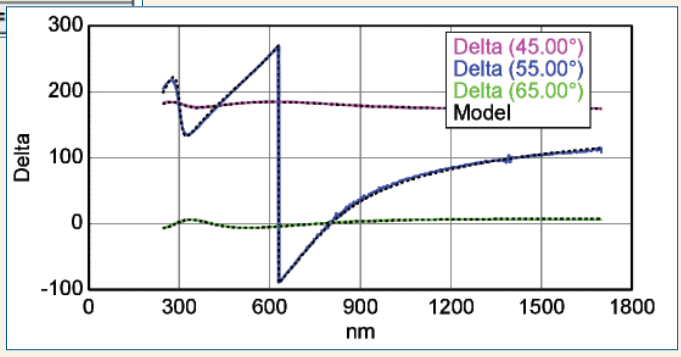
Thin Films

SiO_2 on Glass

Adjustable light output optimizes measurements for low-reflection coatings such as index matched films on glass.

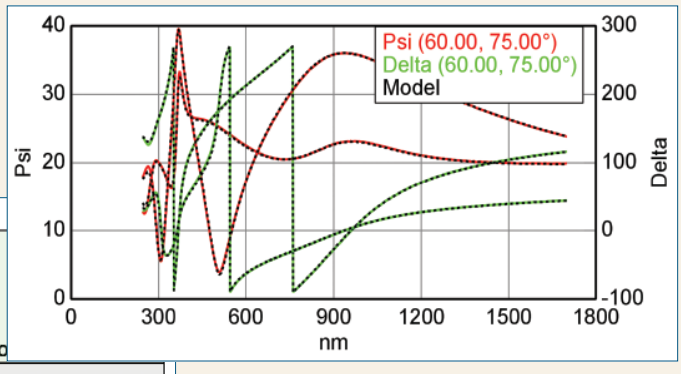


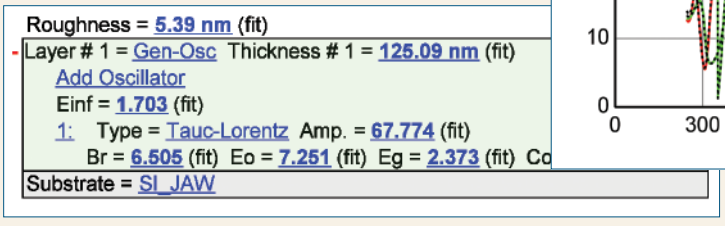


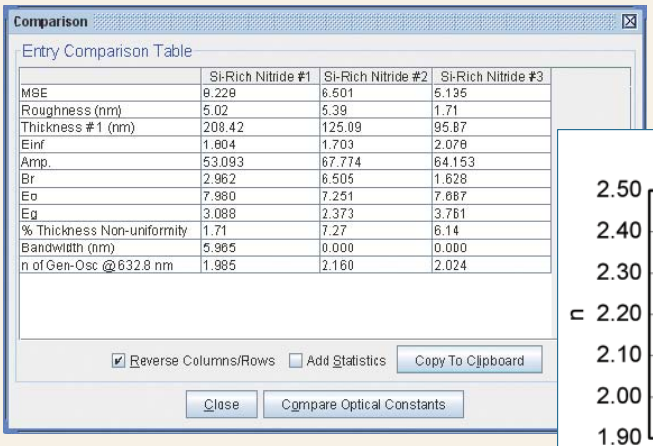


Si-rich Nitride

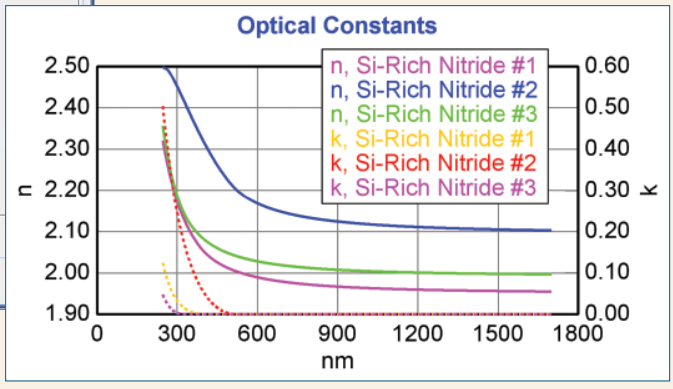
Get quick results for any thin film - dielectrics, organics, semiconductors, metals...and more.







	Si-Rich Nitride #1	Si-Rich Nitride #2	Si-Rich Nitride #3
MSE	8.229	6.501	5.135
Roughness (nm)	5.02	5.39	1.71
Thickness #1 (nm)	208.42	125.09	95.87
Einf	1.804	1.703	2.078
Amp.	53.093	67.774	64.153
Br	2.962	6.505	1.628
Eo	7.980	7.251	7.687
Eg	3.088	2.373	3.761
% Thickness Non-uniformity	1.71	7.27	6.14
Bandwidth (nm)	5.965	0.000	0.000
n of Gen-Osc @ 632.8 nm	1.985	2.160	2.024



Compare optical constants measured from a series of silicon-rich nitrides to study changes with process conditions.

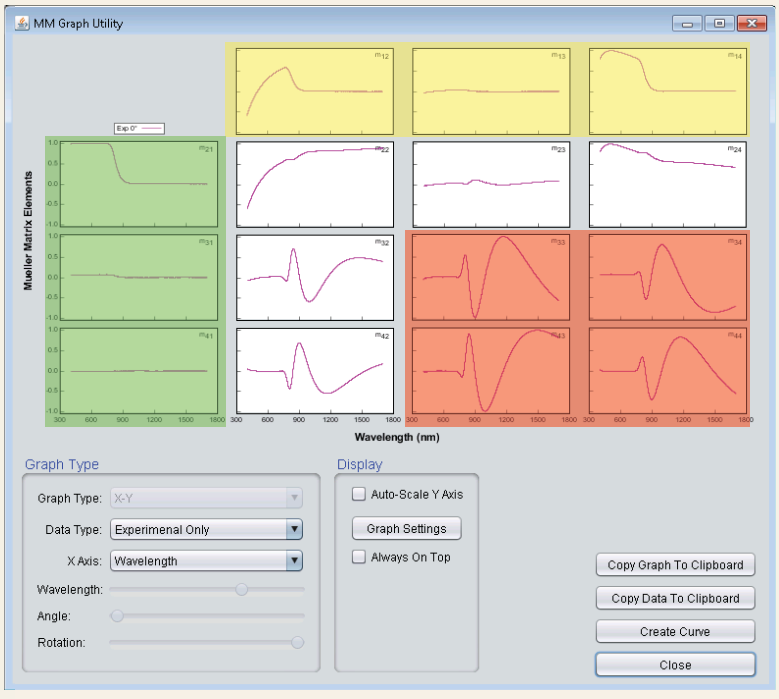
Mueller Matrix SE

Complete Mueller Matrix

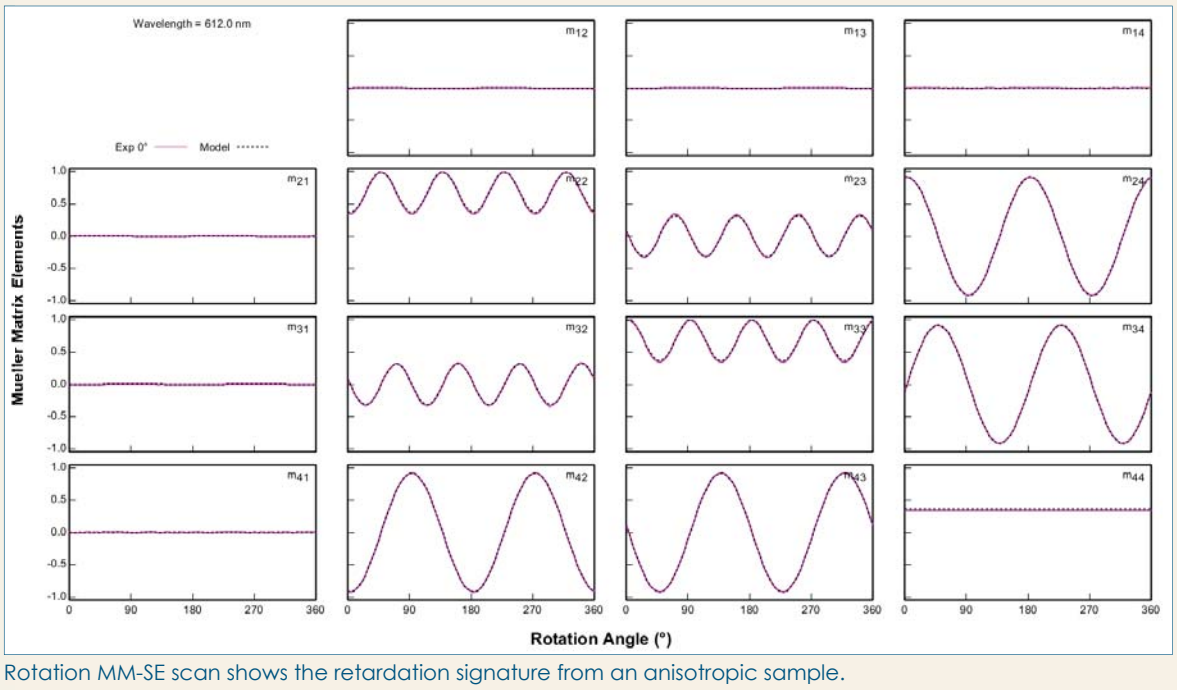
The RC2® can characterize the full Mueller matrix of a sample. This advanced data type ensures appropriate characterization of complex samples that are both anisotropic and depolarizing.

$$\frac{1}{m_{11}}\begin{bmatrix} 1 & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \\ m_{41} & m_{42} & m_{43} & m_{44} \end{bmatrix}$$

Mueller matrix ellipsometry for an anisotropic, depolarizing samples can contain information in every element.



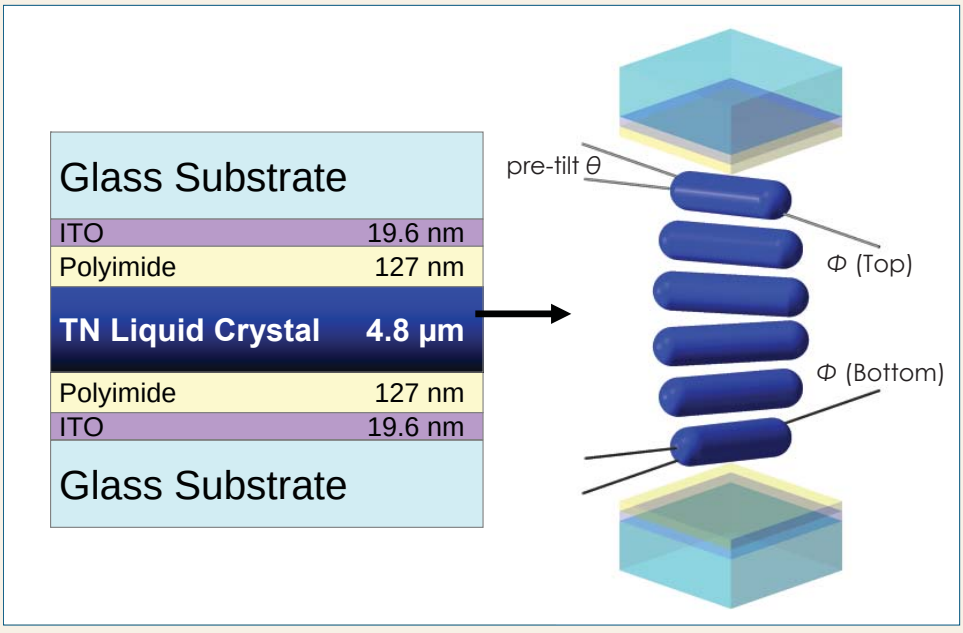
Viewing the entire Mueller matrix allows access to different polarization effects in advanced samples. The yellow and green sections are related to Diattenuation and Polarizance, respectively. The red section shows unrotated Retardance. Further rotating the sample will shift this information into different regions of the Mueller matrix.



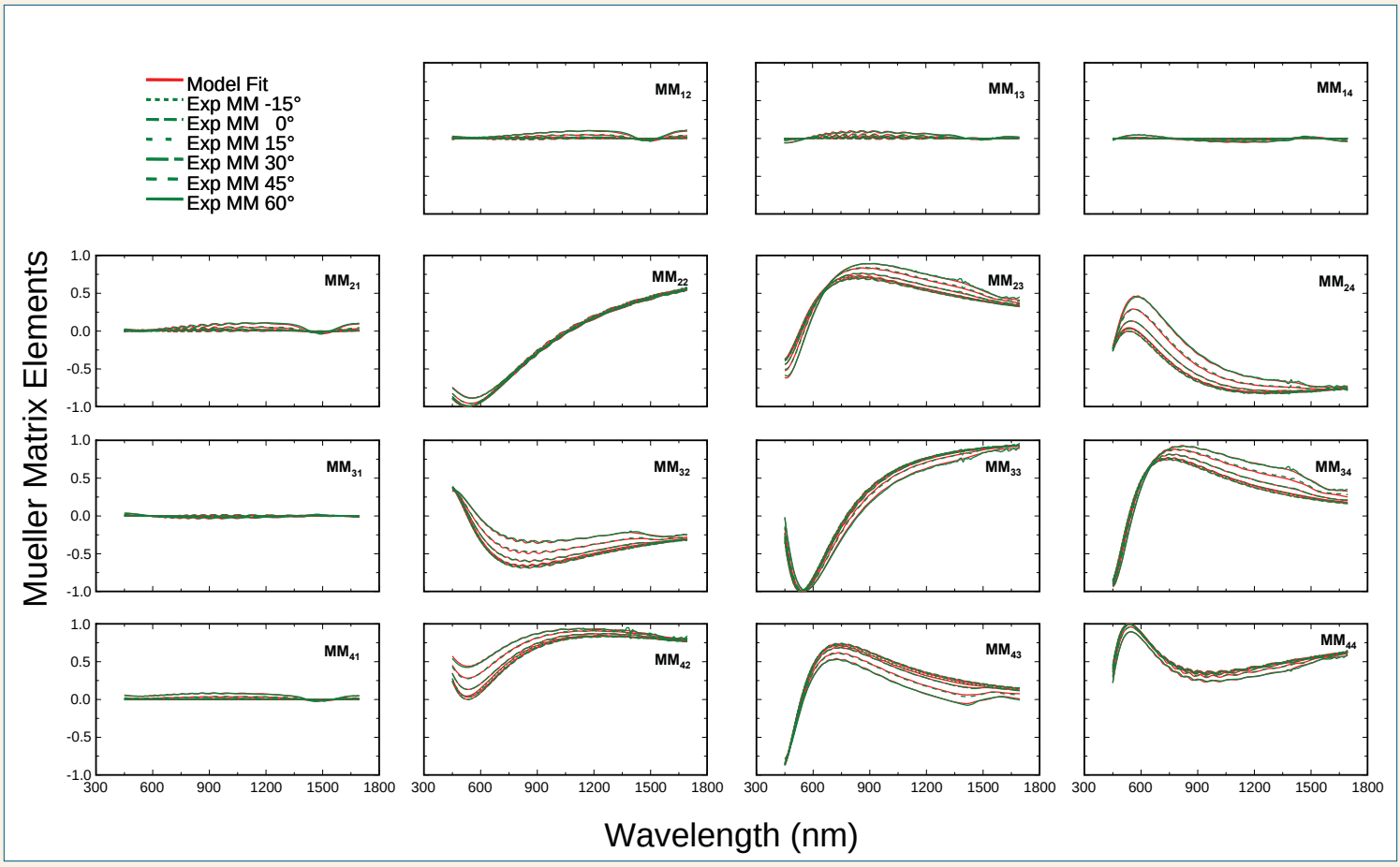
Rotation MM-SE scan shows the retardation signature from an anisotropic sample.

Liquid Crystals

Twisted nematic liquid crystal films introduce the complexity of an anisotropic film with a smoothly varying optical axis orientation. MM-SE is the best choice for thick liquid crystal layers sandwiched between glass substrates - as depolarization and anisotropy effects will both exist.



The complete Mueller matrix was measured for a twisted liquid crystal. This enabled characterization of the optical axis twist and pre-tilt, and liquid crystal anisotropic refractive index.



Specifications

System Overview

Patented dual rotating compensator ellipsometer with simultaneous CCD detection of all wavelengths, flexible system configuration.

Measurement Capabilities

- Standard SE: Both Psi and Delta over their full range.
- Generalized-SE: Characterize samples with complete 2x2 Jones matrix.
- Mueller matrix SE: Measure 15 normalized MM elements or all 16 un-normalized MM elements.
- Depolarization: Quantify the amount of light that is unpolarized.
- Intensity Reflectance and Transmittance.
- Like- and Cross-polarized Intensity: Determine pp, ss, ps and sp Reflectance or Transmittance.

Wavelength Range

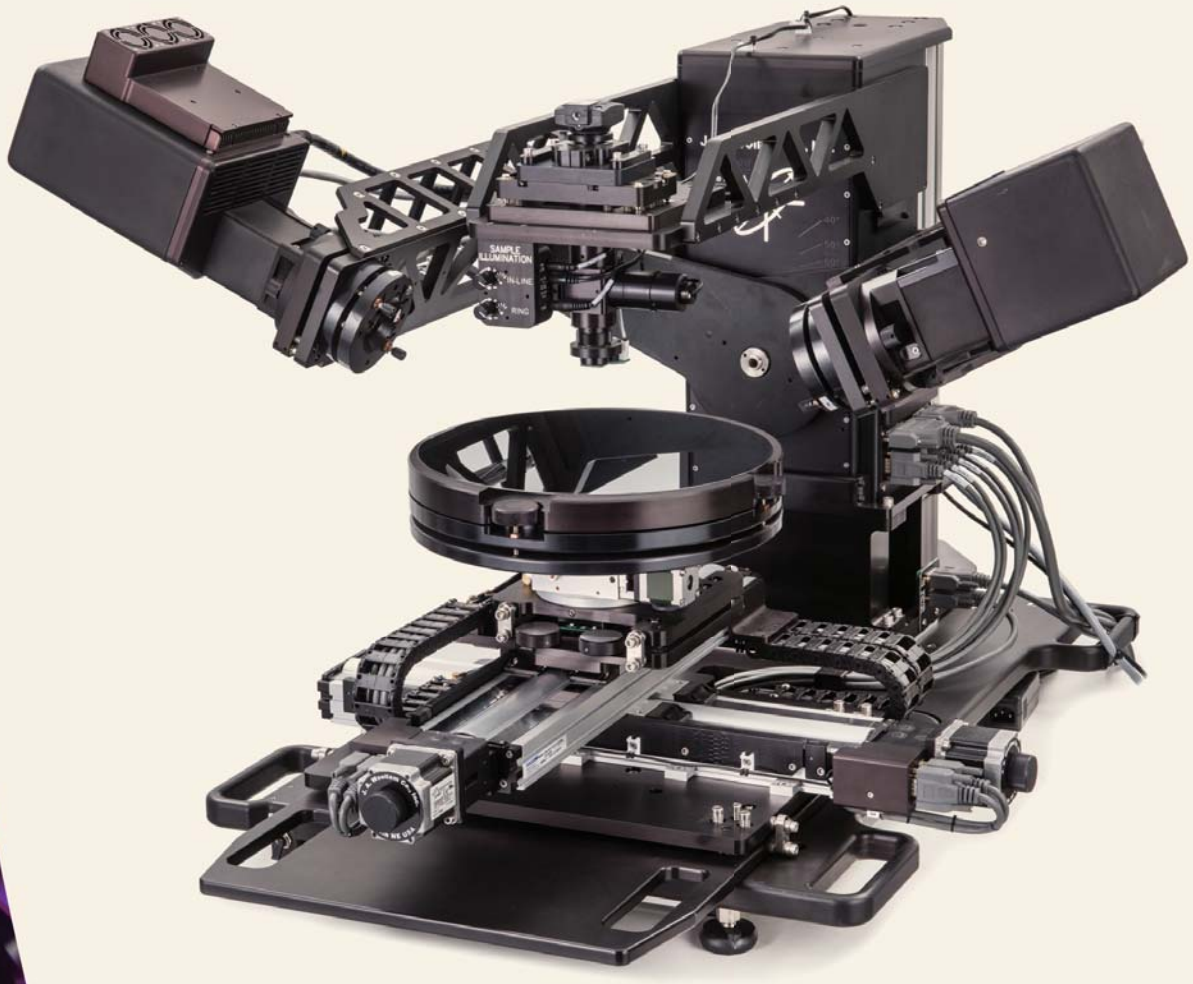
210-1690 nm
(over 1000 wavelengths)

Data Acquisition Rate

Measure complete spectrum in 1/3 of a second.

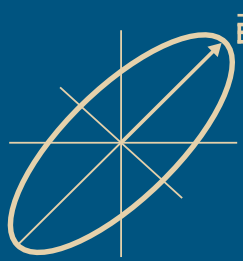
Angle Range

Fixed Angle	60° or 65°
Horz. Auto Angle	45° - 90°
Vert. Auto Angle	20° - 90°



Horizontal Auto Angle RC2

Advanced



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