OLYMPIAN

Ultra-High Resolution &
Ultra-High Sensitivity Scatterometer
with Thin Film Measurement Capabilities
Based on DUV-Vis-IR Reflectometry

FULLY AUTOMATED, HIGH THROUGHPUT OPTICAL METROLOGY SYSTEM FOR SEMICONDUCTOR APPLICATIONS INVOLVING ULTRA-THICK & ULTRA-THIN FILMS, EPI-SI LAYERS AND OCD MEASUREMENTS OF HIGH ASPECT RATIO TRENCHES AND CONTACT HOLES

n&k® the true measure

OLYMPIAN

METHOD OF ANALYSIS

The n&k Olympian utilizes n&k's patented optical design that combines polarized DUV-Vis-NIR and unpolarized IR reflectance data to determine the optical properties (*n* and *k*), and thicknesses of ultra-thick and thin films, plus depths, CDs and profiles of complex 2-D and 3-D structures. This fully automated system can be configured for various wafer sizes (300 mm (12"), 200 mm (8"), and 150 mm (6")) and for a variety of semiconductor applications. The n&k Olympian expands the capabilities of n&k's UV-Vis-NIR system (the n&k OptiPrime-CD) by adding IR wavelengths for measurements of Epi-Si layers and very thick photoresists and polymers (>100 µm), as well as complex 2-D and 3-D structures with ultra-high aspect ratios.

On the software end, a valid physical model combines the Forouhi-Bloomer Dispersion Equations for *n* and *k* and Rigorous Coupled Wave Analysis (RCWA) to analyze raw reflectance data. The Forouhi-Bloomer (FB) model describes the refractive index, *n*, and the extinction coefficient, *k*, as functions of wavelength, λ, and was derived based on first principles of quantum mechanics. The scientific derivations of the FB model were originally published in 1986 and 1988, and a related patent was subsequently granted in 1990.

KEY FEATURES OF OLYMPIAN

- *Polarized UV-Vis-NIR Reflectance (Rs and Rp) Data*
  - *Wavelength Range: 190 - 1000 nm*
  - *Micro-Spot Technology*
- *Unpolarized IR Reflectance (R) Data*
  - *Wavelength Range: 1000 - 15000 nm*
  - *Micro-Spot Technology*
- *Can be Configured for 300 mm (12"), 200 mm (8") and 150 mm (6") Wafers*
- *Fully Automated*
- *Based on Patented Optics that Optimizes the Signal-to-Noise Ratio*
- *Strong Sensitivity to Sub-Nanometer Structural and/or Material Variations*
- *Thin Film Measurements*
  - *Thickness, n and k spectra (190 - 15000 nm)*
- *OCD Metrology for 2-D and 3-D Structures (Trenches and Contact Holes)*
  - *Depth, CD, Profile*
- *Cognex Pattern Recognition Software*
- *No Re-Alignment Issues Upon Light Bulb Replacement*
- *Modular design - Easy to Maintain and Service*
- *GEM/SECS Communication Interface*
- *SEMI Standards and Third Party Certifications*

PHYSICAL CHARACTERISTICS

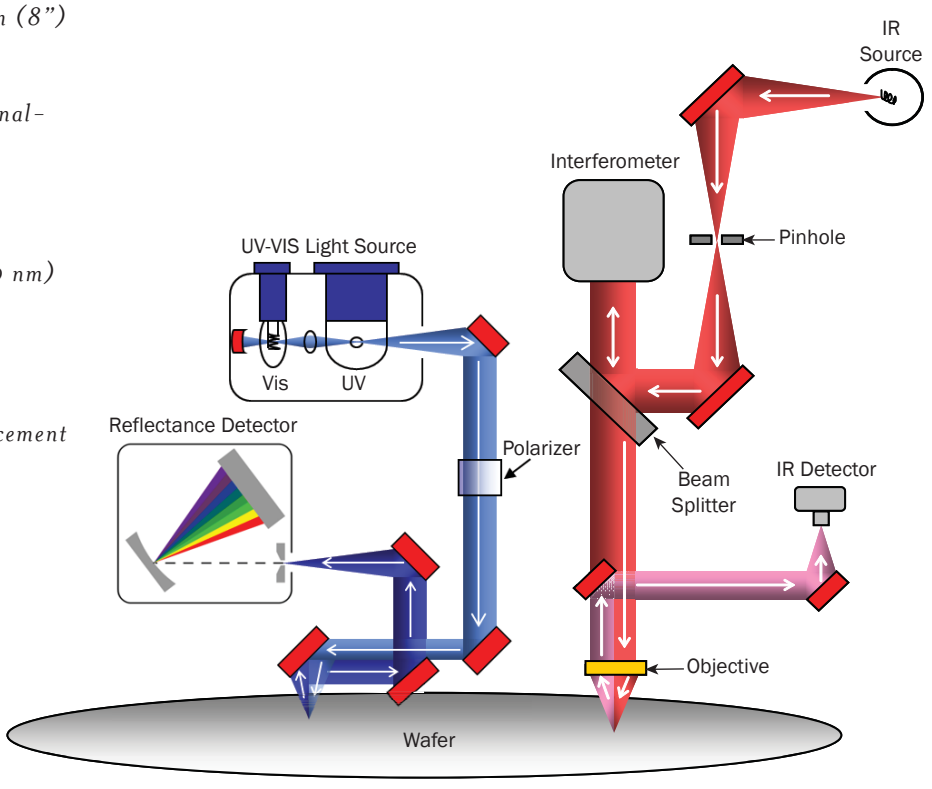
Dimensions (W x D x H):	*112 cm x 202 cm x 189 cm*
Weight (unpacked):	*775 Kg*
Facility Requirements:	*100 - 240 V, 50/60 Hz, 1ϕ*
	Vacuum, Water, Nitrogen Gas,
	CDA (for FOUP Load Port)

SYSTEM OPERATION FLOW

Data Acquisition
- Optimized Polarized UV-Vis-NIR Reflectance: (*Rs* and *Rp*) from 190 - 1000 nm
- Optimized Unpolarized IR Reflectance: (*R*) from 1000 - 15000 nm

Analysis
- Forouhi-Bloomer Dispersion Equations
- Rigorous Coupled Wave Analysis (RCWA)

Results
- Optical Properties: *n* and *k* from 190 - 15000 nm
- Film Thickness
- OCD Metrology (depth, CD, profile)

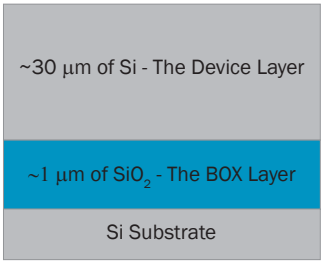


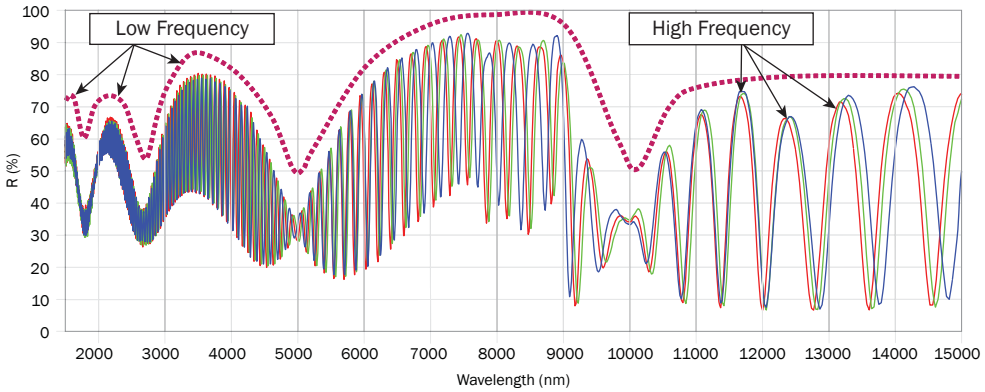
Thin and Thick Film Application

The n&k Olympian's thin and thick film applications cover both current and next generation measurement demands for R&D and production: Ultra-Thin Films and Residue Layers, Multi-Layer Stacks, Inhomogeneous films, 193 nm & 248 nm ARCs and Resists, Low-κ Films, High-κ Films, films deposited on rough surfaces, Epi film stacks, and Ultra-Thick Resists.

ULTRA-THICK FILM MEASUREMENT

SOI Schematic

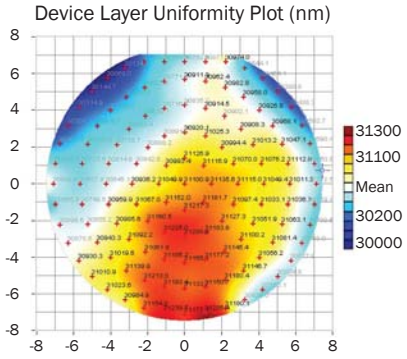




Experimental reflectance spectra in the IR region measured at three different locations. Low frequency interference fringes are due to BOX thickness; high frequency interference fringes are due to Si device layer thickness.

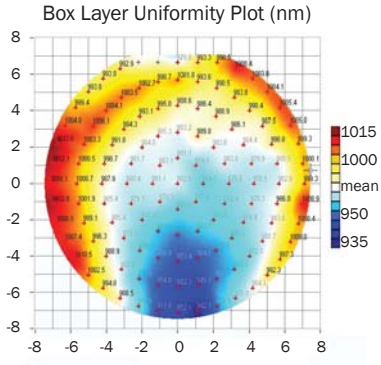
Device Layer Thickness Results (nm):

Max = 31285
Mean = 30902
Min = 30069
Std Dev = 254



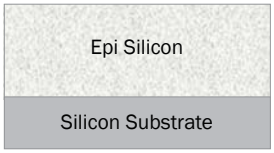
Box Layer Thickness Results (nm):

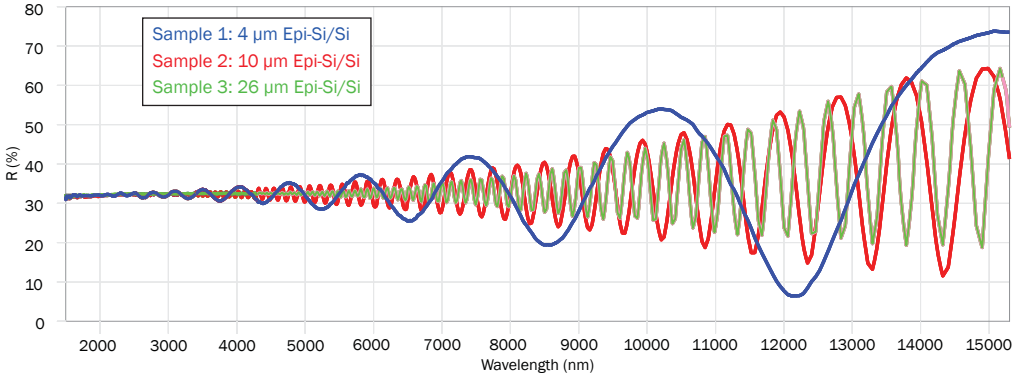
Max = 1014
Mean = 985
Min = 941
Std Dev = 16.3



EPI SILICON MEASUREMENT

Epi Silicon Schematic





Experimental reflectance spectra in the IR region measured for three different Epi-Si/Si samples. The frequency of interference fringes relates to the Epi-Si thickness.

- The IR wavelength range (1000 - 15000 nm) is sensitive to Epi-Si thickness
- IR reflectance spectra is dependent on the Epi-Si thickness and the optical properties of the Epi-Si and Si substrate
- Epi-Si thickness has been measured for films as thin as 200 nm and as thick as 100 µm

OCD Scatterometry Applications

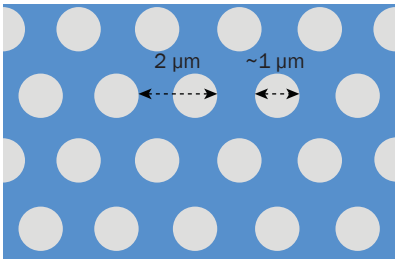
The n&k Olympian's OCD scatterometry applications cover structures with very large and very small pitches, 2-D and 3-D complex structures with high & low aspect ratios, and structures with films inside and outside of trenches and contact holes.

DEEP 3-D STRUCTURE

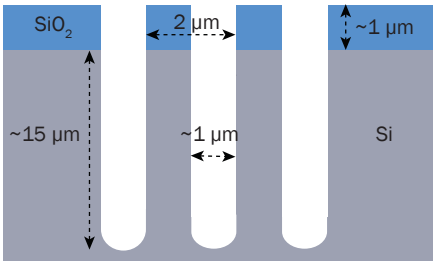
Structure Information

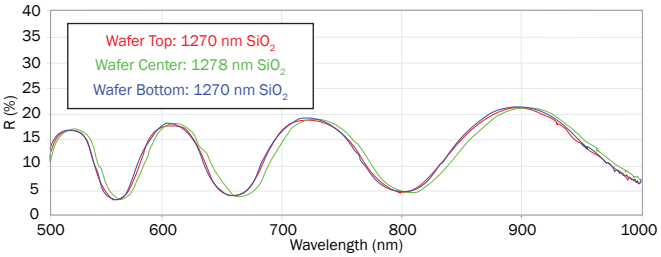
Contact Hole Depth: 10 – 20 µm
Oxide Thickness: ~1 µm
X-Pitch: 2 µm
Contact Hole Diameter: ~1 µm

Top View Schematic

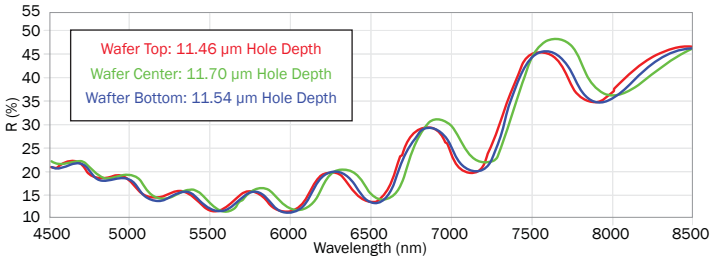


Cross Section Schematic





Experimental Spectra: In the Vis-NIR range, the shift of the interference fringes occurs because of the variation in the mesa SiO_2 thickness. No variation due to the changes in contact hole depth is observed in this wavelength range.



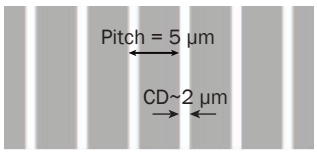
Experimental Spectra: In the IR range, the shift of the interference fringes occurs because of the variation in the trench depth. The frequency of the interference fringes at the center of the wafer has the largest value. Therefore, the contact holes at the center are the deepest of the three.

Role of UV-Vis-NIR and IR Measurements for OCD Applications

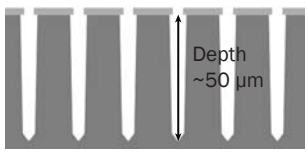
- Reflectance in the UV-Vis-NIR wavelength range (190 - 1000 nm) does not contain all necessary spectral information to analyze OCD structures with high aspect ratios.
- The 190 - 1000 nm range is necessary for thin film stacks and top trench or top hole measurement analysis. The 190 - 1000 nm range is sufficient for conventional trench or hole profile measurements with standard aspect ratios.
- The IR (1000 - 15000 nm) reflectance range is especially sensitive to variation of Ultra-Deep trenches or holes, due to silicon being transparent within this wavelength range.
- The IR range contains information about the critical dimensions of the deep trench or hole structure (detailed profile), including CD and depth of high aspect ratio structures

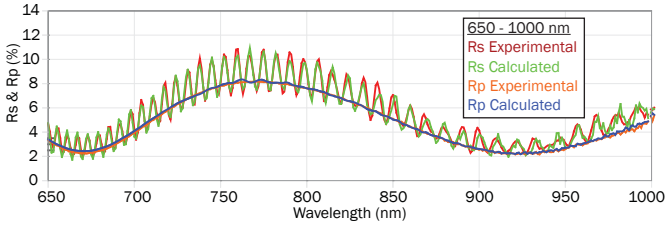
DEEP TRENCHES IN Si WITH OXIDE

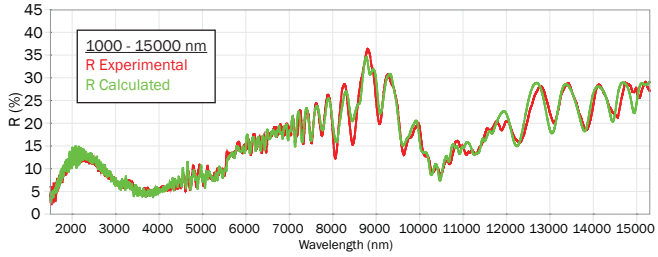
Top View



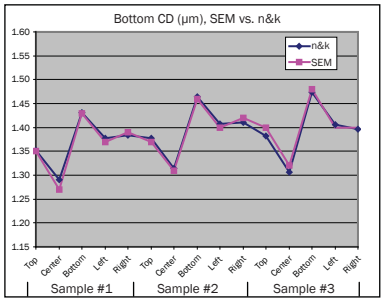
Profile

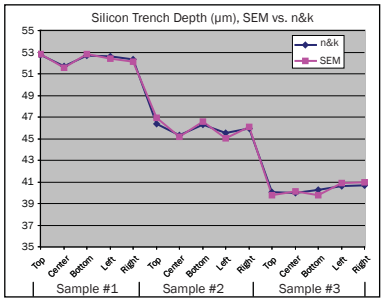






Deep Trenches in Si with Oxide SEM vs. n&k Results





- Measurements include Oxide Thickness, Silicon Trench Depth, Top CD, and Bottom CD
- n&k results correlate well with cross section SEM results
- Measurement results are obtained using both the UV-Vis-NIR (190 - 1000 nm) and IR (1000 - 15000 nm) wavelength ranges

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