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.
**Features**

**Patented Rotating Compensator Ellipsometer (RCE) Technology**

RCE technology overcomes the limitations of other ellipsometers.

<table>
<thead>
<tr>
<th></th>
<th>RCE</th>
<th>RAE</th>
<th>RPE</th>
<th>Phase Modulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure all $\Psi/\Delta$ accurately</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes * Requires 2 measurements</td>
</tr>
<tr>
<td>Measure $\Delta$ handedness</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Combine with fast CCD detection</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

**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.

**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.

**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.
**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: \( \Psi (0°-90°) \) and \( \Delta (0°-360°) \)

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.)

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

*When looking at ellipsometric specifications, it is easy to erroneously compare \( \Delta \) to \( \cos(\Delta) \) and \( \Psi \) to \( \tan(\Psi) \). We provide both numbers for your convenience. The Woollam Company M-2000 is orders of magnitude better than the competition when measuring \( \Delta \) near 0° and 180°. This is a benefit of our patented rotating compensator technology.

**Typical Repeatability**

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

\[
\delta\Psi = 0.015° * \quad \delta\Delta = 0.015° *
\]

*1-standard deviation

Thirty repeated measurements of SiO\textsubscript{2} (2nm)/Si at 65° angle and ten second averaging with fixed sample position:

\[\delta\text{thickness} = 0.002\text{nm}*\]

*1-standard deviation
**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:** $1 \times 10^{-6}$

**Continuously Rotating Compensator**  
Spectroscopic compensator operates over entire wavelength range.  
**Rotation Rate:** $\sim$ 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:** $1 \times 10^{-6}$  
**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:** $0.001^\circ$

**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.
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)
40mm by 40mm XY (horizontal only)
45mm by 45mm XY (vertical 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 = 2.5µm
**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**


**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:

<table>
<thead>
<tr>
<th></th>
<th>Focusing System with Heater or Liquid Cell</th>
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<tbody>
<tr>
<td><strong>Magnification</strong></td>
<td>9x</td>
</tr>
<tr>
<td><strong>Zoom</strong></td>
<td>6.5x</td>
</tr>
<tr>
<td><strong>Field of View</strong></td>
<td>0.6mm</td>
</tr>
</tbody>
</table>
| **Working Distance**| 35mm                                    | 85mm
**Operating Environment**

A sturdy table (weight of instrument is system dependent, 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.

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*standard rack mount cases, 24” deep*