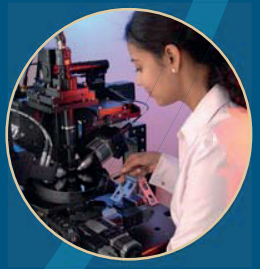


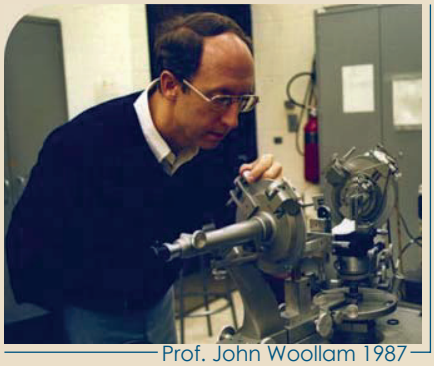
J.A. Woollam Co., Inc.

Ellipsometry Solutions

Integrity

Company History

The J.A. Woollam Company was founded in 1987 by Professor John Woollam as a spin-off of research in materials science and engineering at the University of Nebraska. The ellipsometer developed at that time was crude and not a product.



Prof. John Woollam 1987

Formation of the company allowed graduates from engineering and physics programs to rapidly design new ellipsometer hardware, software, and long-life products supported around the world. The company grew steadily thereafter.

Over the years, we have focused our business on ellipsometry, allowing us to become world-renowned in hardware, software, applications, and support. Instruments now measure from vacuum ultraviolet to far infrared. We serve numerous industries, research topics, and disciplines including fundamental materials research, lithography, semiconductor processing, optical coatings, data storage, display materials, polymer chemistry, biomaterials, photovoltaics, and many more.

Our employees are dedicated to serving customers around the world – from start-up companies to multinational corporations, from research institutes and government laboratories to small and large universities.

Our business is to help solve problems in research, development, and production. We often engineer special instruments and systems to meet individual customer needs. Many become new products. Examples are vacuum ultraviolet ellipsometers for 193nm and 157nm lithography, in-line ellipsometers for coatings on metal bands in a production environment, and in-situ ellipsometry for real-time control of thin coatings in the data storage industry.

We have a proud history, a strong science and engineering base, and look forward to many more decades serving customers.

J.A. Woollam Co. 2007

20th Anniversary 2007 RC2

2005

2004 ALPHA-SE

2003 MASE

2000

1999 VUV-VASE

1998 IR-VASE

1997 M-2000

1995

1994 M-88

1993 M-44

1990

1989 WVASE32 Software

Company founded 1987 VASE

Commitment

Our People

A business is only as good as its people. From initial customer contact to post-sale support, the Woollam Company strives to keep close contact with our customers. Our dedicated team of over 40 employees and network of worldwide representatives are committed to providing the personal attention and service you expect from a small company of dedicated individuals.

Measurement & Applications Support

Our Focus

Concentrating on one technology allows the Woollam Company to remain focused on spectroscopic ellipsometry, instrumentation, software, applications, and support. Instruments are designed, assembled, tested, shipped, programmed, and supported at our facility in Lincoln, Nebraska. Keeping all activities at one location maintains quality through close cooperation throughout the company.

Instrument Testing

Our Customers

We recognize our customers are the reason for our success. Our extended family of users include top researchers, professors, scientists, engineers, and students throughout the world. We value customer feedback and use it to improve our products. We learn as much from our customers as they learn from us.

Short Course for Woollam Customers

Worldwide Sales & Support

We serve our customers worldwide through a network of well-trained representatives. Each representative focuses within a specific geographical region, allowing close ties with customers as well as local support and training in their countries.

We maintain a close partnership with our representatives worldwide. Woollam Company engineers often visit our representatives in their respective countries to attend seminars and visit customers. They visit our office in Lincoln regularly for updated training.

Our Family of Representatives

Australia
ScientificSolutions
www.scisol.com.au

China
Lamda Pacific Inc.
www.lamdapacific.com

Europe
Quantum Desgin GmbH
www.qd-europe.com

India
Sinsil International
www.sinsilinternational.com

Israel
Vacuum System & Technology
www.vacuumltd.com

Japan
J.A. Woollam Japan Corporation
www.jawjapan.com

Korea
WizOptics
www.wizoptics.com

Singapore
Crest Technology
www.crest-technology.com

South and Central America
Valley Research Corporation
www.valleyresearch.com

Taiwan
Titan Elecro-Optics
www.teo.com.tw

United Kingdom
Quantum Design UK & Ireland
www.qd-uki.co.uk/

Additional contact information is available at www.jawoollam.com.

Dedication

Spectroscopic Ellipsometry

Spectroscopic Ellipsometry (SE) uses polarized light at many wavelengths to characterize thin films and bulk materials. The light probes each layer; reflecting and transmitting at every interface until the total reflection contains information from each transparent layer. SE allows measurement in a transparent region for films that absorb over other portions of the spectrum. Thus, SE can fully characterize multilayered and structurally complex materials.

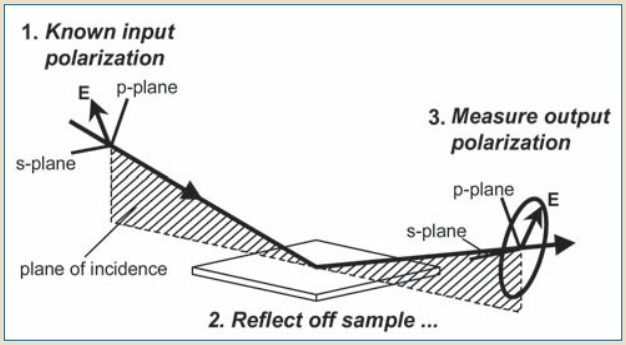


Figure 1

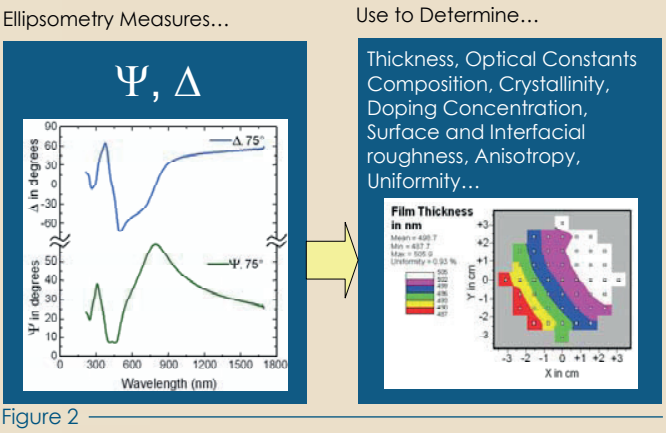


Figure 2

The most common application of SE is determination of thickness and optical constants. However, these properties are not directly measured. Ellipsometry data describes the change in polarization for reflected or transmitted light as an amplitude ratio (Ψ) and phase change (Δ). Thickness and optical constants are determined through regression analysis, where a proposed layer structure is compared and "fit" to find the best match to experimental measurement.

We have developed SE instruments to cover the spectrum from vacuum ultraviolet to far infrared. The optical constants of materials vary dramatically over this range, as short UV wavelengths produce electronic transitions and long wavelengths vibrate the lattice or molecular bonds within a material. Figure 3 shows the optical constants of an organic film over this entire spectrum. In the figure, notice strong IR absorptions due to molecular vibrations, the transparent visible and NIR, and strong UV absorptions due to electronic transitions.

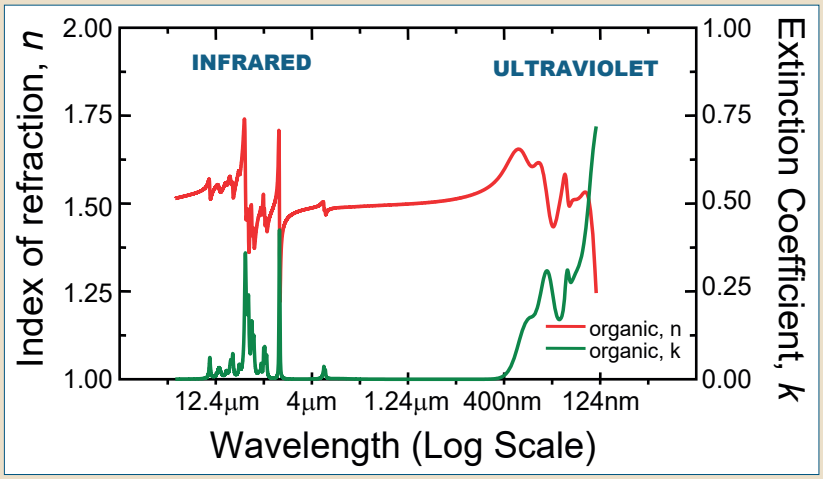


Figure 3

The shape and position of material absorption provides information regarding material properties – process conditions, crystallinity, composition, conductivity, and more. Spectroscopic ellipsometry is used to analyze compound semiconductor films such as $Al_xGa_{1-x}As$ and $Hg_{1-x}Cd_xTe$, where UV absorption shifts with composition, *x* (Figure 4). The UV absorption also varies for polycrystalline silicon films, depending on crystallinity (grain size and shape). Figure 5 shows changes with crystallinity for annealed poly-silicon. Infrared absorption increases for doped semiconductors and transparent conducting oxides as conductivity increases. Spectroscopic ellipsometry is used to monitor sheet resistance in films such as Indium Tin Oxide (Figure 6).

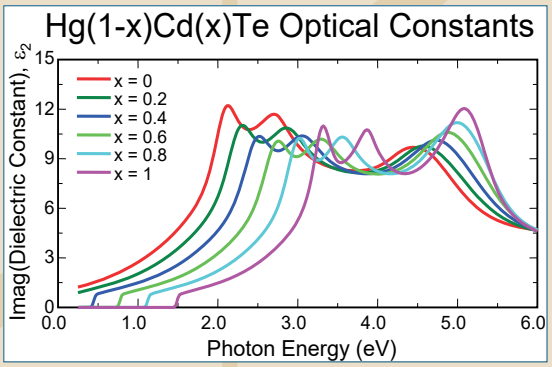


Figure 4

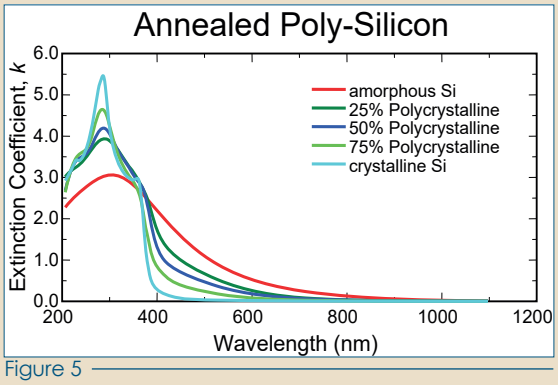


Figure 5

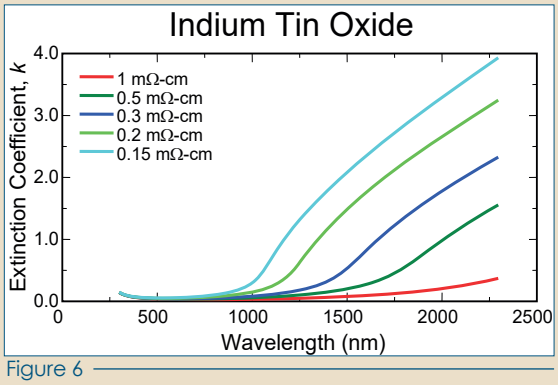


Figure 6

Applications

Spectroscopic ellipsometry measurements are flexible and can be applied to different layer types: semiconductor, metal, dielectric, and organic. For this reason, SE has found application in a variety of industries and research areas.

Optical Coatings

- SiO_2, TiO_2, Ta_2O_5, Al_2O_3, MgF_2, anti-reflection coatings and stacks, SnO_2, ITO, electrochromics, photochromics, beamsplitters, and retarders.

Semiconductors

- Resists, photomasks, SiON, ONO stacks, low-K dielectrics, high-K gates, SOI, SiGe, II-VI and III-V ternary and quaternary compounds.

Display

- a-Si, poly-Si, micro-crystalline-Si, OLED layers, color filters, ITO, MgO, viewing angle compensation films, polyimide, and liquid crystal tilt profiles.

Chemistry/Biology

- Organics, self-assembled monolayers, Langmuir-Blodgett films, protein adsorption, glass transition temperatures in polymers, and ATR ellipsometry in the infrared.

Data Storage

- Diamond-like carbon, phase-change media for recordable CD and DVD, and magneto-optics.

Photovoltaics

- SiN_x, a-Si, textured Si, CdS, and CdTe.

Product Overview

Largest variety of spectroscopic ellipsometers in the world.

M-2000®

The M-2000 line of spectroscopic ellipsometers are engineered to meet many demands of thin film applications. Advanced optical design, large spectral range, and fast data acquisition combine in an extremely powerful and versatile tool.

M-2000 ellipsometers are ideal for applications where speed and accuracy are required. This ellipsometer truly excels for in-situ monitoring, quality control, uniformity mapping, and general purpose thin film characterization.

RC2®

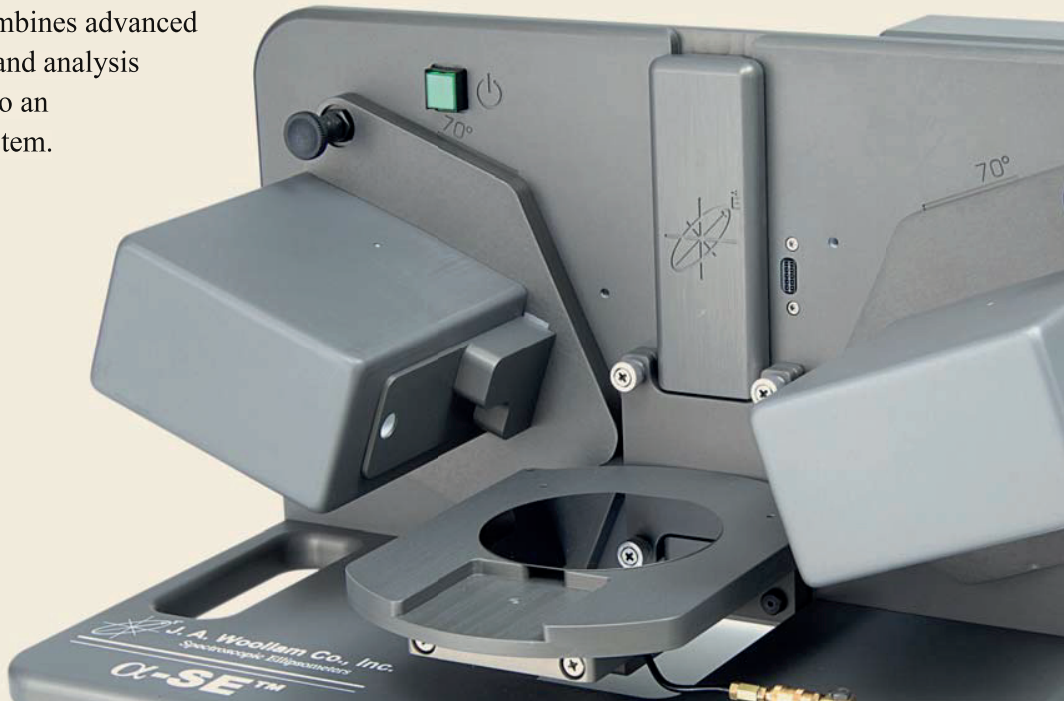
The RC2 design builds on 20 years of experience. It combines the best features of previous models with innovative new technology:

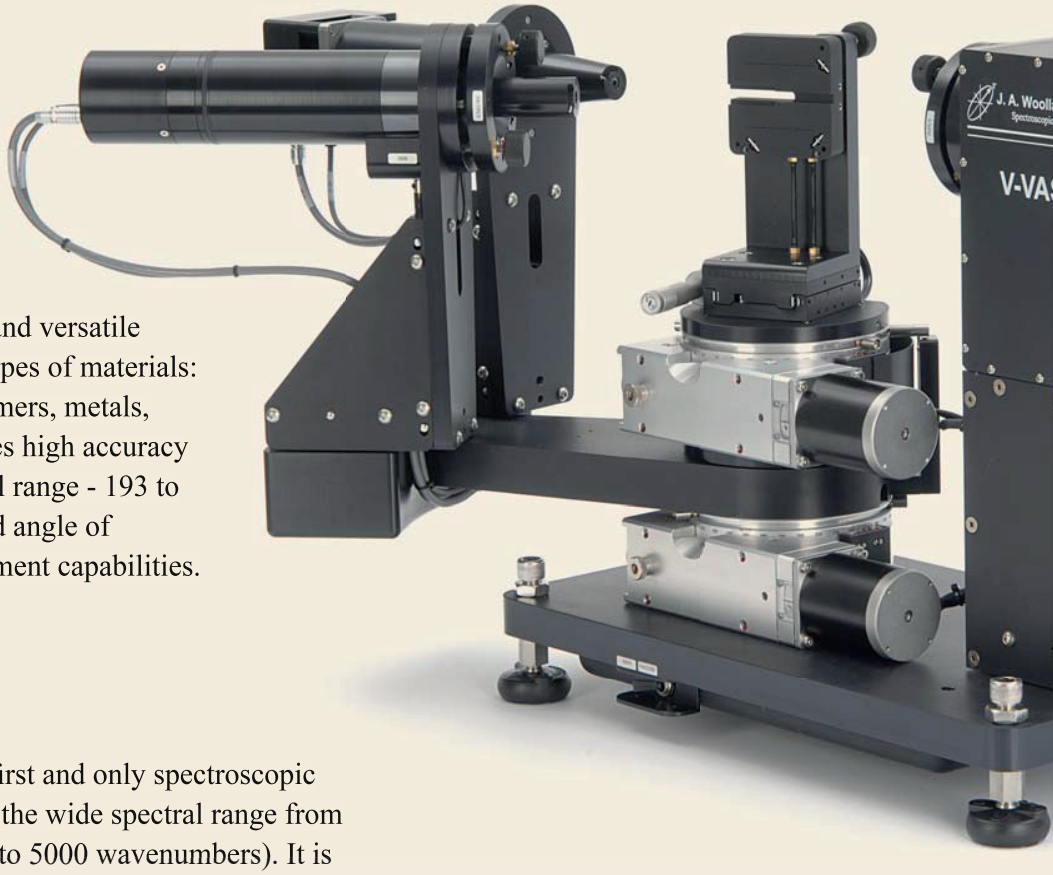
- DUAL rotating compensators for high accuracy, high speed, and complete Mueller-matrix measurements
- Patent-pending achromatic compensators for optimized performance over a wide spectral range
- Advanced light source and spectrometer design for improved measurement data.

The RC2 is a near-universal solution for the diverse applications of spectroscopic ellipsometry.

ALPHA-SE®

Need to measure thin film thickness and index? The alpha-SE provides an easy solution. It combines advanced measurement and analysis technology into an entry-level system.





VASE®

The VASE is our most powerful and versatile ellipsometer for research on all types of materials: semiconductors, dielectrics, polymers, metals, multilayers, and more. It combines high accuracy and precision with a wide spectral range - 193 to 2500nm. Variable wavelength and angle of incidence allow flexible measurement capabilities.

IR-VASE®

The IR-VASE is the first and only spectroscopic ellipsometer to cover the wide spectral range from 2 to 30 microns (333 to 5000 wavenumbers). It is used to characterize both thin films and bulk materials.

VUV-VASE®

The VUV-VASE measures from vacuum ultraviolet (VUV) to near infrared (NIR). This allows incredible versatility to characterize all types of materials. It has been the standard spectroscopic ellipsometry tool used for advanced lithography applications since its introduction. Wide spectral coverage also make it a premier tool for new materials characterization.

INNOVATION

Research & Development

While some aspects of spectroscopic ellipsometry are maturing technologies, there is room for growth and we are excited about future possibilities. New innovations continue to improve measurement speed, accuracy, and wavelength range for future ellipsometers. As instruments improve and expand, they enable new and exciting applications. Software plays an important role. We are working to simplify routine operations while expanding the powerful capabilities to model complex structures. Below are a few exciting areas that are current state-of-the-art.

In-Line Production Monitoring

In-line monitoring of substrates in constant motion requires rapid data acquisition. The M-2000 is ideal for this application - with the full spectrum acquired in a fraction of a second. We have developed a "Return Path" M-2000 for roll-coating applications. A double bounce reflection technique allows all ellipsometer parts to be housed as a single unit (Figure 1).

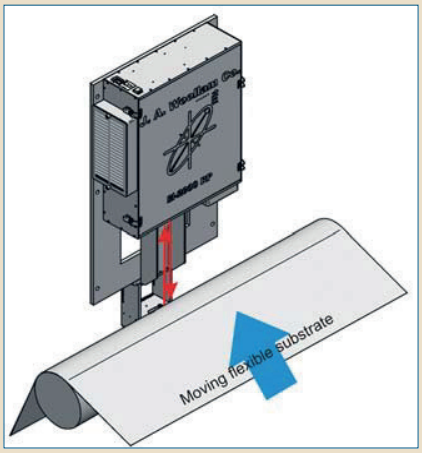


Figure 1

The J.A. Woollam Company has worked with Von Ardenne to develop a measurement system for in-line monitoring of multiple-layer coatings on metal bands (Figure 2). Ellipsometers are positioned after each deposition to provide accurate measurements of all layers. Optical models and parameter values are communicated between spectroscopic ellipsometers along the process to insure accurate results for each layer.

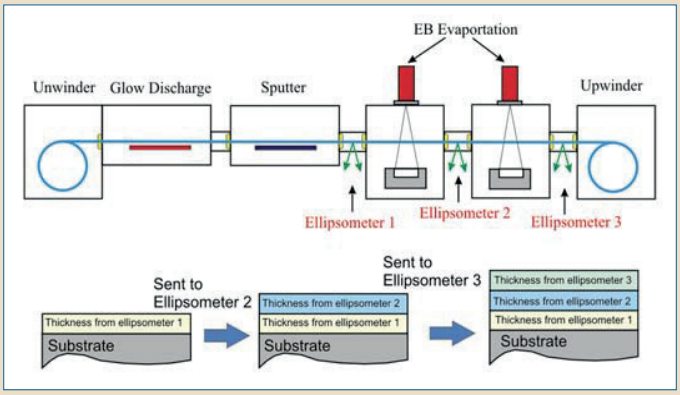


Figure 2

Complex Sample Structures

Advanced measurement techniques, such as Generalized Ellipsometry and Mueller-matrix ellipsometry, have enabled characterization of new, complex sample structures. Anisotropic liquid crystals can be measured to determine the optical axis orientation and tilt profile. Nanostructured and nanoporous materials are characterized to study depth profile and anisotropy. As ellipsometer technology expands, it opens new doors for complex materials characterization.

Solutions

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