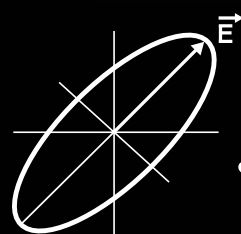
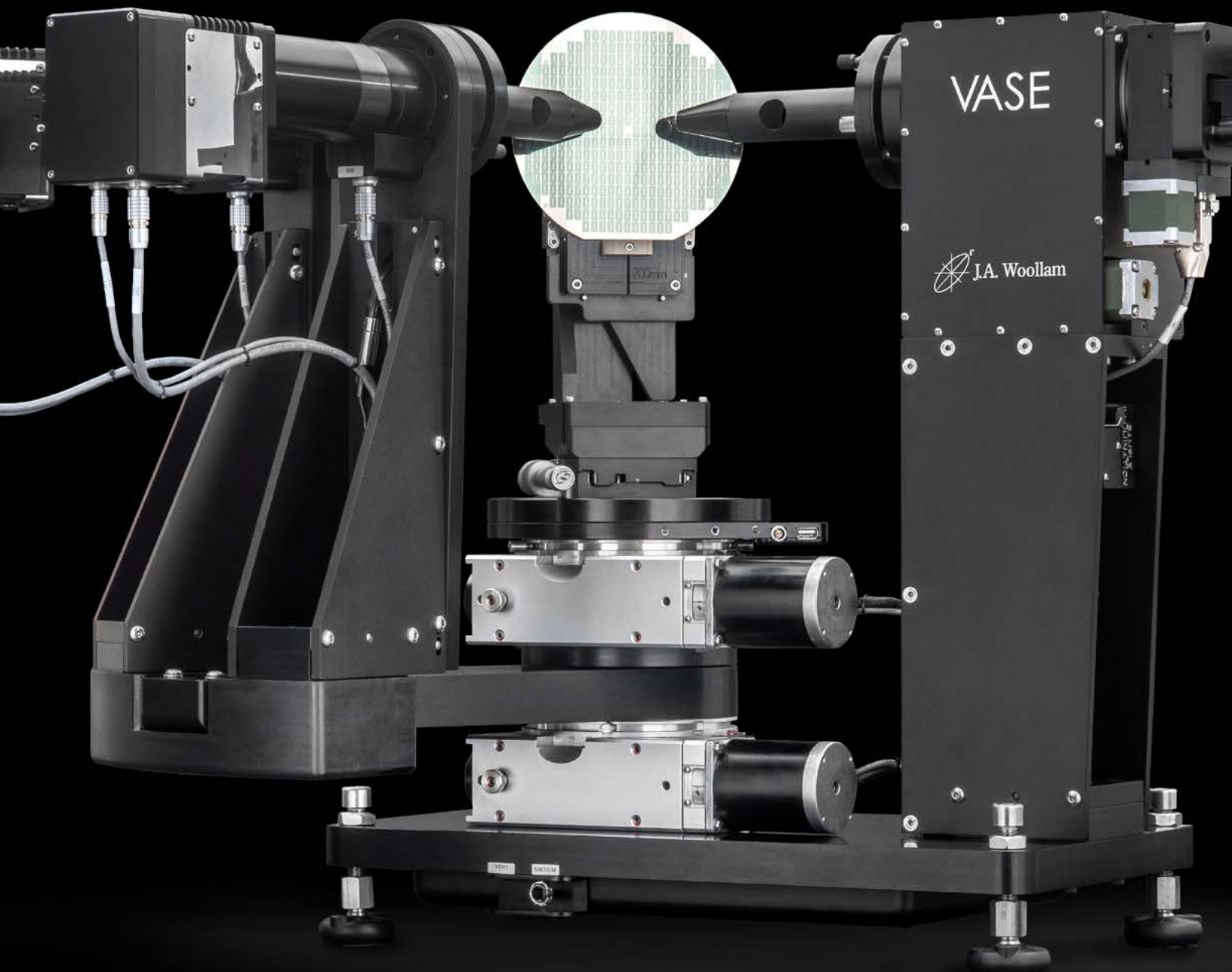


VASE



J.A. Woollam
Ellipsometry Solutions



Accurate

Overview

The VASE® is our most established and versatile ellipsometer. Useful for research on all types of materials, including semiconductors, dielectrics, polymers, metals, multi-layers, and more.

Variable wavelength and angle of incidence enable flexible measurement capabilities. The VASE combines high accuracy and precision with the widest spectral range in the industry, 193 to 4000 nm.

Why VASE

+Maximum Data Accuracy

The VASE features a rotating analyzer combined with our patented AutoRetarder® for unparalleled data accuracy.

+High Precision Wavelength Selection

Our custom-built scanning monochromator is designed specifically for spectroscopic ellipsometry, optimizing speed, wavelength accuracy, and light throughput, while automatically controlling wavelength selection and spectral resolution.

+Flexible Measurements

The VASE features a vertical sample mount and vacuum stage to accommodate a large variety of measurement geometries including reflection, transmission, and scattering.

+Extended Wavelength Range

The VASE offers multiple combinations of detectors, including our latest 4IR extension which allows for measurements up to 4000 nm, shown in red below.



VASE featuring 4IR and DUV detectors with focusing probes.

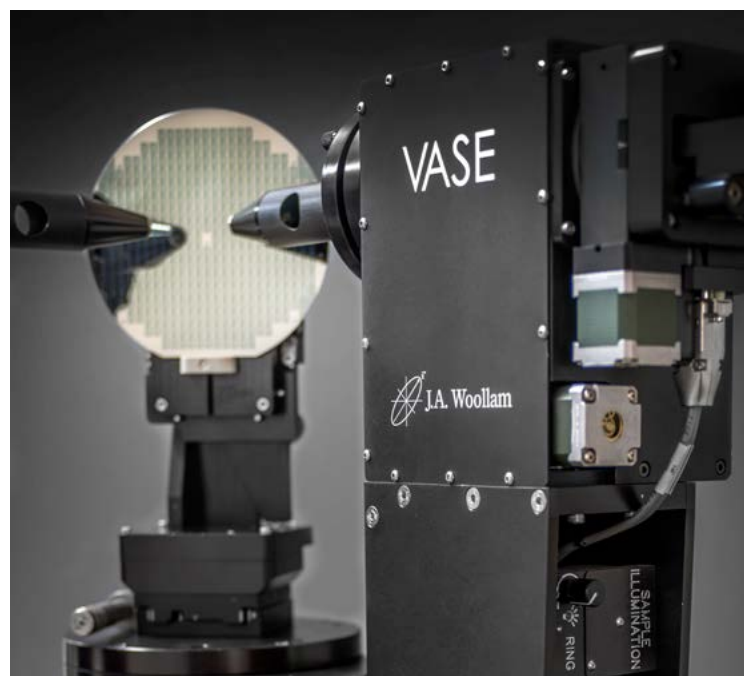
Featured Components

AutoRetarder Technology

The VASE is able to collect the most accurate data of any ellipsometer through its use of our patented AutoRetarder. The AutoRetarder adjusts the polarization state of the incident measurement beam to provide optimal sensitivity for all types of materials. This provides an optimum measurement for any sample, under any conditions.

AutoRetarder accurately measures:

- + Ψ and Δ over the full range
- +Generalized (anisotropic) Ellipsometry
- +Depolarization data
- +Mueller-matrix data



Custom Monochromator

Our custom-built, double-chamber monochromator provides superior stray-light rejection. Up to four gratings are used to provide the most efficient reflectivity across the measured spectral range. The monochromator is located *before* the sample, which restricts the intensity of light incident on the sample to just a narrow bandwidth around the wavelength being measured. This avoids photo-bleaching of light-sensitive samples, as can happen for other ellipsometers where the monochromator is placed *after* the sample.

Extended NIR Detection

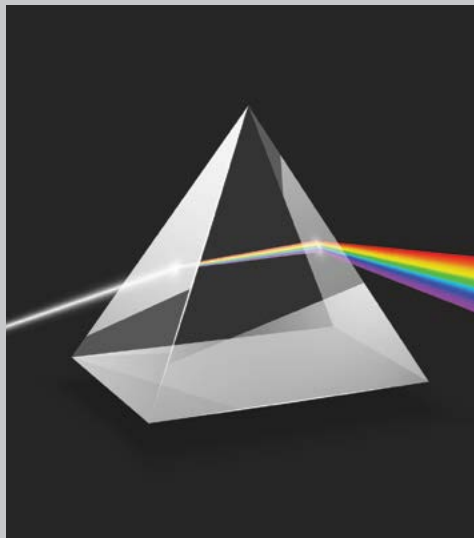
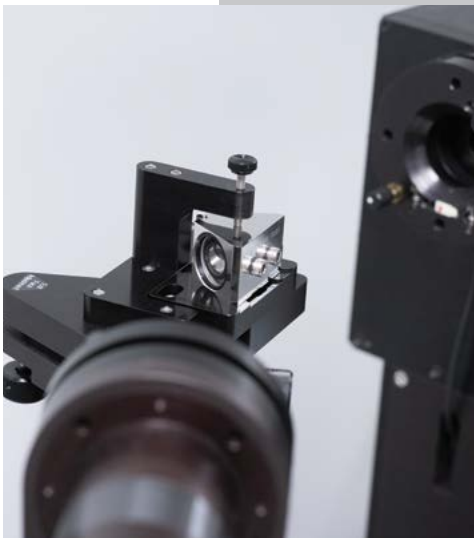
The VASE has always offered the widest wavelength range of our UV-VIS-NIR ellipsometers. We recently added a new liquid-nitrogen-cooled InSb detector for measurements up to 4 μm in the infrared. The detector is enclosed inside a liquid nitrogen dewar; when filled before data acquisition, it provides up to eight hours of data collection. Combined with our standard UV-VIS detector, the continuous spectral range from 193 to 4000 nm can be measured.



Advanced Measurements

Mueller Matrix & Generalized Ellipsometry

Ellipsometry is a non-contact, non-destructive optical characterization technique which measures the change in polarization of light upon reflection from or transmission through a sample. The change in polarization caused by a sample is typically reported as Ψ and Δ for isotropic samples. However, Generalized and Mueller Matrix ellipsometry are not limited to measuring isotropic samples where film thickness and optical constants are the primary interest. By measuring the Mueller matrix, we can characterize the most advanced materials. Some examples include arbitrarily anisotropic, crystalline substrates and films, birefringence in stretched polymer foils as found in roll-to-roll applications, polarization filters in AR/VR devices or cameras, entire liquid crystal cells, oriented nanostructures, metamaterials, or periodic 3D-structured materials. The Mueller matrix contains all essential optical information, including intensity propagation, cross-polarization due to linear and circular birefringence, linear and circular dichroism, and phase retardance. Essentially, any optical effect possible will be described by the Mueller matrix.



Transmission, Reflection & Minimum Deviation

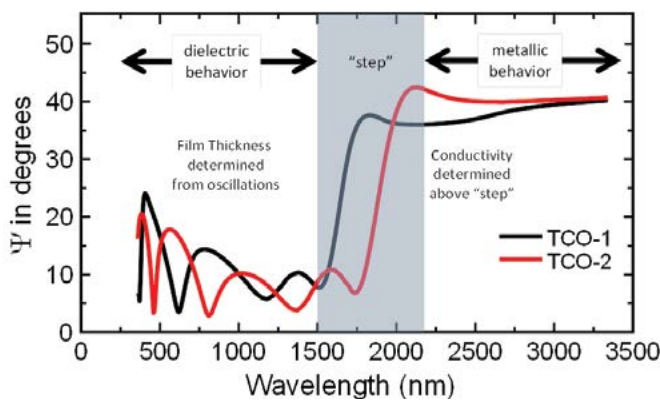
The VASE can be used to acquire a variety of intensity-based measurements, such as reflection, transmission or the minimum deviation angle of a beam through a prism. Since the VASE contains a vertical sample mount, it is ideal for these types of measurements. Transmission and reflection measurements can be analyzed in combination with ellipsometry data to increase sensitivity and break correlation between thickness and absorption. The VASE features automated interleaving technology to ensure the intensity baseline measurement is fresh and consistent throughout the scan.

The VASE is also well-suited for the prism minimum deviation technique. Refractive index measurements are common using this technique on solid materials, such as bulk transparent glasses. This technique is also commonly used for measuring the refractive index of liquids. To determine the refractive index of liquids using the minimum deviation procedure, our custom-designed hollow prism is used to contain the liquid. Measurements are made through transparent windows of CaF_2 or high-purity fused silica. Light passing through the prism is then refracted and the angle of refraction can be used as a measure of the refractive index. Furthermore, the extinction coefficient can be determined by measuring the liquid at multiple locations along the prism and calculating a ratio of intensities.

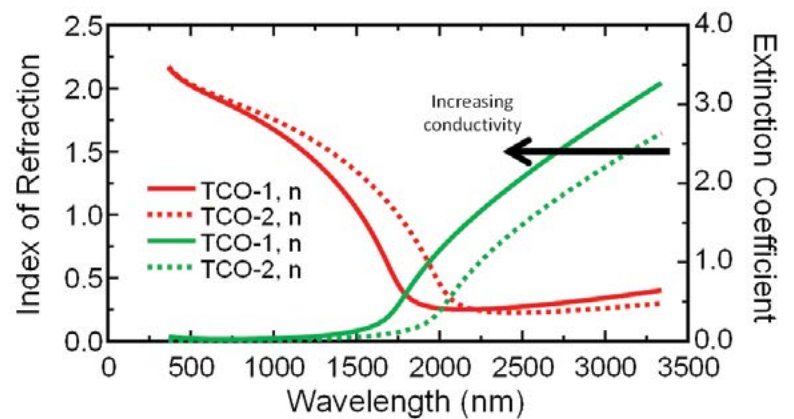
Near-Infrared Benefits

Transparent Conductive Oxides (TCOs)

Materials such as indium tin oxide (ITO), aluminum doped zinc oxide (AZO), and fluorinated tin oxide ($\text{SnO}_2:\text{F}$) are transparent conductive layers used in many modern products, such as touchscreen phones, solar panels, widescreen televisions, etc. While highly transparent across the visible spectrum, these materials are conductive, which leads to near infrared absorption. The graphs below demonstrate measurements of two different TCO layers; both exhibit similar behavior: i) data at short wavelengths oscillates due to the transparent film thickness, and ii) data at long wavelengths is flat where the film behaves like a metal. The transition between these regions occurs in the near-infrared and provides insight into the properties of the TCO layer. As the transition region moves to shorter wavelengths, the film conductivity also increases, as described by the Drude free-electron model.



Wide wavelength range capabilities enable characterization of the dielectric behavior, plasma edge and metallic behavior of transparent conductive oxides.

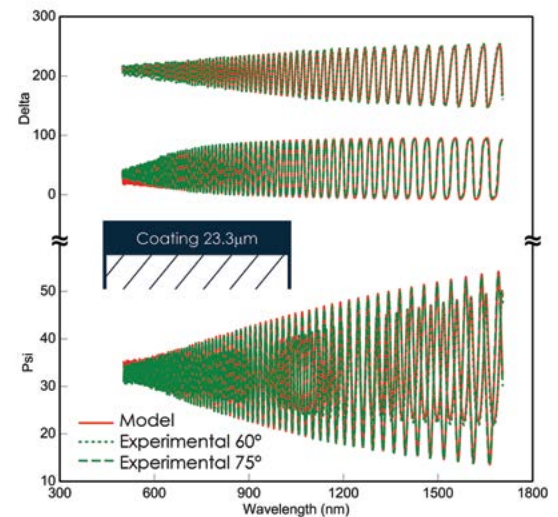


Conductivity can be accurately determined by measuring IR wavelengths.

Thick Films

For thicker films ($>5 \mu\text{m}$), good spectral resolution is needed to resolve the oscillating interference features in the Ψ/Δ data. To accomplish this, the user can define the monochromator step size and narrow the bandwidth to help resolve fine spectral features.

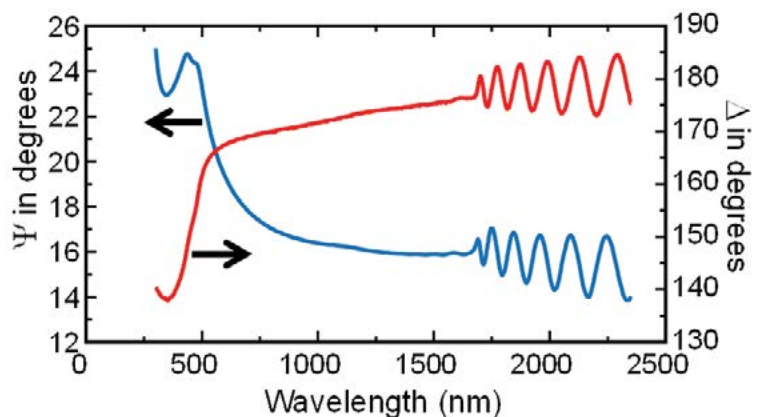
In addition, the interference oscillations associated with film thickness become naturally spread out as wavelength increases. Thus, near-infrared measurements help extend the useful thickness range to films that are tens of microns thick.



Measurements of ultra-thick transparent films can be achieved with fine wavelength resolution.

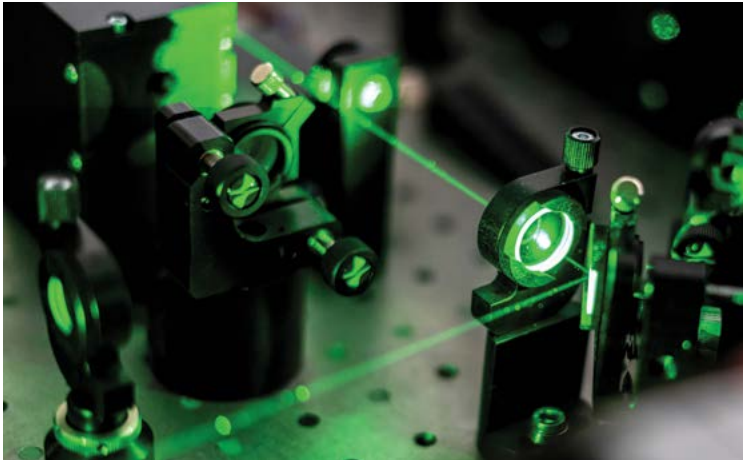
Low-Bandgap Materials

Extended near-infrared spectral range is also valuable when characterizing low-bandgap semiconductors that remain absorbing across through visible and near-infrared wavelengths. The longer wavelengths probe the transparent region of these materials, allowing thickness determination for films such as InGaAs, SiGe, etc.



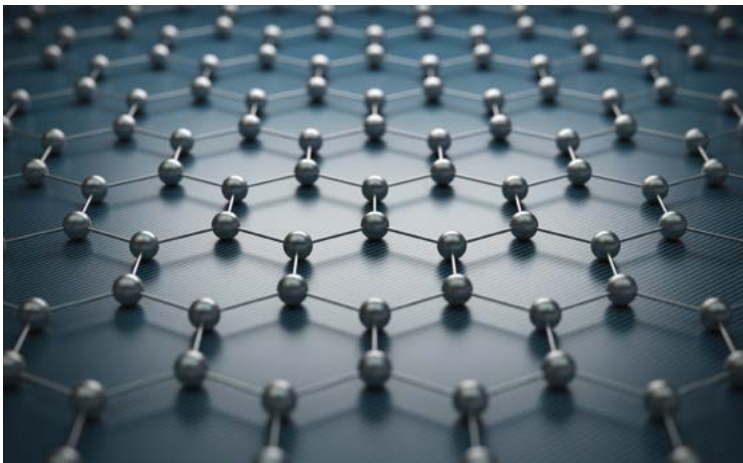
Interference oscillations at longer wavelengths enable easy thickness determination.

Applications



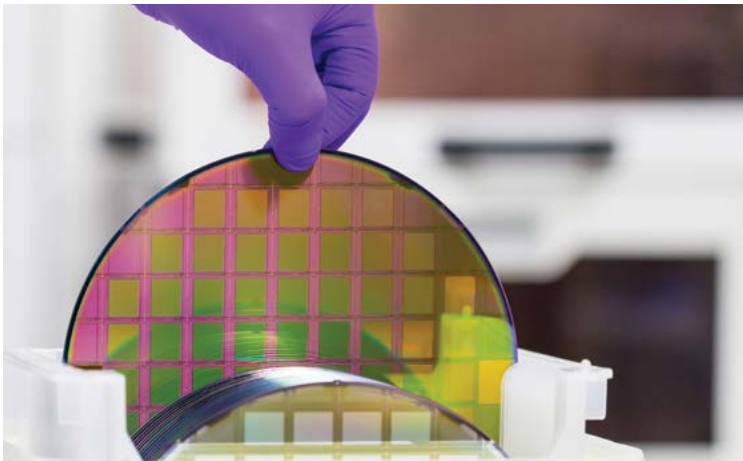
Optical Coatings

Ellipsometry plays an effective role in both the design and manufacturing stage of optical coatings. Anti-reflection coatings, notch filters, and highly reflective film stacks are all examples of material systems composed of high/low-index films. The optical properties and thickness of each layer in a coating stack play a pivotal role in determining the performance of a coating stack within a given wavelength range.



Thin Absorbing Films

The variable angle capability of the VASE enables characterization of thin metal films. Transmission intensity measurements are easily acquired with the VASE. Simultaneous analysis of ellipsometry and transmission-intensity data enables characterization of very thin, non-opaque metal films less than 50 nm thick, including graphene, TiN, Au and more.



Semiconductors

Ellipsometry is highly sensitive to surface roughness and oxide layers that natively grow on most semiconductors. In addition, optical bandgap, electronic transitions, and critical points can be determined for bulk and thin-film semiconductor materials such as GaN, InP, SiGe, CdTe, etc. Crystallinity and alloy composition can also be determined by monitoring the shape and wavelength position of the critical points.



Liquid Studies

Liquid cells enable in-situ, real-time study of surfaces under varying liquid ambients. Typical studies include protein attachment, etch rates of photoresists, and oxide growth through electrolysis. Optical properties of liquids can also be accurately determined using the VASE with our liquid prism cell via the minimum-deviation experiments.

Accessories

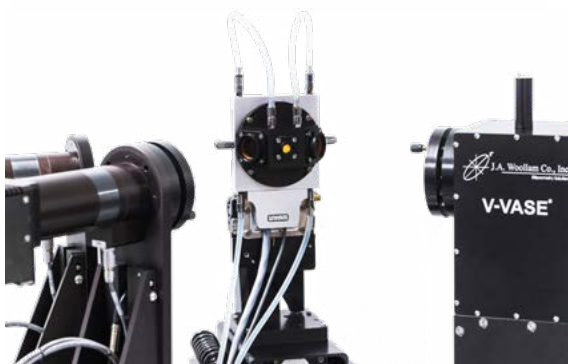
Temperature Control

By adding a cryostat or heat stage to the VASE for variable temperature studies, measurements can be conducted at temperatures as low as 4.2K and as high as 1000° C.



Linkam Standard Heat Stage

The Linkam Standard Heat Stage enables temperature-controlled ellipsometry measurements between -70° to 600° C with stability of 0.1° C. The heating chuck is 22 mm in diameter and can accommodate similarly sized samples. The heat stage features a custom lid with optical ports configured for ellipsometry measurements at 70° (AOI) to promote a controlled environment and enable purging when necessary.



Linkam High-Temperature Heat Stage

Linkam's High Temperature Heat Stage is intended for applications that require temperature above 600° C. This heat stage enables measurements up to 1000° C by incorporating a crucible heater in the temperature stage. The crucible design is compatible with samples up to 17 mm in diameter and is sold with a custom lid that enables ellipsometry measurements at 60° (AOI). Customers with primary interest in temperature measurements below 600° C should consider the standard heat stage.



Lake Shore Cryostat

The Lake Shore Cryostat provides an ultra-high-vacuum, continuous-flow cryostat for variable temperature studies between 4.2 to 800 K. The cryostat can accommodate samples up to 25 x 25 mm and has optical viewports for ellipsometry measurements at 70° (AOI). The cryostat includes a temperature controller, turbo vacuum pump, custom table, and software for coordinating temperature control with ellipsometric measurements.

Liquid Studies

Several cells with optical windows for measurement through liquid ambient enable characterization of liquid/solid interface. Options are shown below.



45 mL Electrochemical Cell



270 µL Liquid Cell



5 mL Liquid Cell



Liquid Prism Cell

Mounting and Focusing

Sample Mounting Options

We offer a variety of sample stage mounts to accommodate your measurement needs. Our standard and small sample stages are provided with every ellipsometer, while the others are available as upgrades.



Standard Stage



Manual Stage



Small Sample Stage



Automated Translation



Sample Rotator



Auto-Z Stage

Focusing & Camera

Add focusing optics to decrease the measurement beam diameter. Our standard focusing option provides a 100 μm beam diameter. Our alternate focusing option provides a slightly larger, 200 μm beam diameter, but can be used during transmission measurements. Focusing optics are detachable for normal use. Add a camera to view the measurement spot on the sample and improve beam positioning.



Specifications

Spectral Range

Standard 240 to 2500 nm
+DUV extension 193 to 240 nm
+XXIR extension 2500 to 3200 nm
+4IR extension 2500 to 4000 nm (requires liquid nitrogen cooling)

Angle of Incidence

+Fully-automated
+Range: 15° to 90° (standard system)
+Accuracy: 0.01°

System Configuration

Rotating Analyzer Ellipsometry (RAE) with patented AutoRetarder®, and automated wavelength selection via our custom monochromator

Data Acquisition Rate

+Typical: 0.1 to 3 seconds per wavelength, depending on reflectivity of sample.
+High Accuracy: measurements using full-AutoRetarder capability require 20 seconds per wavelength.

Software

WVASE – data acquisition, data analysis, optical simulations

Light Source

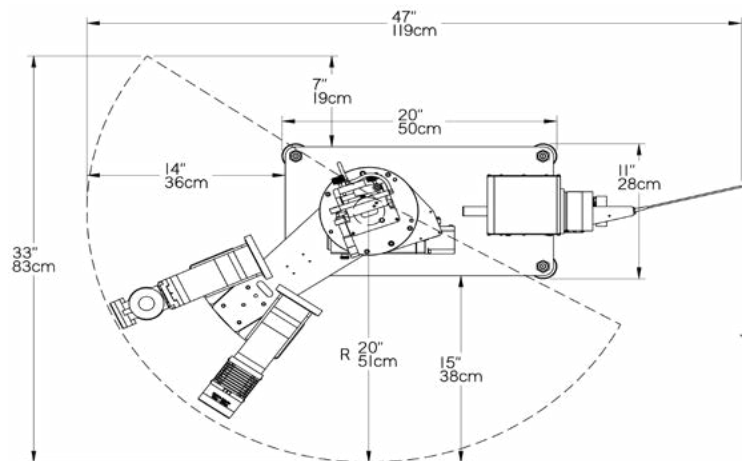
75 watt, convection-cooled xenon lamp

Power Requirements

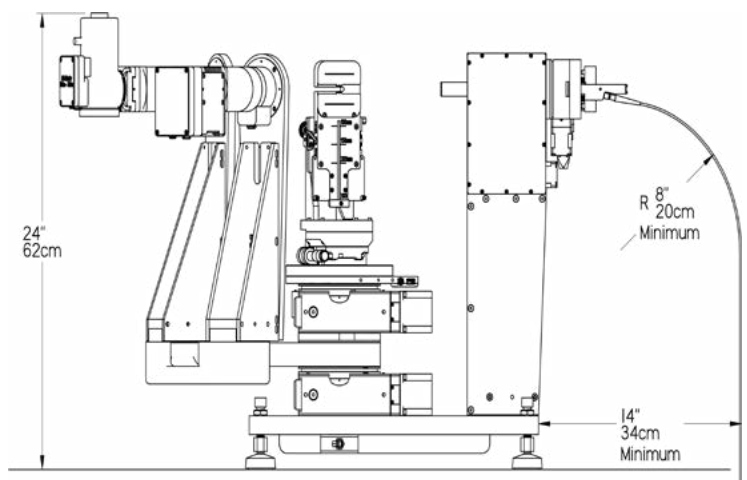
100, 110, 220, 240 VAC, 50-60 Hz, 4/8 Amps



VASE featuring DUV and XXIR extensions with focusing probes



Top View



Front View



Versatile

For more information:



J.A. Woollam

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