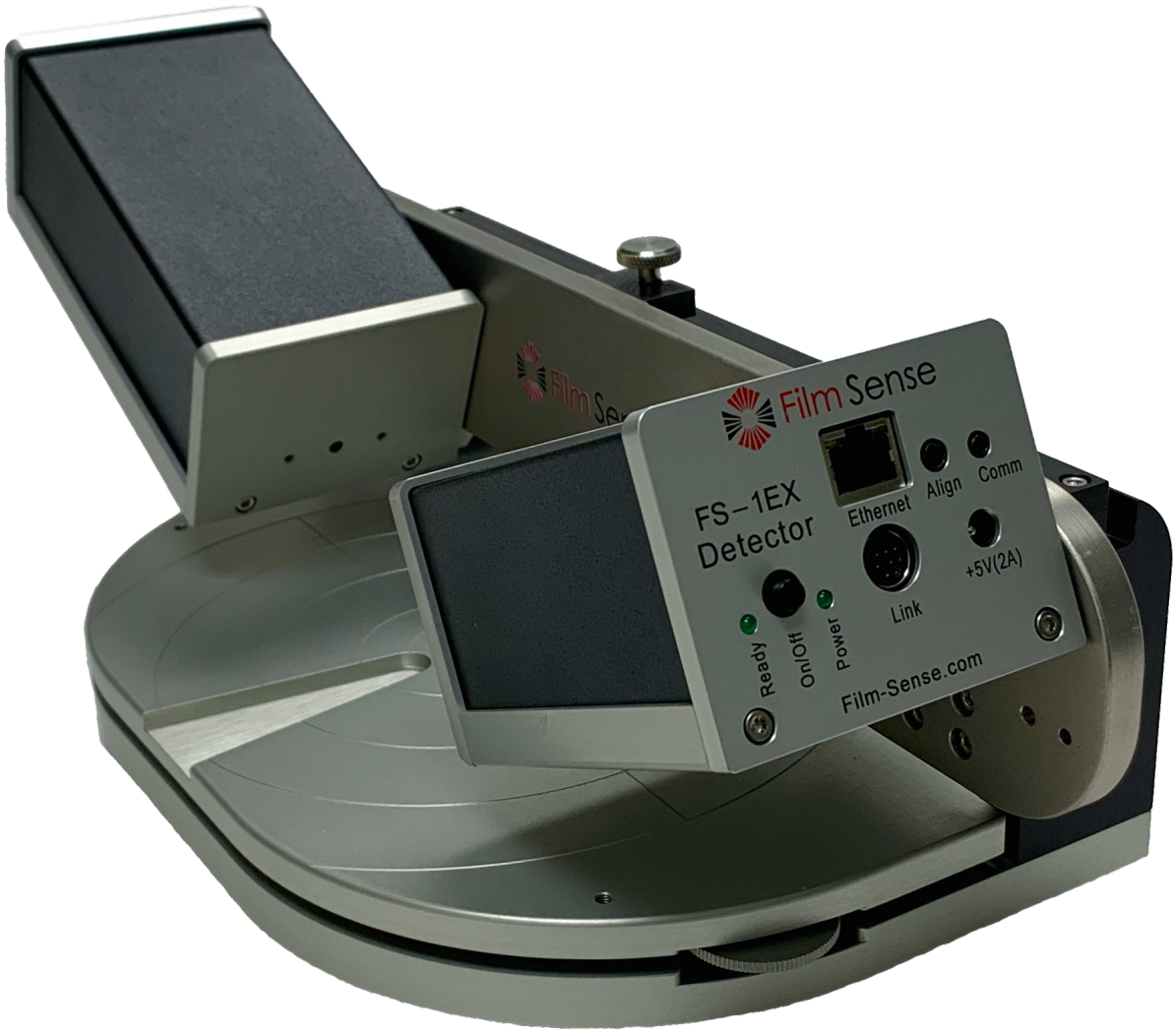


Film Sense™

MULTI-WAVELENGTH ELLIPSOMETERS

Innovative ■ Powerful ■ Affordable

Film Sense Multi-Wavelength Ellipsometers use long-life LED's and a no-moving-parts ellipsometric detector to provide fast and reliable thin film measurements in an easy-to-use, compact system.

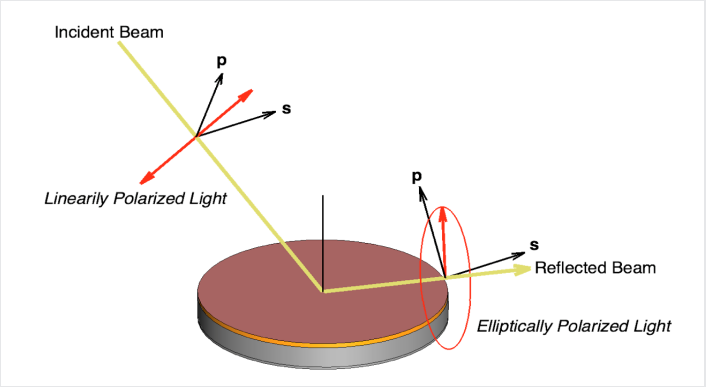
The film thickness and index of refraction of most transparent thin films can be determined with excellent precision and accuracy by a simple 1 second measurement. Optical constants n & k and other film properties can also be measured for many samples.

Multi-Wavelength Ellipsometry provides powerful thin film measurement capabilities, while at the price point of single wavelength ellipsometer and spectroscopic reflectometer systems. Film Sense ellipsometers are ideal for measurements in the research lab, classroom, in situ process chambers, industrial quality control, and more.

What is Ellipsometry?

Ellipsometry measures the change in polarization state for light reflected from a Sample. The ellipsometric measurement is quantified by the formula below, where ρ is the complex ratio of the reflectivities for p- and s- polarized light (R_p and R_s). The ellipsometric Ψ parameter is related to the magnitude of the complex ratio, and the ellipsometric Δ parameter is the phase of the complex ratio.

$$\rho = \frac{R_p}{R_s} = \tan(\Psi) \cdot e^{i \cdot \Delta}$$

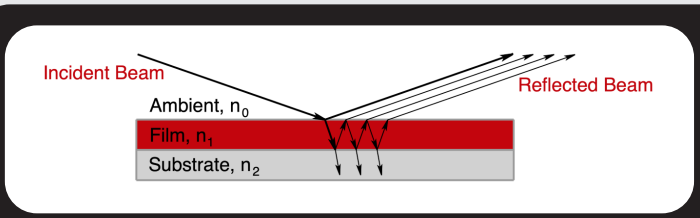


Advantages of Ellipsometry

- Ellipsometry measures a ratio, so it is not sensitive to changes in the beam intensity, or sample imperfections that scatter light away.
- Since ellipsometry measures 2 quantities (Ψ and Δ) at each wavelength, it can determine 2 quantities, such as film thickness & index, or substrate n & k.
- The ellipsometric Δ parameter is extremely sensitive to thin films, enabling accurate film thickness measurements down to 0 Å.

Advantages of Multiple Wavelengths

- Enable unique determination of film thickness for transparent films (no thickness periodicity issues).
- Determine additional sample parameters, such as: surface roughness, multiple film thicknesses, index dispersion.
- Provide a consistency check on the data analysis—a "good" analysis model should fit the data at all measured wavelengths.
- For very thin films (< 20 nm), a multi-wavelength ellipsometric data set can provide information content similar to spectroscopic ellipsometric data (contact Film Sense and request our "FS-1 vs. Spectroscopic Data" white paper for more details).



To determine sample parameters of interest, such as film thickness and index of refraction, an optical model is used to analyze the ellipsometric data.

Film Sense Multi-Wavelength Ellipsometer Technology

KEY FEATURES	BENEFITS
Multiple LED sources (either 4 or 6, with wavelengths ranging from 405 – 950 nm, depending on the system)	Long lifetimes (>50,000 hours), with no costly lamp changes, time consuming alignments or PM procedures
No moving parts in the ellipsometric detector*	Fast measurement times (multi-wavelength data in 10 ms) and long term reliability
Excellent thickness precision, better than 0.0004 nm for many samples (for a 1 second acquisition), even for sub-monolayer film thicknesses	Measurement precision that is only possible with an ellipsometer
Integrated computer for instrument control and data analysis, with a web browser interface accessible from any modern computer, laptop, or tablet	No complicated software setup and maintenance
Completely self-contained system	No external electronics box or fiber connections

NOW AVAILABLE

Film Sense Multi-Wavelength Ellipsometer Systems

The 3rd generation Film Sense Multi-Wavelength Ellipsometer systems are now available! The primary improvement in this generation is the motorized source polarizer, which enables auto-calibration and zone-averaged measurements. The new systems offer the same benefits of the patented* FS-1 ellipsometer technology (long life LED light sources, fast and reliable no moving parts detector, compact design, and web browser software interface), while maintaining ease of use and affordability.

Gen. 3 Common Specifications

- Compact optics: Source 142 x 80 x 60 mm
  Detector 110 x 80 x 60 mm
- Simple connections: +5V wall plug power supply, Ethernet, and Source-Detector link cables
- Motorized Source Polarizer:
  - provides automated instrument calibration
  - enables zone-averaged measurements, for improved measurement accuracy
- 4x more intensity (compared to original FS-1), and updated detector electronics provide improved measurement precision: 2x for ex situ, 4x for in situ

FS-1 (Gen. 3)

- 4 wavelengths, 450 – 660 nm spectral range (replaces the original FS-1)
- Excellent choice for measuring single layer transparent films in the 0 – 2 µm thickness range, with precision down to 0.0004 nm

FS-1EX™

- 6 wavelengths, 405 – 950 nm spectral range
- The 2 longer wavelengths (850 and 950 nm) enable the measurement of thicker transparent films (up to 5 µm), and absorbing semiconductor films (such as poly-Si, SiGe, amorphous-Si, etc.)
- Film resistivity measurements (using the Drude model) are also improved with the 2 longer wavelengths.
- 6 wavelengths and wider spectral range provide enhanced measurement capability for multilayer film stacks

FS-1 Wavelengths

System	Number of Wvls	Wavelength (nm)								
		405	450	465	525	595	635	660	850	950
FS-1 (original)	4			X	X	X	X			
FS-1 (gen. 2 & 3)	4		X		X	X		X		
FS-1EX (gen. 2 & 3)	6	X	X		X			X	X	X

*US Patent #9,354,118

Capabilities and Performance

Film Sense Multi-Wavelength ellipsometers excel at measuring the thickness and index of refraction of transparent single films. The upper thickness limit depends on the ellipsometer system (typically 2 – 5 µm), but is also dependent on the substrate and film optical constants. As with any ellipsometer system, a minimum film thickness (typically 10 nm) is required to obtain accurate index of refraction measurements.

Optically absorbing films can also be measured, but the data analysis becomes more complicated as the film optical constants (both n and k values) are required. The Film Sense software contains multiple methods for determining n&k values: 1) multi-sample analysis, 2) combined ellipsometry + transmission measurements, and 3) dispersion models. The upper thickness limit for absorbing films is strongly dependent on the type of material; for metallic films, the upper limit is typically 50 nm.

Multi-Wavelength Ellipsometry can also be used to measure multilayer film stacks (in some cases up to 5 layers), depending on the thicknesses and indices of refraction of the layers. Simulations can be performed in the Film Sense software to determine if a particular sample structure is possible. For some samples, surface roughness and index gradients in the film can also be characterized.

The typical Film Sense ellipsometer measurement Accuracy and Precision for a variety of samples, including a multi-layer sample, is shown in the table below. For more details on the testing methodology, contact Film Sense and request our "FS-1 Performance" white paper.

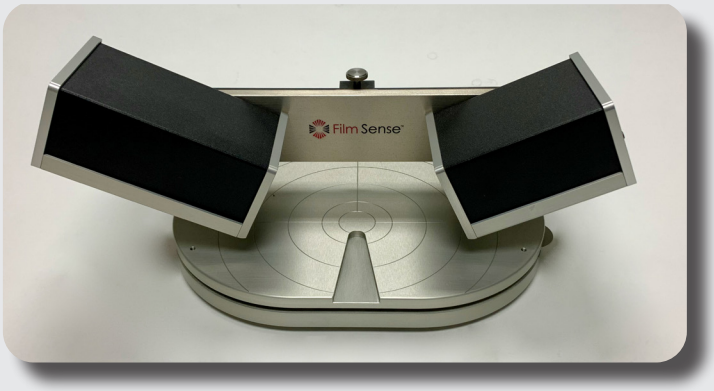
Sample	Parameter	Accuracy	Precision
#1. 2nm Native Oxide on Si	Thickness	0.013 nm	0.00035 nm
#2. 90nm Oxide on Si	Thickness Index @ 633 nm	0.18 nm 0.0006	0.00029 nm 6.7E-6
#3. 1000nm Oxide on Si	Thickness Index @ 633 nm	0.70 nm 0.0002	0.0046 nm 4.1E-6
#4. 100-50-100 nm ONO on Si	Top SiO2 Thickness Si3N4 Thickness Bottom SiO2 Thickness SiO2 Index @ 633 nm	0.12 nm 0.16 nm 0.58 nm 0.0029	0.0022 0.0028 0.0023 7.1E-6
#5. 6 nm TiO2 on Si	Thickness Index @ 633 nm	0.022 nm 0.032	0.00034 nm 2.9E-4
#6. 70 nm Al2O3 on Si	Thickness Index @ 633 nm	0.071 nm 0.0001	0.00029 nm 9.4E-6
#7. 500 nm SiN on Si	Thickness Surface Roughness Index @ 633 nm k @ 633 nm	0.51 nm 0.18 nm 0.0031 0.0003	0.0031 nm 0.0019 nm 8.7E-6 1.4E-6
#8. 300 nm Ta2O5 on Glass	Thickness Surface Roughness Index @ 633 nm	0.45 nm 0.15 nm 0.0013	0.0026 nm 0.0018 nm 1.3E-5
#9. 60 nm a-Si on Glass	Thickness Oxide Thickness Band Gap	0.16 nm 0.04 nm 0.0009 eV	0.0012 nm 0.00066 nm 5.5E-5
#10. 10 nm TiN on Si	Thickness Resistivity	0.037 nm 2.0 uOhm-cm	0.00044 nm 0.015 uOhm-cm

SEND US YOUR SAMPLES!

As thin film applications are so varied and diverse, the best way to determine if a Film Sense Multi-Wavelength Ellipsometer is right for your application is to perform demonstration measurements on your actual samples. Please contact us to discuss your application, and arrange for sample measurements.

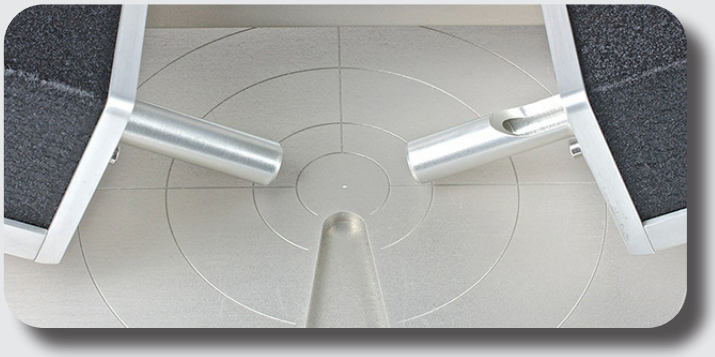
Standard Ex Situ Configuration

- 65° Angle of Incidence.
- Manual sample loading and height adjustment.
- Sample sizes up to 200 mm dia. and 20 mm in thickness.
- Sample tilt with +/-2° range
- Beam size on sample: 4 x 9 mm.
- Compact footprint (180 x 400 mm) and light (5 kg).



Focused Beam Option

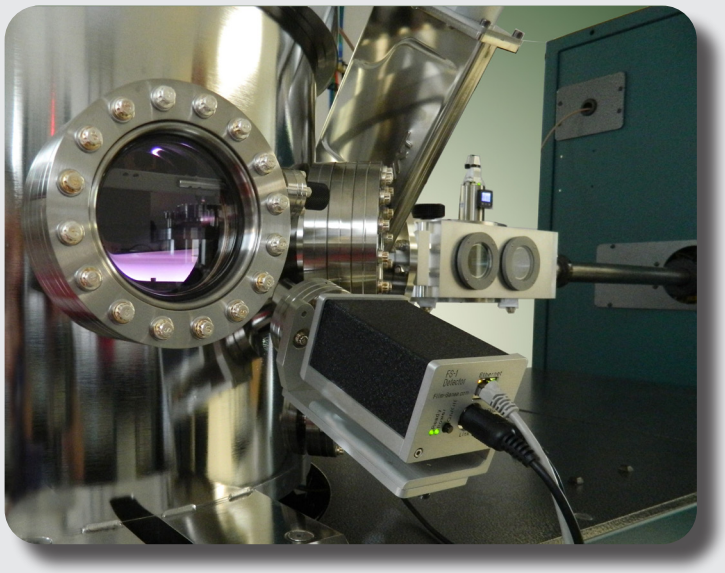
- Reduces beam size on sample to 0.8 x 1.9 mm or 0.3 x 0.7 mm.



In Situ Features

Film Sense Multi-Wavelength Ellipsometers are ideal for in situ realtime monitoring and control of thin film deposition and etching processes.

- Completely self-contained system, with no external electronics box or fiber connections required
- LED light sources and no moving parts detector, for robust and reliable operation, and fast measurements
- Compact and light weight source and detector units (≈1 kg each)
- Optional adapters for mounting to standard 2.75" or 1.33" conflat flanges, with easy to adjust coarse and fine tilt stages
- Powerful software features for visualizing and analyzing dynamic ellipsometric data



FS-1 Mounted on AJA Sputter Chamber

FS-1 Mounted on Kurt Lesker ALD Chamber

In Situ Capabilities

- Sub-monolayer thickness precision
- Determine film optical constants n&k and deposition rates, at multiple process conditions, without breaking vacuum
- Monitor and control the deposition of multilayer film structures
- FS-API interface for external software control (LabVIEW™ compatible)
- Applicable to most thin film deposition and etching techniques: Sputtering, ALD, ALE, MBE, CVD, PLD, etc.

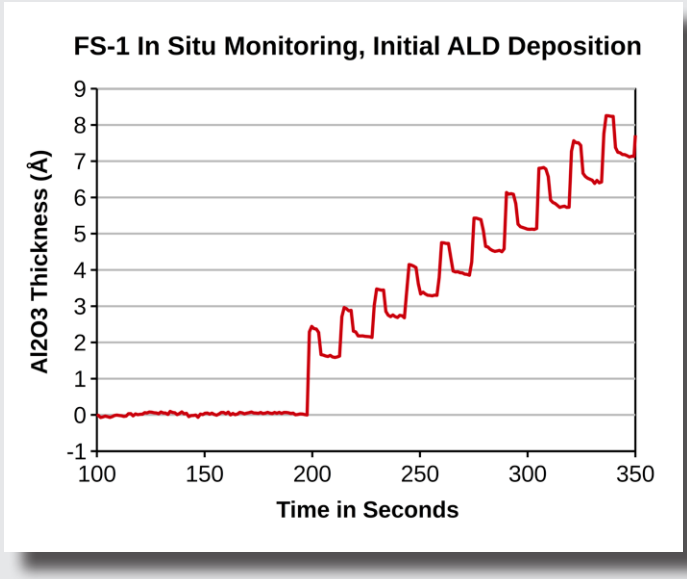


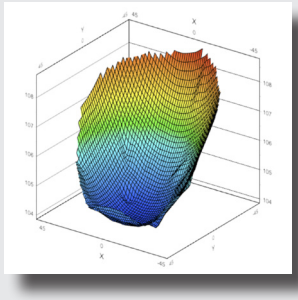
Photo and data courtesy of US Army Research Lab

Automated Mapping Systems

These products combine an FS-1EX Multi-Wavelength Ellipsometer with compact automated mapping stages to provide fast, accurate, and reliable film thickness uniformity measurements across a wafer.

Features and Specifications

- 6 wavelengths of ellipsometric data (405, 450, 525, 660, 850, 950 nm), with long life LED sources, and no moving parts detector
- Accurate thickness measurements for most transparent thin films from 0 – 5 µm
- Typical thickness repeatability: 0.002 nm
- Integrated focusing probes, standard spot size: 0.8 x 1.9 mm (other spot sizes available)
- USB camera option available
- Motorized Z-stage for sample auto alignment
- Flexible Scan Pattern Editor
- Contour and 3D plots of measured parameters



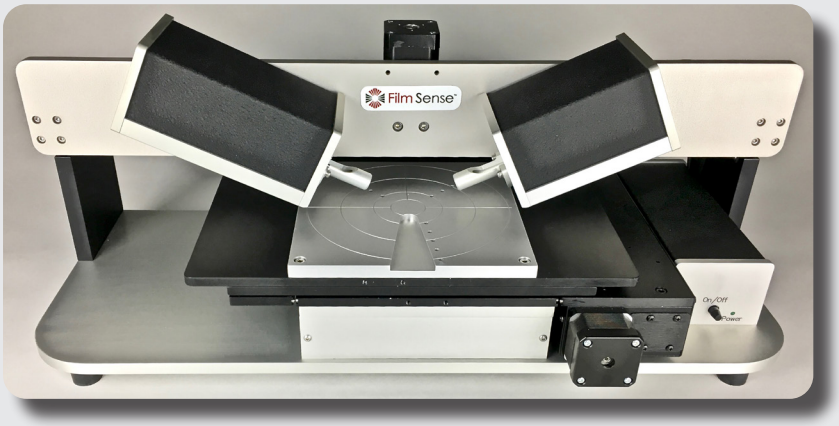
FS-XY150

- Typical time for wafer map: 2 minutes (49 points on a 150 mm diameter wafer)
- Compact footprint: 600x600 mm, 16 kg
- Stage travel (X,Y): 150 x 150 mm, resolution: 5 µm

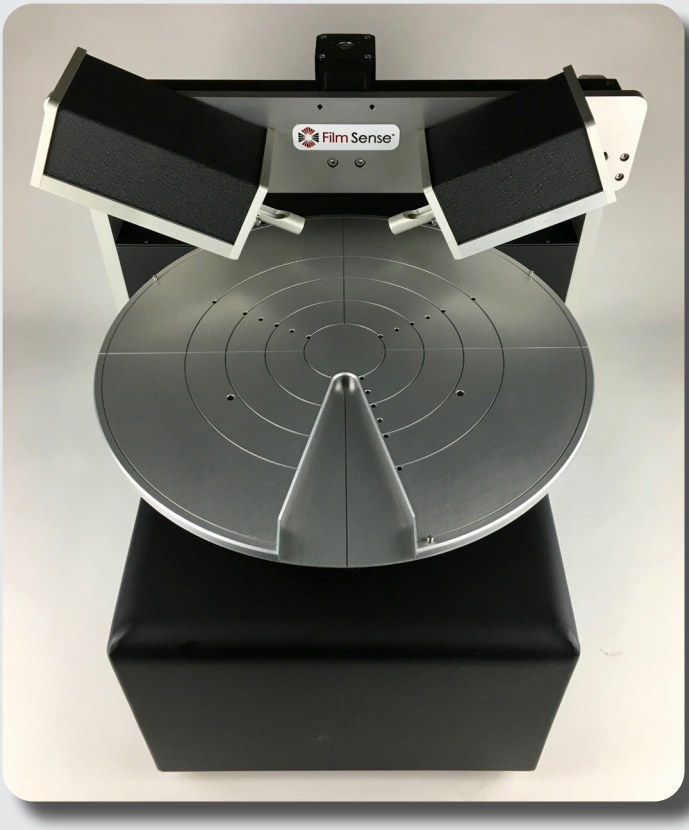
FS-RT300

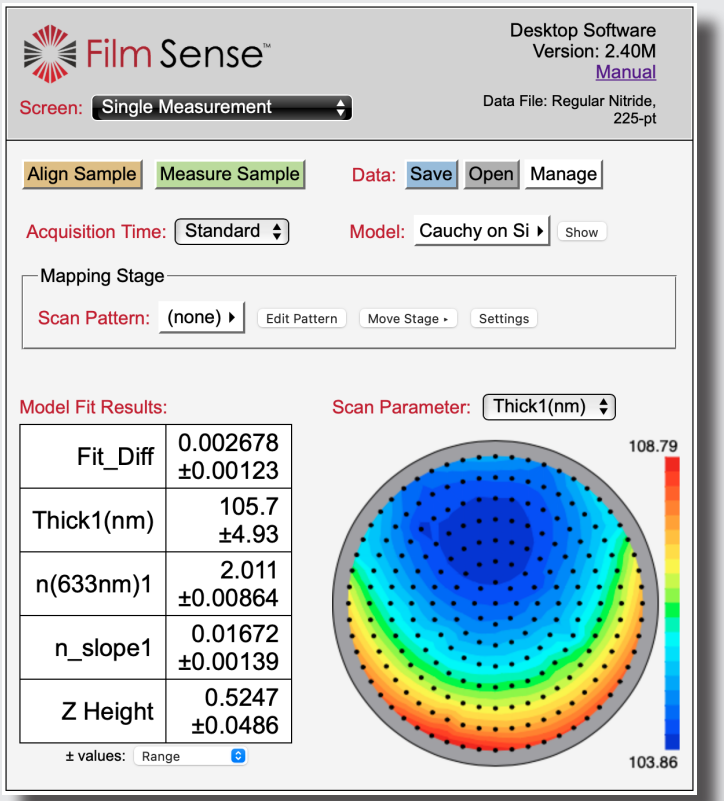
- Typical time for wafer map: 2.5 minutes (49 points on a 300 mm diameter wafer)
- Compact footprint: 400x500 mm, 22 kg
- Stage travel: R (linear) 150 mm, resolution: 12 µm
  Theta (rotation) 360°, resolution: 0.1°

FS-XY150



FS-RT300

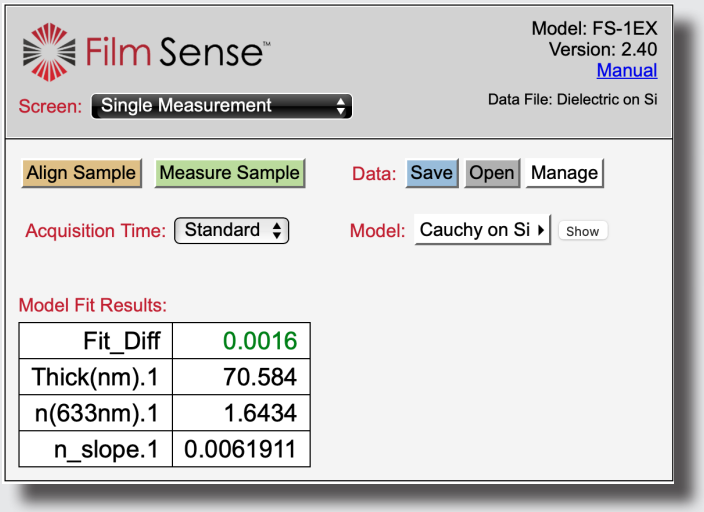




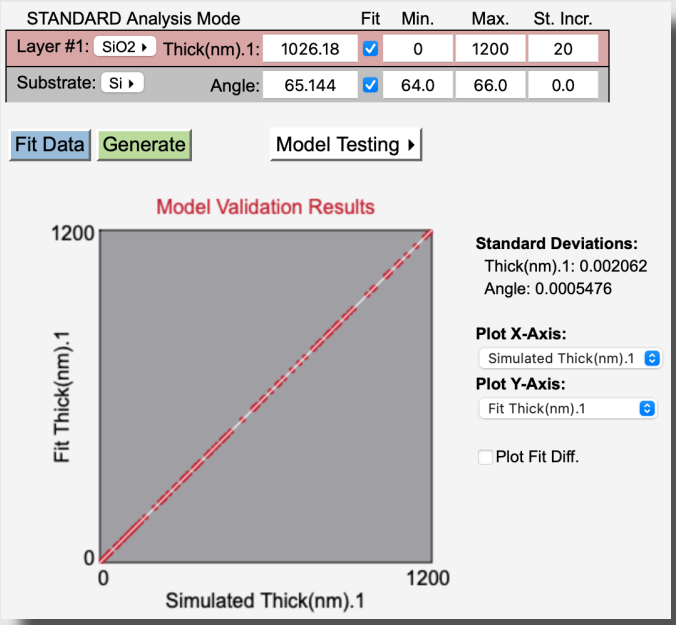
Software

The Film Sense software acquires and analyzes the ellipsometric data, and reports the sample parameters (thickness, index of refraction, etc.) that are derived from the measurement. The Film Sense software runs on a computer which is inside the Detector unit, and a standard web browser provides the user interface for the software. Any desktop, laptop, or tablet computer that supports a modern web browser (Windows, Mac OS X, Linux, iOS, Android) can operate the Film Sense ellipsometer using its Ethernet connection (no Internet or web access is required). A major advantage to the web browser interface is that no software installation is required, which greatly simplifies the setup and operation of Film Sense ellipsometers. (A Desktop version of the software is also available to support offline analysis.)

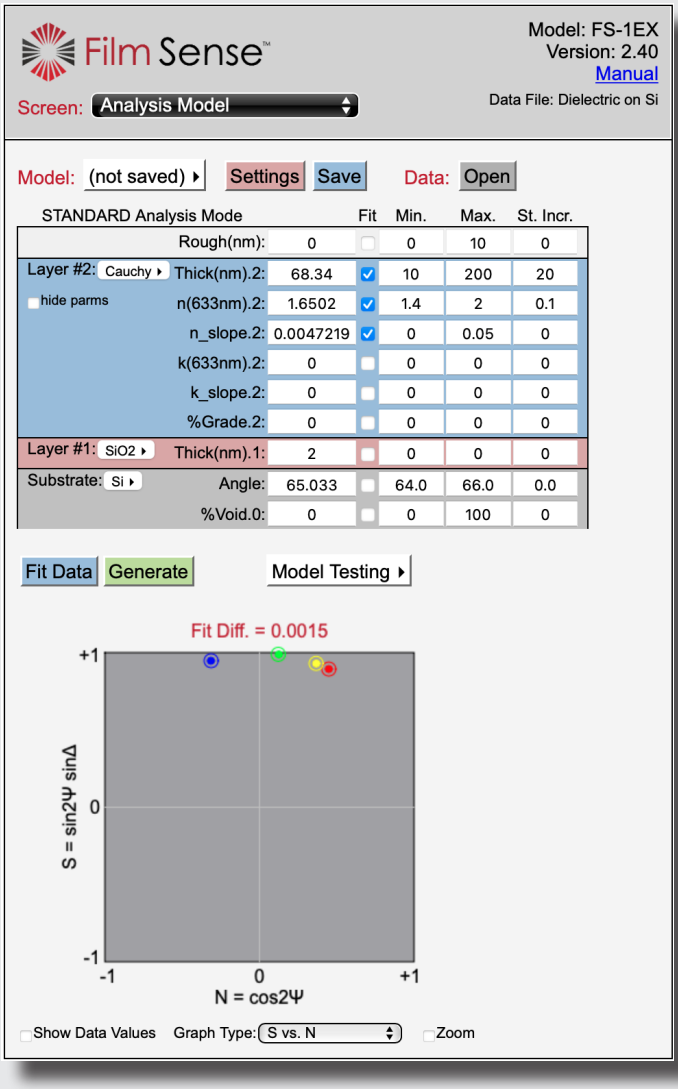
The **Single Measurement** screen makes routine sample measurements as easy as clicking a button.



The **Model Validator** feature verifies that all model fit parameters will uniquely converge over the specified ranges.



The **Analysis Model** screen provides powerful features to analyze and visualize the Film Sense ellipsometric data.



Features

- Standard, In Situ Multi-Layer, Multi-Sample, Trajectory, and Near Surface data analysis modes.
- Up to 10 model layers, with optional surface roughness, and substrate backside correction.
- Parameter ranges and starting increments to improve fit parameter convergence.
- Bruggeman effective medium approximation for mixed materials, and graded index layers.
- Cauchy, Sellmeier, Lorentz, Drude, Tauc-Lorentz, and Multi-Osc dispersion models.
- Temperature or composition dependent optical constant library files.
- Depolarization or transmission intensity data can be combined with the multi-wavelength data analysis.
- Simulate single measurement or dynamic data, and plot the Fit Diff vs. parameter value.
- Display fit parameter 90% confidence limits and correlation matrix, and estimate parameter accuracy