CompleteEASE

J.A. Woollam

Ellipsometry Solutions

Powerful

Overview

J.A. Woollam began software development for automated ellipsometry measurements in the 1980s. Over the years, our software has continued to evolve with advancements in our field, improvements in computing power, and feedback from our customers. CompleteEASE is the culmination of 35 years of ellipsometry experience and software development.

Industry Leading Software

+Powerful

A comprehensive software platform for data acquisition and model development custom designed for use with J.A. Woollam ellipsometers, CompleteEASE provides the most functional and intuitive interface for data analysis and reporting of results.

+Intuitive

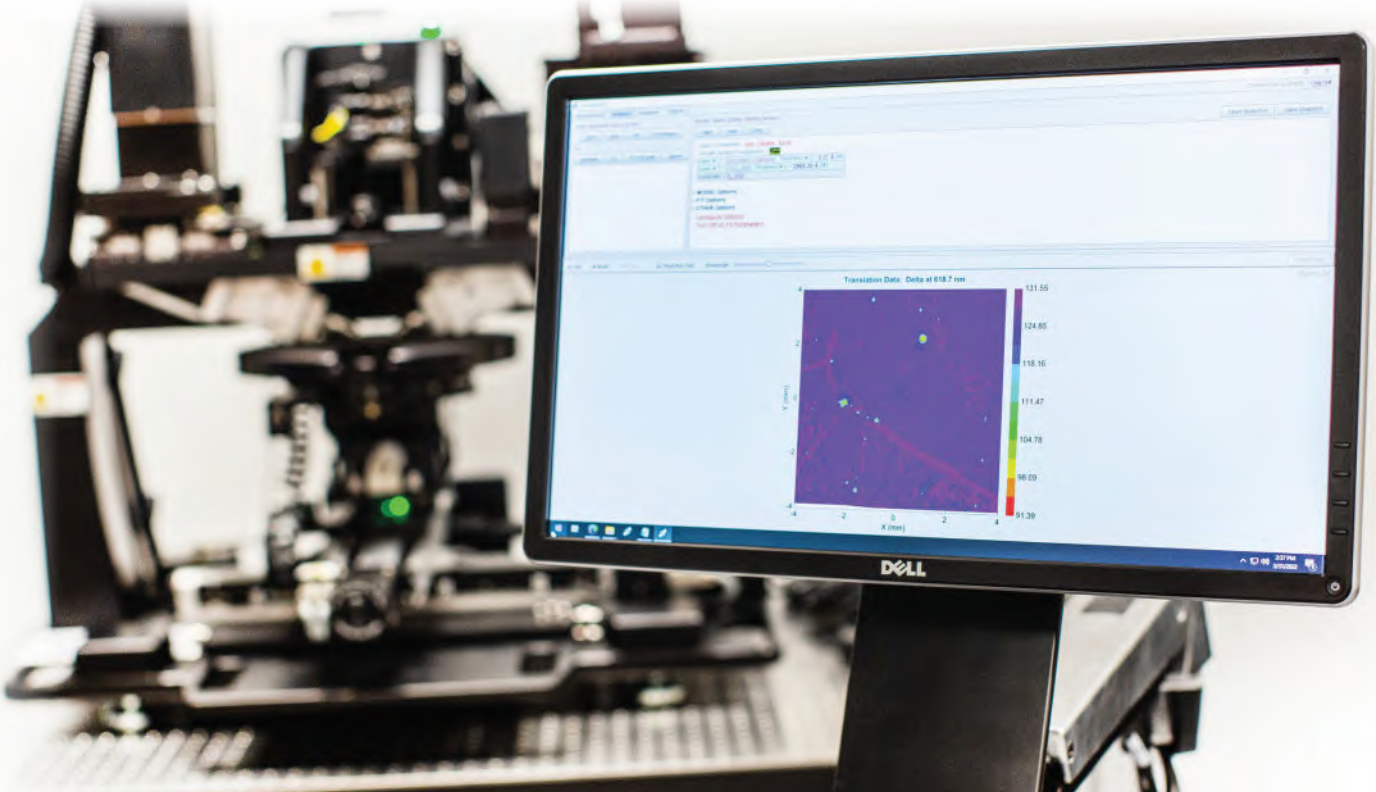
CompleteEASE features a variety of analysis tools to assist in model development. Our thickness pre-fit and global-fit algorithms automate thickness and refractive index determination for transparent films. We recently automated our patented B-Spline model to determine optical properties in absorbing regions with a single mouse click.

+Fully Integrated

CompleteEASE automatically detects hardware configuration changes to seamlessly transition between focusing optics, liquid cells, heat cells, and others. Integrated support for mapping stages, camera, pattern recognition, and comprehensive graphing tools to display results are all standard features of CompleteEASE. CompleteEASE also features an API to enable custom communication and real-time feedback control.

+Fast

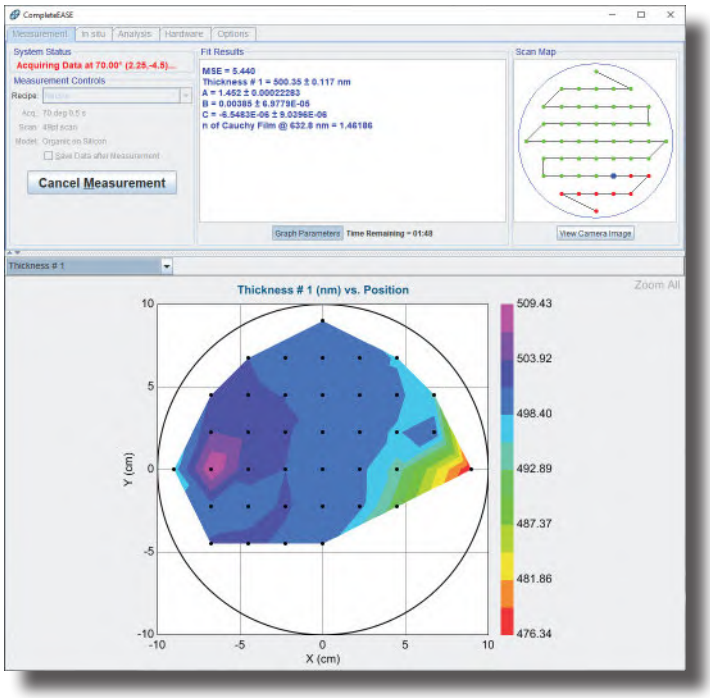
The Levenberg-Marquardt regression algorithm has been optimized to provide the fastest possible model fit to raw data, including compatibility with multi-core processing. This is especially useful for the analysis of complex absorbing samples and real-time characterization of thin films where the data is analyzed as the measurements are acquired.



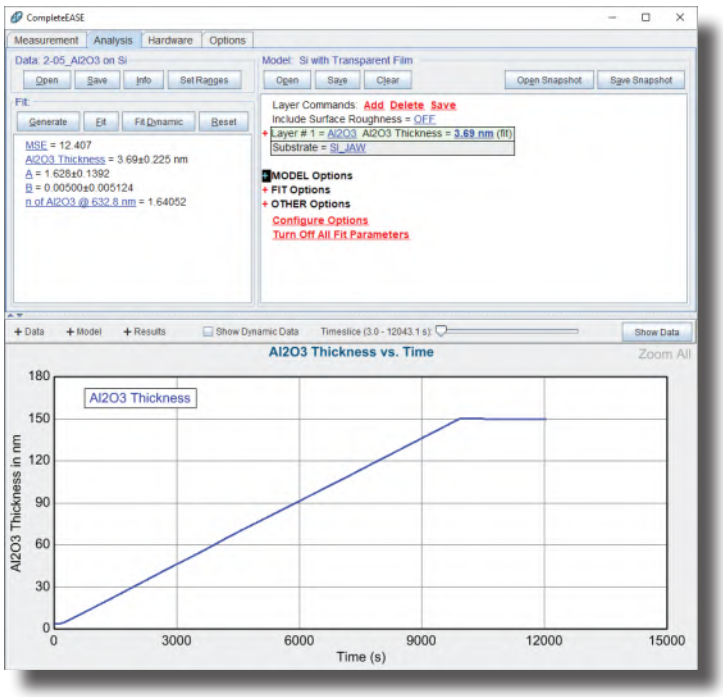
Data Acquistion

Versatile Measurements

CompleteEASE is an all-inclusive software package to handle all your ellipsometry requirements. Conveniently measure the uniformity of your samples with automated sample mapping. Use spectroscopic ellipsometry to collect in-situ data on your process chamber or with accessories like our Environment Cell or temperature-control stages. All your data acquisition needs are combined into one easy-to-use software package.



Film thickness, optical properties, and derived parameters can be viewed in real time during mapping measurements.



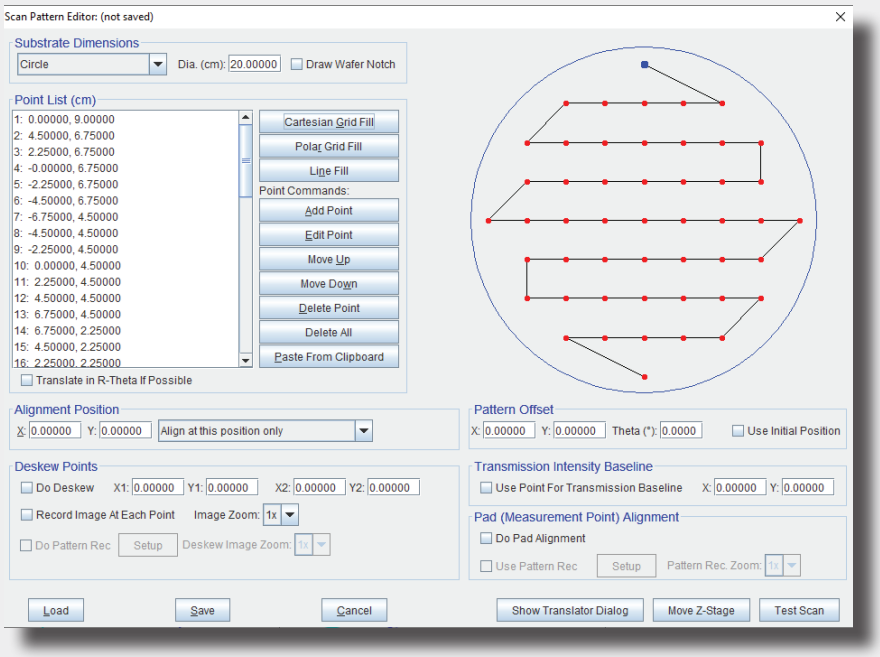
In-situ ellipsometry is routinely used to monitor growth or etch of thin films and can be implemented for real-time feedback control.

Convenient Recipes

Create recipes to collect data, automate mapping, and analyze your samples–all contained in one step. Convenience and simplicity combine for push-button operation.

The scan pattern editor in CompleteEASE is used to define the measurement positions for recipes. Positions can be easily defined in cartesian or polar coordinates. If specific locations are required, the coordinates can be directly loaded into CompleteEASE through the scan pattern editor.

Combining scan patterns with pre-built models enables automated measurement and analysis with results reported in real time as the sample is measured. Once completed, statistics are provided, and contour plots enable easy visualization of the sample properties.



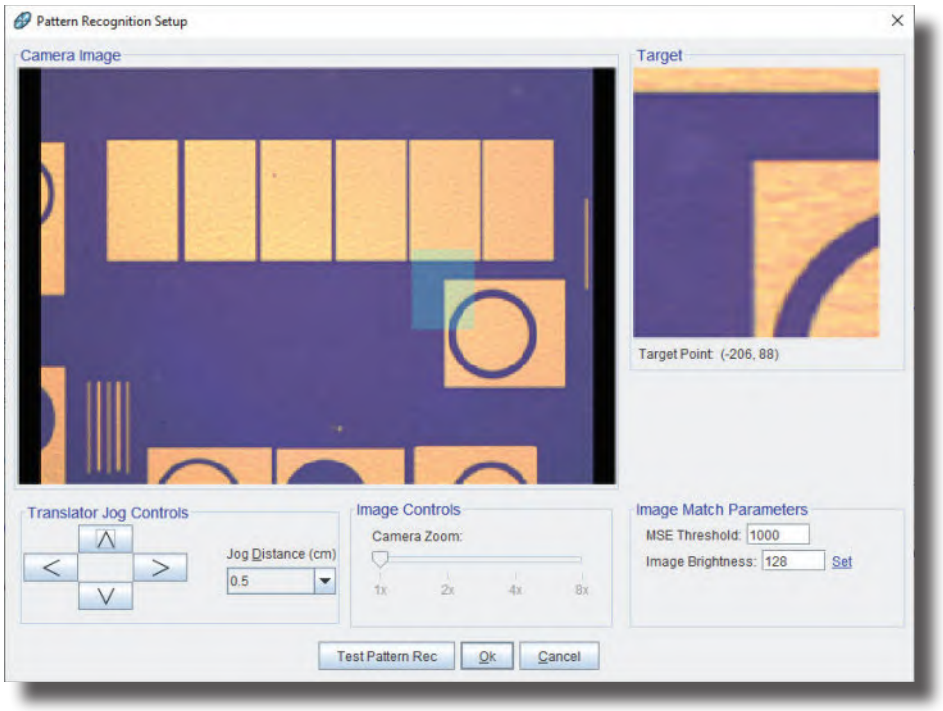
Advanced Features

Pattern Recognition

Deskew and Pattern Recognition are features in CompleteEASE designed to accurately locate measurement positions. Deskew corrects rotation, offset, and slight scaling to match the sample coordinates with the stage coordinates.

Pattern Recognition uses machine-vision image recognition to locate small features or pads to ensure measurements are consistenlty collected within the intended area.

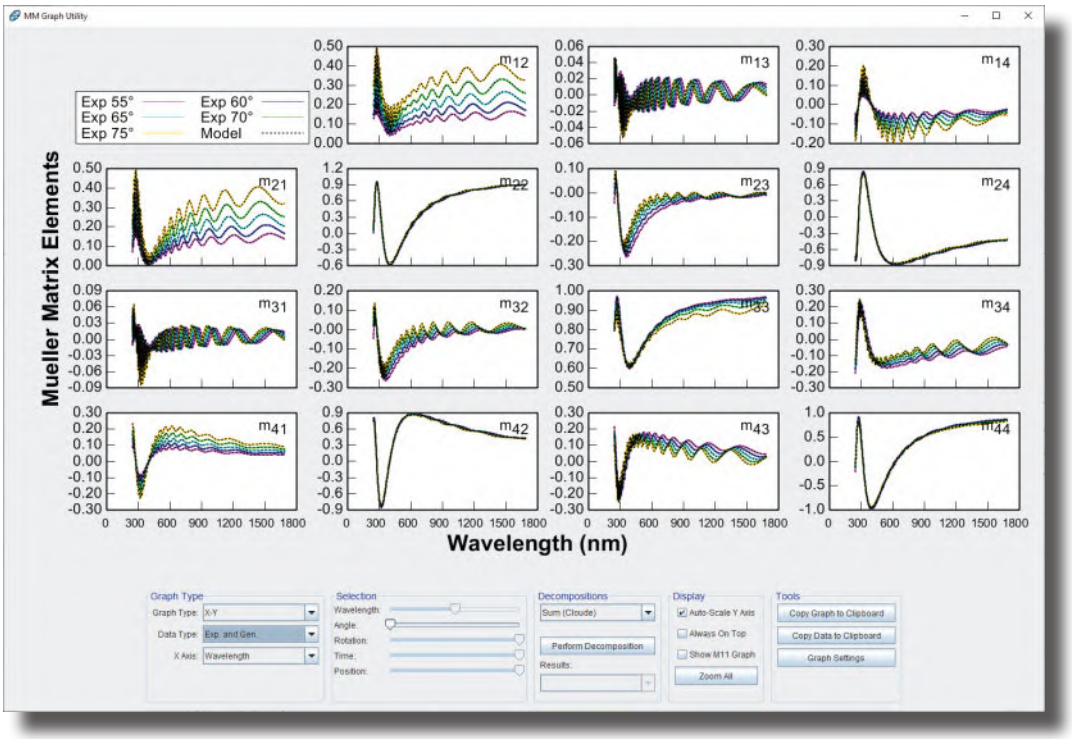
System Requirements:
+Automated Translation
+Focusing Probes
+Lookdown Camera
+Visible repeated features on sample



Mueller Matrix Measurement and Analysis

Mueller matrix measurements provide the most complete description of the dielectric response of a sample upon interaction with a light source. All J.A. Woollam ellipsometers are capable of collecting Mueller matrix data from a sample. CompleteEASE is not only the engine behind accurate data acquisition, it provides intuitive graphing and analysis tools that help you get the most out of your measurements.

Viewing the entire Mueller matrix allows access to different polarization effects in advanced samples, including diattenuation and polarizance. The Mueller matrix Graph Utility, shown below, is a graphing and visualization window that enables users to easily view measured and modeled Mueller matrix data. The Graph Utility also enables users to perform decompositions on Mueller matrix data. Mueller matrix decompositions provide an alternate approach for extracting information from the Mueller matrix and can be especially useful when measuring highly complex samples.



Absorbing Materials

Absorptions in materials can be caused by electronic transitions, lattice vibrations, and free carrier absorptions, among other things. The nature of absorption resonances vary by material and are dependent on a variety of factors. For this reason, mathematical descriptions for absorbing materials are traditionally more complex. CompleteEASE features multiple tools for modeling absorbing films easily and efficiently.

Gen-Osc

The General Oscillator layer, or Gen-Osc, was developed to simplify the modeling of material optical constants. The Gen-Osc layer models the dielectric function of a material as a linear summation of wavelength-dependent oscillators.

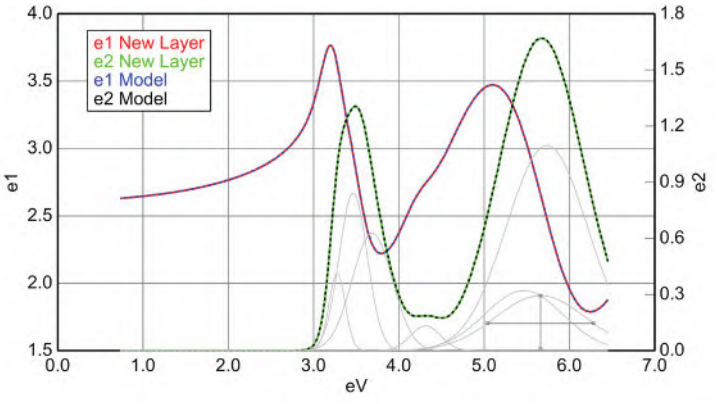
The oscillators described mathematically in the Gen-Osc layer represent the dipole response of the material and can be used to describe comparable physical parameters, such as band gap.

CompleteEASE provides a convenient Gen-Osc parameterization layer which helps to define the initial starting values of each oscillator in the model.

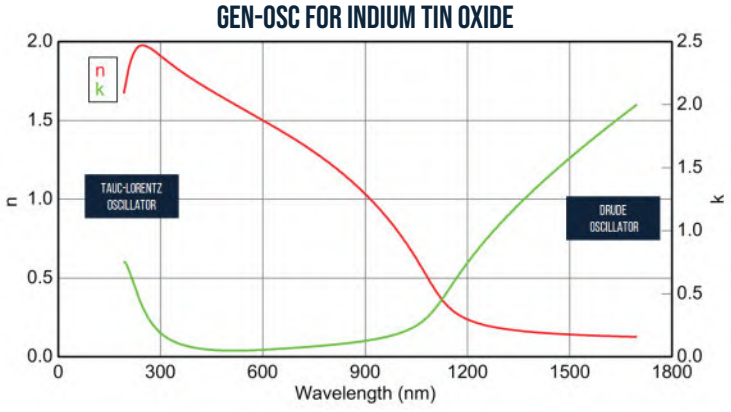
Build your own oscillators using the parameterization window, beginning with a number of built-in functions, including:

+ Lorentz
+ Tauc-Lorentz
+ Gaussian
+ Cody-Lorentz
+ Harmonic
+ Tanguy
+ Drude
+ PSEMI

GEN-OSC FOR ORGANIC THIN FILM



GEN-OSC FOR INDIUM TIN OXIDE



B-Spline

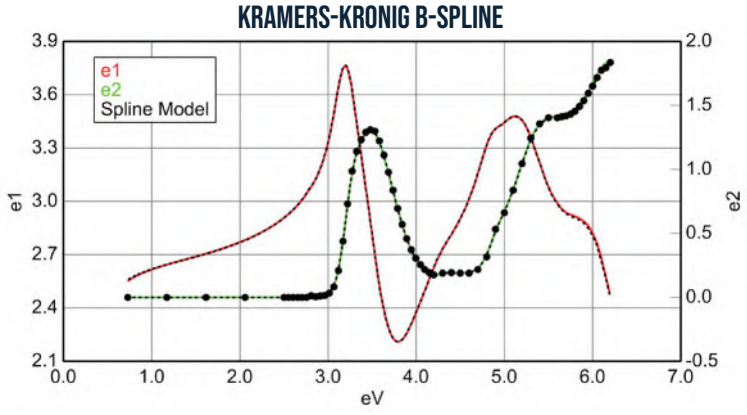
The B-Spline layer was developed in CompleteEASE as an alternative to direct data inversion or oscillator models and has revolutionized optical modeling of semi-absorbing materials. The B-Spline has the following benefits:

+Reduced number of fit parameters
+Complete flexibility in optical constants for any material
+No guesswork about where to place oscillators and what type to choose

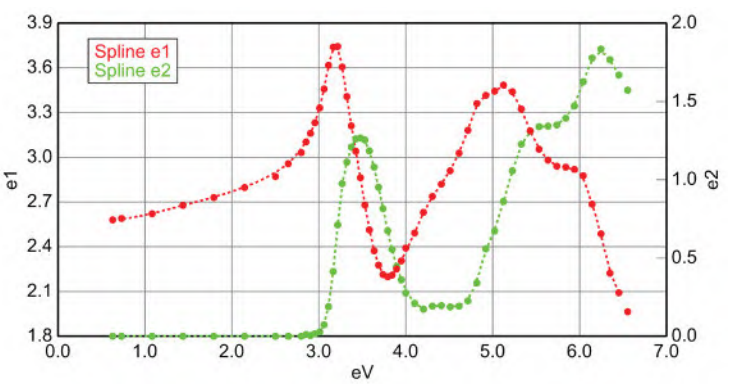
The B-Spline is especially useful for describing complex dispersion shapes in a physical manner.

The latest versions of CompleteEASE feature an automated B-Spline feature which enables users to determine the optical properties of semi-absorbing materials with just a few clicks without the need of background information on the material or a reference file.

KRAMERS-KRONIG B-SPLINE



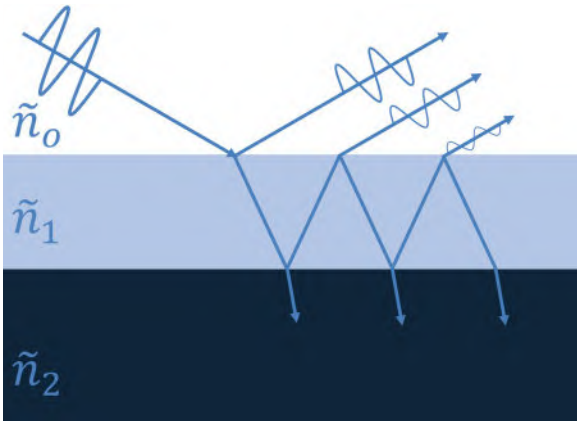
B-SPLINE MATCHED TO ORGANIC FILM



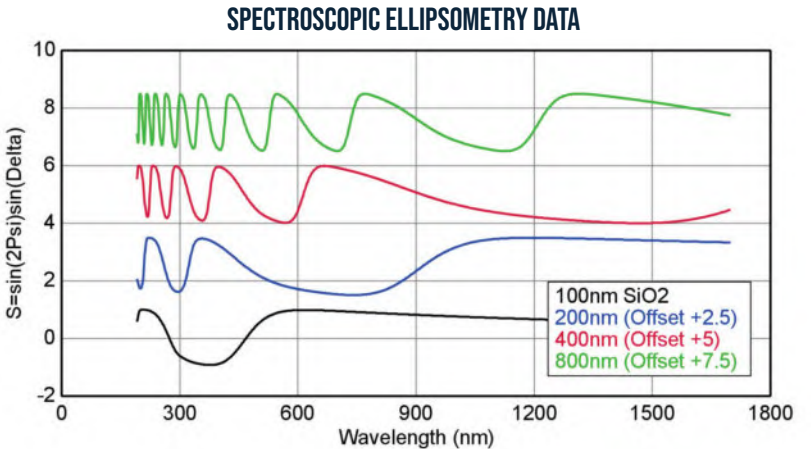
Automated Modeling Features

Thickness Pre-fit

Ellipsometry takes advantage of the coherent nature of light to determine thickness of thin films. Light interacts with the various interfaces within the film stack and eventually recombines with the initial surface reflection causing constructive or destructive interference in the detected signal.



Light propagating through a transparent film provides sensitivity to film thickness via a coherenct interaction of the reflected and refracted beams.



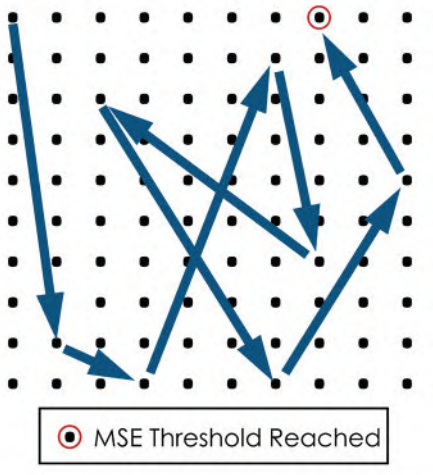
The thickness of a film is measured by ellipsometry based on the interference oscillations caused by light combining from the surface and bottom of the film. The thicker the film, the more oscillations.

The CompleteEASE thickness pre-fit algorithm quickly estimates the film thickness for an unknown layer by leveraging the presence of interference oscillations in the raw measured data. This feature helps to avoid local minima in your fit by providing an automated starting value that is close to the optimized solution.

Global Fitting

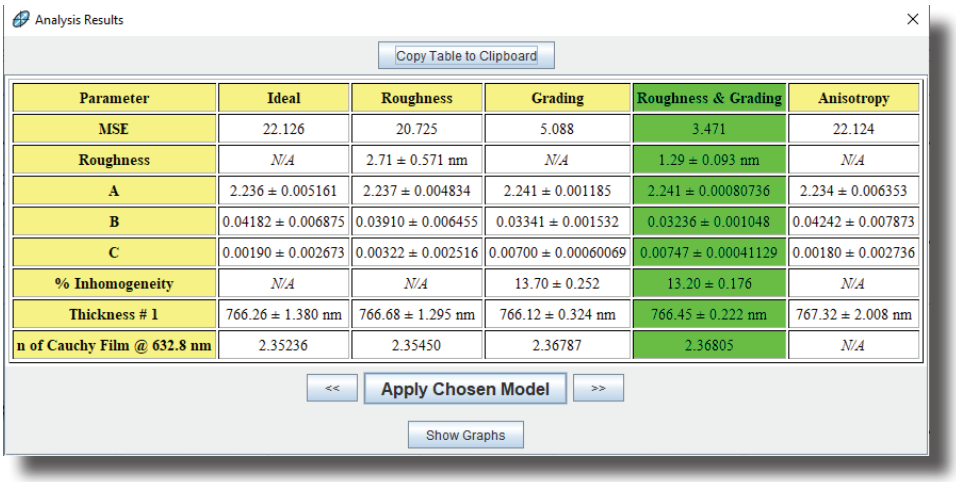
Global fitting is a feature used to search a defined parameter space for a global minimum. This approach is helpful to avoid local minima that might prevent the correct fit from being obtained. A standard global fit will scan two or more parameters as a grid. Each point gets assigned an MSE value, and the minimum MSE value along with its corresponding parameters is reported at the end.

CompleteEASE also features a randomized global fit algorithm, which will search the parameter space randomly instead of in a grid. The advantage of this method is that an MSE threshold can be set. Once a point below the MSE threshold has been found, the fit is then followed by a standard Levenberg-Marquardt fit. Tests have shown a reduction in global fit time of 5x or better using this feature.



Alternate Models

Using the Alternate Models function in CompleteEASE is a huge time saver when testing your films for common complexities. In addition to surface roughness and grading, CompleteEASE can now check for simple anisotropy. CompleteEASE allows you to compare the results from each of these models, see which one CompleteEASE suggests as the best fit, and select which one you want based on the results.

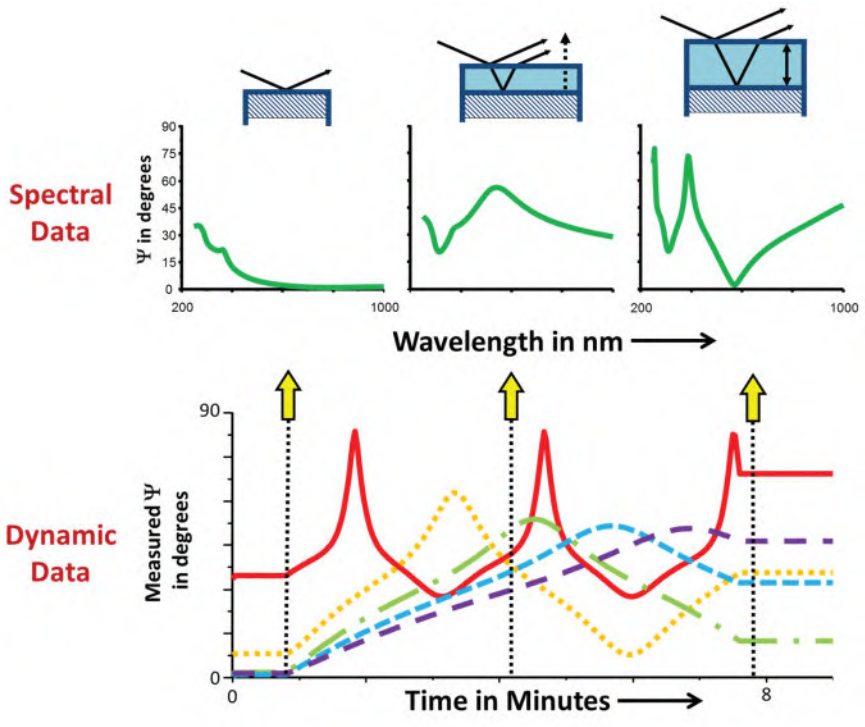


In-situ Analysis + Control

User-friendly Experience

CompleteEASE is the perfect interface for real-time data acquisition, monitoring, and control. It leverages the vast in-situ spectroscopic ellipsometry experience at J.A. Woollam within a user-friendly interface. Real-time ellipsometry data contains a wealth of information. Samples can be fully characterized before, during, and after processing.

Ellipsometry measurements over a wide spectral range provide sensitivity to a variety of material properties such as composition, conductivity, surface conditions, etc. In addition, ellipsometry is sensitive to thickness changes at the sub-angstrom level.



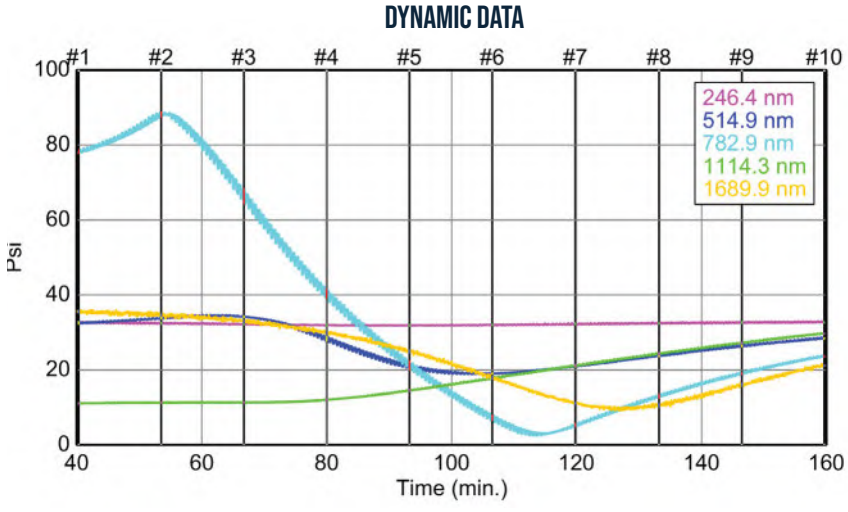
Multi-time-slice Analysis

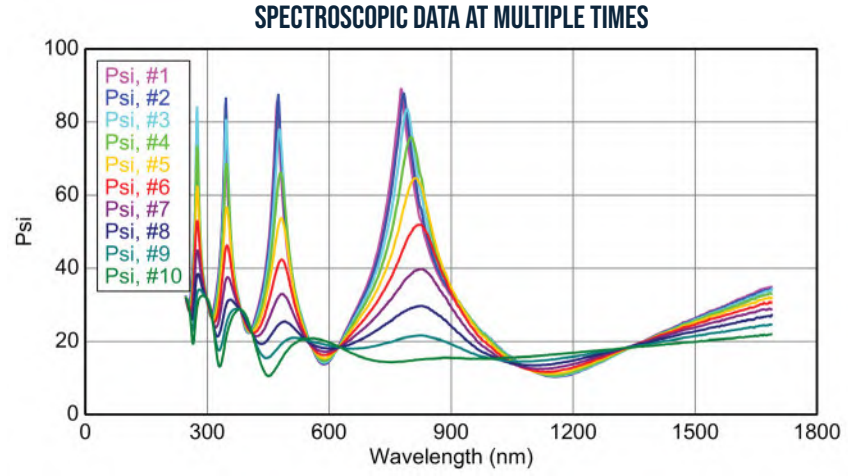
Analyzing in-situ ellipsometry data is made simple in CompleteEASE. Often the best way to interpret and analyze changes observed in real-time is by using the multi-time-slice analysis mode. This approach allows users to distinguish model parameters that vary with time from other parameters which are constant as a function of time.

CompleteEASE enables easy visualization of ellipsometry data acquired as a function of time and allows users to easily select individual time slices to view and compare.

With multiple-time slices selected, a model can be quickly developed to account for variation between measurements acquired at different times. This can include accounting for time-sensitive variations such as film thickness, temperature, or ambient environment. An example of this is atomic layer deposition of aluminum oxide. The optical properties of Al_2O_3 are constant during ALD growth while the thickness changes.

Once the time-dependent parameters are known, CompleteEASE enables quick fitting of all time slices. The results can be quickly viewed as a function of time. If data was collected as a function of another parameter, such as temperature or relative pressure, results can be quickly plotted as a function of the relevant parameter.





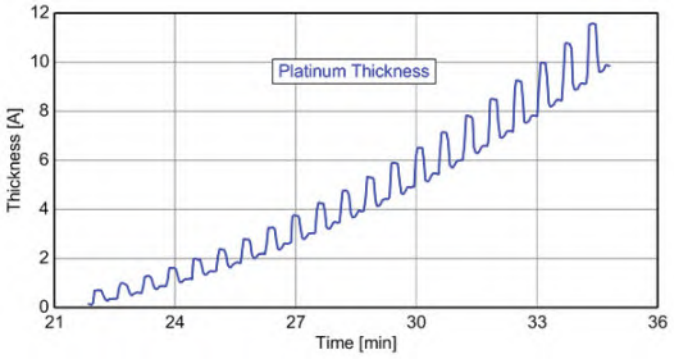
In-situ Applications

In-situ spectroscopic ellipsometry characterizes the thickness and optical properties of a sample in real-time as conditions are varied. This includes measurements during film growth or etch; while varying sample temperature, humidity, or other environmental conditions; and during other external stimulation of the sample, including magnetic, electric and others.

Real-time Deposition Characterization

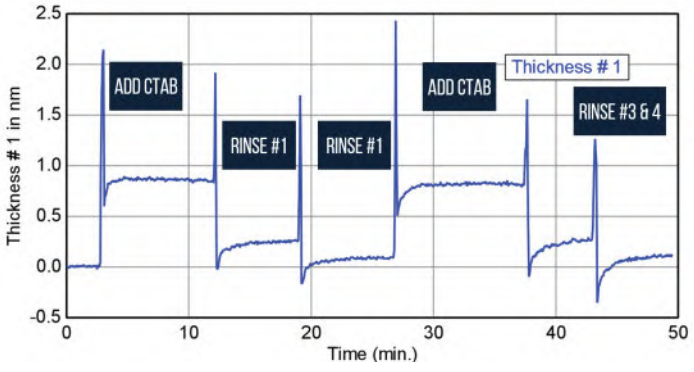
Real-time feedback of thin film properties during deposition enables early detection of variations in films and provides the necessary information to dynamically modify the process to consistently produce high quality coatings. In-situ ellipsometry is also used to characterize substrate monolyaer adhesion, reagent conditions, rinsing, etc.

ATOMIC LAYER DEPOSTION OF PLATINUM ON SILICON



Atomic Layer Deposition has demonstrated monolayer control for thin film growth. In-situ ellipsometry is the perfect tool to match monolayer sensitivity to this unique process capability.

CTAB ADSORPTION AT SURFACE

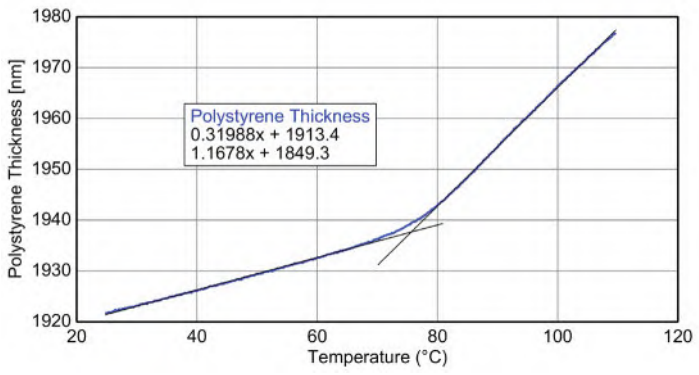


Phase (Delta) is highly sensitive to thin films, which allows precise characterization of this organic monolayer during attachment and rinsing steps.

Temperature Studies

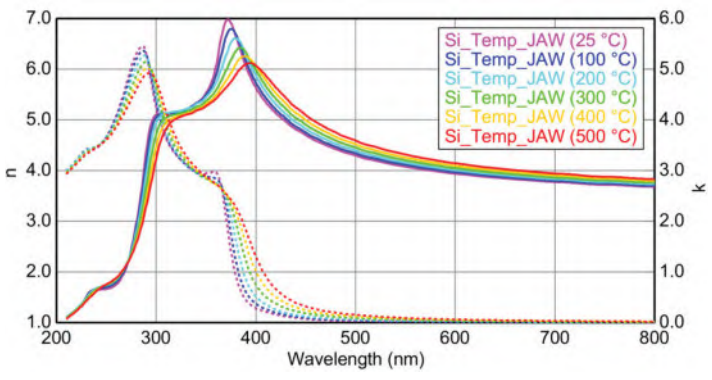
Variable temperature measurements can be very useful for a wide variety of applications. Low temperatures are valuable for optical coatings designed for use in satellite telescopes, superconductive materials, and critical point detection in semiconductors. Elevated temperatures are often used to study phase transitions in materials and to accurately determine material properties at growth temperatures.

POLYSTYRENE THICKNESS VS. TEMPERATURE



The change in rate of thermal expansion of films caused by temperature change clearly identifies the glass transition temperature. These results are easily obtained using the Graph Scratchpad in CompleteEASE.

OPTICAL CONSTANTS OF SILICON VS. TEMPERATURE



The optical properties of silicon and many other materials are temperature dependent. Users can easily create their own temperature or composition libraries for various materials.

Customer Support

SHORT COURSES

We offer short courses multiple times per year at various locations across the globe. Our course syllabus follows a three-day format with two sessions per day:

Session 1: Introduction to Ellipsometry
Session 2: Transparent Materials
Session 3: B-Spline for Absorbing Materials
Session 4: General Oscillator Modeling
Session 5: Complexities & Non-idealities
Session 6: Anazying Mapping & In-situ Data

Short courses include extensive training through examples and interaction between other students and instructors. Contact your local representative or sales@jawoollam.com for more information regarding upcoming short courses.

ON DEMAND

Our commitment to continual customer support is what sets us apart. We offer a variety of learning opportunities each year that take place all over the world–both online and on-location. We stand behind our products and continuously offer guidance and assistance, so you can be confident about getting the most out of your experience with our products and move forward with your research and custom projects.

There are a variety of subjects that we cover through our online webinars that feature applications such as porosimetry, anisotropy, Mueller matrix, and infrared ellipsometry.

For those interested in online training, we've developed the CompleteEASE training series. For more information, visit our website or scan the QR code below.

UPGRADES

CompleteEASE 6 made its debut in late 2017 with a host of new features that enhance the user interface and enable analysis of more complex sample types. We are continuously updating the software to improve the user experience. Some of the recent updates include:

+Easily fit semi-absorbing materials

We've recently simplified the analysis procedure for semi-absorbing films by automating the B-Spline layer. It's now possible to analyze the entire wavelength range of a UV-absorbing material with just a few clicks.

+Add common complexities using Alternate Models

We've upgraded the ability to test for common complexities with a single click of the mouse. Now, you can check for surface roughness, grading, and anisotropy. CompleteEASE will suggest the most appropriate model and give you the option to apply it.

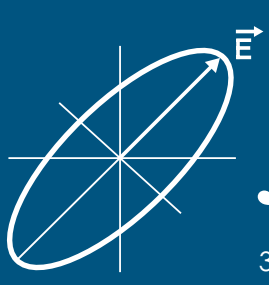
+Analyze complex material systems with the Full Tensor Layer

Each element of the dielectric function tensor can be modeled individually with the addition of the Full Tensor layer. The KK B-Spline has been integrated into this approach to ensure your results are physically realistic and devoid of noise propagation.

PLEASE CONTACT US FOR MORE INFORMATION ABOUT THESE MODELING FEATURES AT INFO@JAWOOLLAM.COM. IF YOU'RE INTERESTED IN A FREE UPGRADE, SCAN THE QR CODE TO THE RIGHT.

Versatile

For more information:



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