J.A. Woollam Co., Inc.
Ellipsometry Solutions

M-2000®
Specifications

The M-2000® Spectroscopic Ellipsometer is the perfect combination of speed and accuracy. Measurements covering the entire spectral range from deep ultraviolet to near infrared are accomplished in seconds–making the M-2000 ideal for a large range of applications:quick quality control, real-time process monitoring and in situ control, uniformity mapping, and more.

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Features

Patented Rotating Compensator Ellipsometer (RCE) Technology

RCE technology overcomes the limitations of other ellipsometers.

	RCE	RAE	RPE	Phase Modulated
Measure all Ψ/Δ accurately	Yes	No	No	* Requires 2 measurements
Measure Δ handedness	Yes	No	No	Yes
Combine with fast CCD detection	Yes	Yes	Yes	No

CCD Detection System

The M-2000® uses a CCD detector for simultaneous measurement of hundreds of wavelengths. This allows measurement from the UV to NIR in less than a second.

Wide Spectral Range

The M-2000 is available in a variety of spectral ranges with options from the UV to the NIR. The widest spectral range is 193nm to 1690nm with simultaneous data collection at more than 690 wavelengths.

Precise Alignment

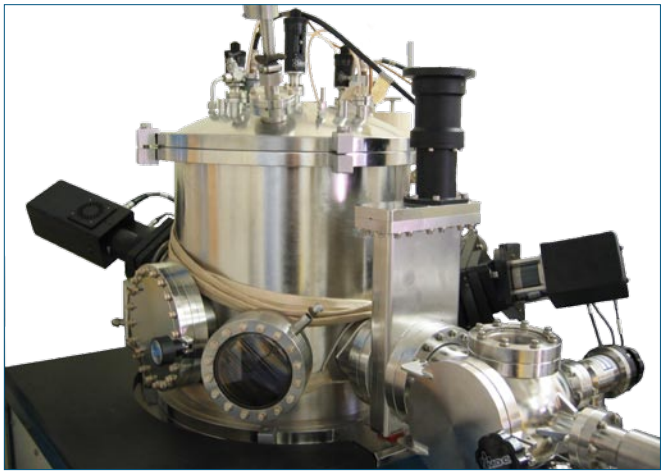
A built-in 4-quadrant alignment detector allows precise sample alignment, whether mounted on your process chamber or a variable-angle base.

Software

Ellipsometry is an effective characterization technique, but requires powerful software to get full benefit from the measurement. Our WVASE32® (*ex situ*) and CompleteEASE™ (*in situ/ex situ*) software packages provide easy calibration, data acquisition, and analysis for all of your applications.

In Situ M-2000

With fast measurement speed and high accuracy, the M-2000 is a perfect match for real-time deposition/etch monitoring and control.



M-2000 attached to a process chamber.

Ex Situ (Benchtop) M-2000

The M-2000 is offered on a variety of bases to meet your application and budget. Choose from fixed angle, manually-controlled angle, or automated angle with either horizontal or vertical sample mount. Additional options include focusing optics, manual or automated sample translation, heat stages, liquid cells, and more. See page 5 for available options.

M-2000 with automated angle base, featuring a horizontal sample mount.

System Specifications

Spectral Range

Model:

V	370nm to 1000nm, 390 wavelengths
VI	370nm to 1690nm, 590 wavelengths
U, X	245nm to 1000nm, 470 wavelengths
UI, XI	245nm to 1690nm, 670 wavelengths
X-210	210nm to 1000nm, 490 wavelengths
XI-210	210nm to 1690nm, 690 wavelengths
D	193nm to 1000nm, 500 wavelengths
DI	193nm to 1690nm, 700 wavelengths

"I" indicates NIR upgrade

Spectral Resolution Bandwidth

Model:

V, U, X, D	1.6nm pixel resolution ~ 5nm bandwidth
VI, UI, XI, DI	1.6nm pixel resolution (UV/Vis) 3.4nm pixel resolution (NIR) ~ 5nm bandwidth (UV/Vis) ~ 10nm bandwidth (NIR)

Data Acquisition Rate

The maximum data acquisition rate is determined by the compensator rotation speed, which is 20Hz* for most M-2000® models. Typical measurements for best signal-to-noise average between 1 and 5 seconds.
**With reduced number of wavelengths.*

Beam Diameter

2mm to 5mm, depending on model and configuration.
**Focusing is available down to 30 microns in spot diameter.*

Beam Divergence

Less than 0.3° (without focusing).

Measurable Quantities

Ellipsometry:	Ψ (0°-90°) and Δ (0°-360°)
Transmission intensity:	%Transmission
Reflection intensity:	% Reflection
Depolarization:	% Depolarization
Mueller-matrix:	Measure and fit 11 normalized elements of the Mueller-matrix. Useful for samples that are both anisotropic and depolarizing.

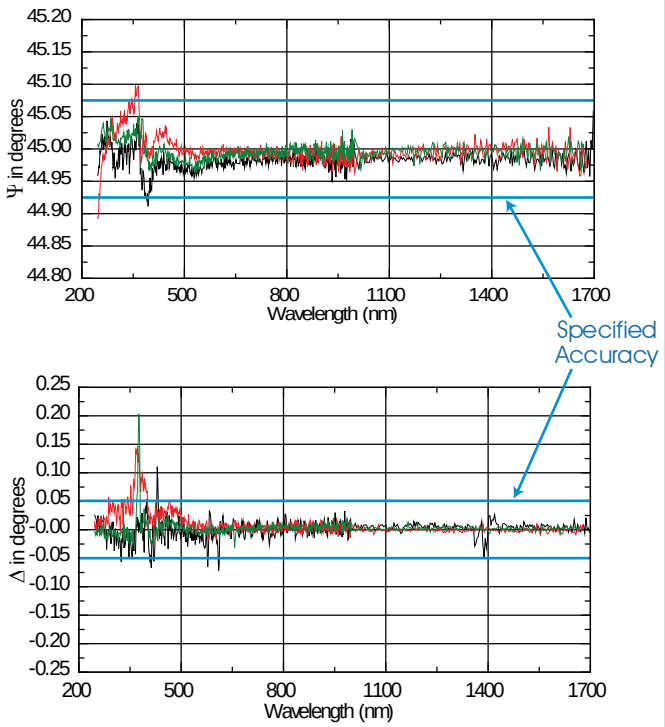
Typical Accuracy

Straight-through measurement of empty beam:
(Met by 95% of the measured wavelengths with ten second averaging time.)

$\Psi = 45° \pm 0.075°$	$\tan(\Psi) = 1 \pm 0.0013$
$\Delta = 0° \pm 0.05$	$\cos(\Delta) = 1 \pm 0.0000015$

**When looking at ellipsometric specifications, it is easy to erroneously compare Δ to cos (Δ) and Ψ to tan(Ψ). We provide both numbers for your convenience. The Woollam Company IR-VASE is orders of magnitude better than the competition when measuring Δ near 0° and 180°. This is a benefit of our patented rotating compensator technology.*

As witnessed in the representative data shown below, the accuracy for most wavelengths is much better than specified.



** Instrument 1 is an M-2000U. Instruments 2 and 3 are M-2000UI (include NIR upgrade).*

Typical Repeatability

Thirty repeated straight-through measurements of empty beam; each with zone-averaging and ten second averaging:

$\delta\Psi = 0.015°$ *
$\delta\Delta = 0.015°$ *
*1-standard deviation

Thirty repeated measurements of SiO_2 (2nm)/Si at 65° angle and ten second averaging with fixed sample position:

δthickness = 0.002nm*
*1-standard deviation

Component Specifications

System Configuration (in order)

Light source
Fixed polarizer
Continuously rotating compensator
Sample
Fixed analyzer
Spectrometer and Detector

Light Sources

Model:

V, VI	Quartz Tungsten Halogen (QTH)
U, UI, D, DI	QTH/Deuterium
X, XI, F	75W Xenon

Fixed Polarizer

All M-2000® systems use a calcite Glan-Taylor polarizer, except the D and DI systems, which use a MgF_2 Rochon polarizer. Both types exhibit:

Beam deviation: <1 arcmin.
Extinction ratio: $1x10^{-6}$

Continuously Rotating Compensator

Spectroscopic compensator operates over entire wavelength range.

Rotation rate: ~ 20Hz
Beam deviation: <1 arcmin.

Fixed Analyzer

Calcite Glan-Taylor or MgF_2 Rochon Polarizer (D and DI models).

Beam deviation: <1 arcmin.
Extinction ratio: $1x10^{-6}$
Mount: Stepper motor driven rotation stage that allow "zone-averaged" measurements

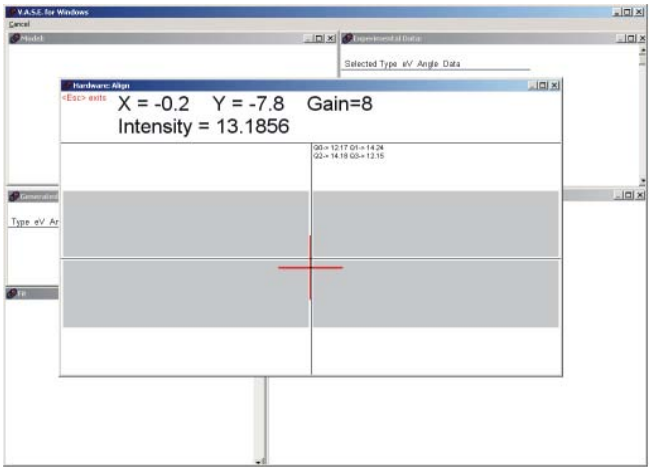
Detectors

- Back-thinned silicon CCD array (UV/VIS)
- InGaAs photo diode array (NIR)

Integrated Alignment Detector

Built-in electro-optic alignment detector is divided into four quadrants. Cross-hair generated by the detector assists accurate alignment. The figure below shows the alignment screen.

Sample alignment resolution: 0.001°



Ellipsometer Control Module

Remote computer with network connections
DC power supplies
Stepper motor drivers
Ratings: 110/220 VAC, 47-63 Hz, 2-4 Amps

Operator Computer (Optional)

Core 2 Duo processor
1 GB RAM, 160 GB hard drive
17" LCD Flat-panel color monitor.
Windows XP Pro

Software Packages

WVASE32® – Data acquisition, data analysis, optical simulations, and routine calibrations.

VASEManager® – Front end for WVASE32 to automate data acquisition, analysis and mapping routines.

CompleteEASE™ – Designed for *Ex situ* and *In situ* applications. Data acquisition, data analysis, optical simulations, routine calibrations and mapping routines.

Options

Available Bases

All bases include 3 axis sample alignment.
X and Y (tip and tilt) resolution: 0.001°
Z (height) resolution: 5 µm

Fixed Angle Base

Angle of incidence: ~ 75°
Accuracy: ± 0.2°
Repeatability: ± 0.005°
Horizontal sample mount
Max sample size: 150mm dia.
Max sample thickness: 20mm

Manual Angle Base

Angle of incidence: 44°-90°
Accuracy: ± 0.02° or better
Repeatability: < 0.005°
Horizontal sample mount
Max sample size: 300mm dia.
Max sample thickness: 20mm

Automated Angle Base

Angle of incidence: 44°-90°
Accuracy: ± 0.02° or better
Repeatability: < 0.005°
Horizontal sample mount
Automated z-height
Max sample size: 300mm dia.
Max sample thickness: 20mm

Vertical Automated Angle Base

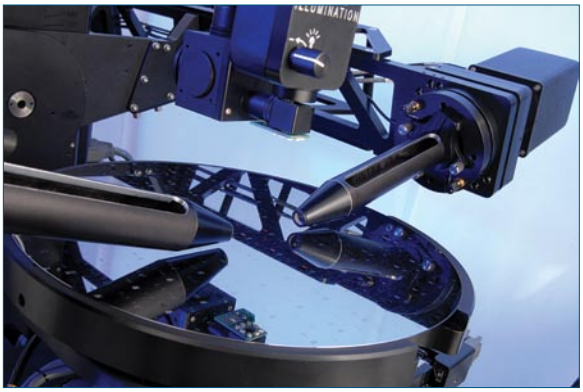
Angle of incidence: 20°-90°
Accuracy: ± 0.02° or better
Repeatability: < 0.005°
Vertical sample mount via vacuum chuck
Max sample size: 200mm dia.
Max sample thickness: 20mm

** Vertical base simplifies acquisition of transmission ellipsometry and transmission intensity data.*

Focusing Optics

Model

V, VI	150µm beam dia.
U, UI, D, DI	300µm beam dia.
X, XI	125µm beam dia.
VF, UF	30µm x 70µm



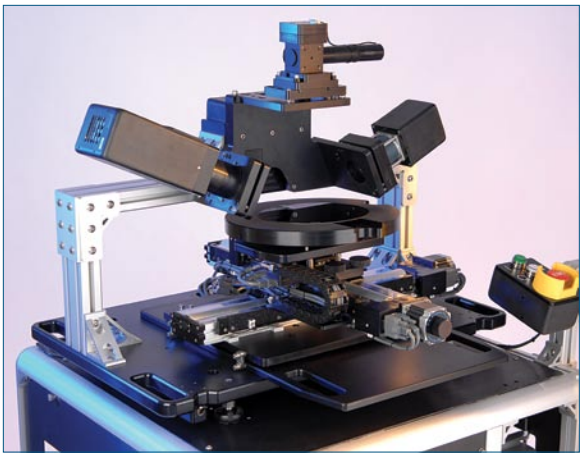
Sample Translation

Manual

25mm by 25mm XY (*horizontal only*)
45mm by 45mm XY (*vertical only*)
40mm by 40mm XY (*horizontal only*)
*Minimum step = 5µm

Computer Automated

100mm by 100mm XY (*horizontal only*)
150mm by 150mm XY (*horizontal or vertical*)
200mm XY or R-Θ (*horizontal only*)
300mm XY or R-Θ (*horizontal only*)
*Minimum step = 1µm



Options

Sample Heater

Measure your samples at elevated temperatures. Heat stage is enclosed with optical windows to allow purge. Includes temperature controller and thermocouple built into the sample chuck to monitor temperature.

Temperature: Room Temp to 300°C.

Sample Size: Up to 50mm diameter, 7.6mm thick.

Liquid Cell

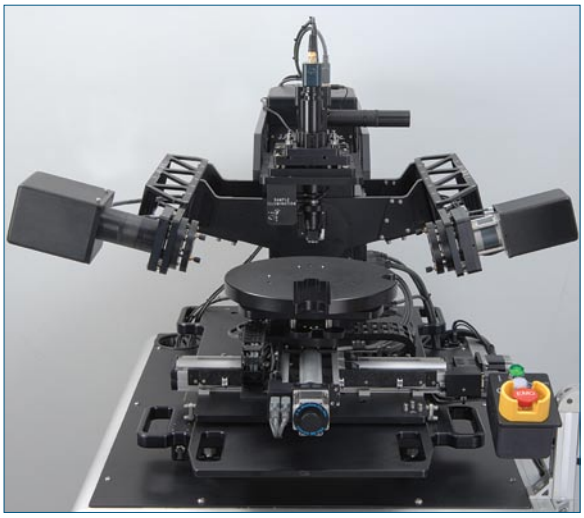
Cell includes optical windows for measurement at 70° through liquid ambient. Allows study of liquid/solid interfaces. Volume: 0.5ml/5ml.

In situ

The *in situ* options come complete with windows, tilt stages, and hardware to mount the M-2000 input and output to standard 2.75 inch Conflat flanges. The suggested measurement angle is between 60° and 80° to sample normal. **See picture on page 2.*

Automated Sample Alignment

Fully automated sample alignment (tip/tilt and z-height adjustment).



Integrated Table

Table designed specifically for M-2000. Rack for mounting electronic boxes, fully enclosed computer and wires. Monitor, keyboard and mouse mounted on arm. **See front page for picture of M-2000 on table.*

Camera

Add a camera to M-2000 systems with focused spot option to visualize the measurement area. The actual beam may not be visible on smooth surfaces, but the location can be identified based on reference location. The camera option includes a 3Mpixel CCD Camera, Lens set, and Illumination setup. The final camera specifications depend on the system configuration:

	Focusing System	Focusing System with Heater of Liquid Cell
Magnification	9x	4.5x
Zoom	6.5x	6.5x
Field of View	0.6mm	1.2mm
Working Distance	35mm	85mm

Facility Requirements

Operating Environment

A sturdy table (weight of instrument is system dependant, contact JAWCo to discuss).
Range of Weights: 50-150 lbs.
Integrated Table with rack mount cabinet (optional)
Note: Vibration isolation table is not required

Power

110/220 VAC, 47-60Hz, 2/4 Amps

Dimensions

Dimensions vary depending on options. Larger system (M-2000 DI with 200mm XY mapping) dimensions are given in the drawings to the right.

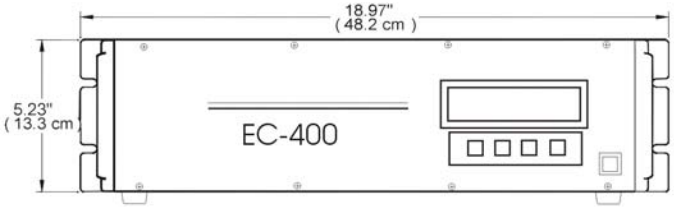
Table Layout

Recommended size:
- Width 60”
- Depth 30”
- Height 36”
- *With shelf or 19” rack mount below (optional)

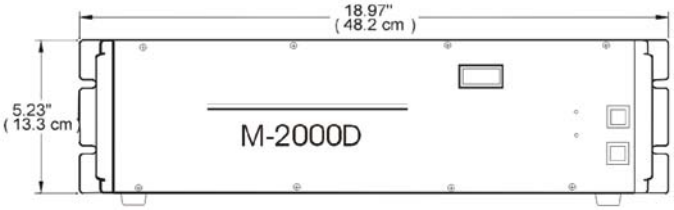
Ambient Lighting

RCE technology allows accurate measurements under normal room light conditions.

Electronics Control Box*

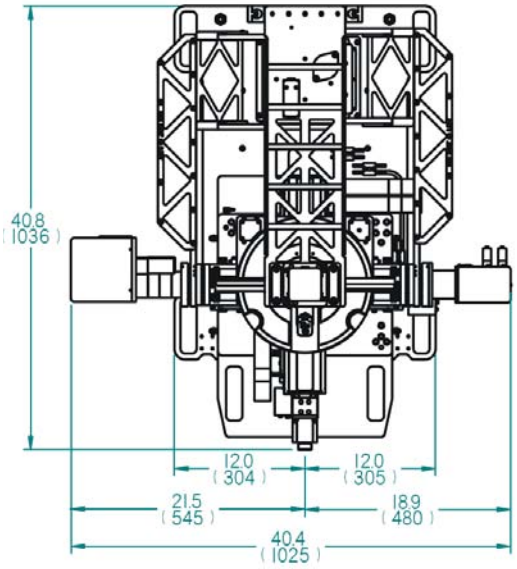


M-2000 Detector Box*

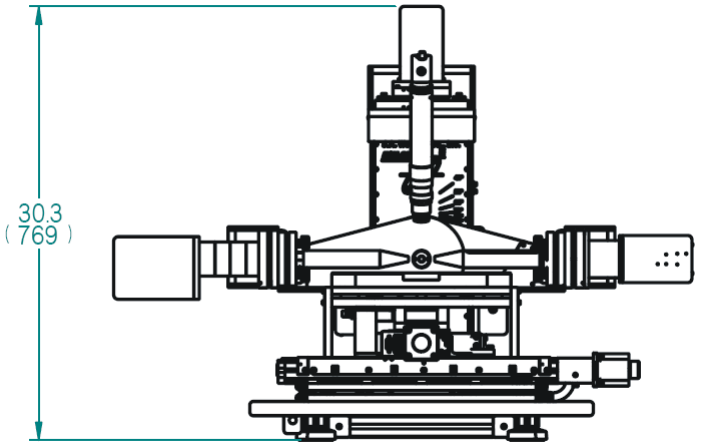


*standard rack mount cases, 24” deep

M-2000 Top View
Dimensions given in inches (mm)



M-2000 Front View



Computer, Monitor, Mouse, and Keyboard

References

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