

# MULTI-ANGLE REFLECTOMETRY FilmTek 4000

Non-Destructive Optical Property and Thickness Measurements for Thin Films and Multilayer Stacks

## FilmTek 4000

#### **High-Resolution In-Line Optical Metrology**

FilmTek<sup>TM</sup> 4000 is a fully automated, non-destructive optical property and thickness metrology tool specifically designed to address the demanding process control needs of silicon photonics, photonic integrated circuits, and planar waveguides. The system utilizes proprietary multi-angle reflectance technology, with beams specifically optimized for 50 nm to 150 µm films, to provide best-in-class index of refraction (*n*) resolution and repeatability. FilmTek 4000 uniquely enables precise real-time in-line monitoring of optical properties *n* and coefficient of extinction (*k*)—necessary when producing materials like BPSG, Ge-SiO<sub>2</sub>, P-SiO<sub>2</sub>, Si<sub>2</sub>N<sub>4</sub>, SiON, and LiNbO<sub>3</sub>.



### **Superior Metrology Performance** for Optoelectronics

FilmTek 4000 is fully equipped to provide exceptional measurement of film thickness and optical properties n and k. It utilizes a patented multi-angle reflectometry design to collect reflectance spectra from 400 nm to 920 nm at both normal incidence and 70°. The FilmTek 4000 platform can also be tailored to specific metrology needs by customizing source and detector to expand capabilities to the NIR wavelength range (up to 1700 nm), where some silicon-based photonics devices operate, or adding an optional spectroscopic ellipsometer to accommodate ultrathin film measurements from 0–500 Å.



#### **Ultimate Non-Contact Refractive Index Resolution**

By combining a specialized optical design with multi-angle reflectometry and Bruker's patented multi-angle differential power spectral density (DPSD) analysis capability, FilmTek 4000 delivers the precision, refractive index resolution, and repeatability required to meet wavequide manufacturing specifications. The DPSD technique switches reflectance data to the frequency domain, independently deriving refractive index from the ratio of normal and 70° peak positions. All aspects of the measurement are optimized, providing independent thickness and refractive index values for transverse electric (TE) and transverse magnetic (TM) modes of cladding and core layers individually. With a refractive index resolution up to  $2 \times 10^{-5}$ , the system provides process and quality engineers a non-destructive solution to match tighter tolerance specifications. FilmTek 4000 boasts 100 times higher refractive index measurement precision than any other optical technique and 10 times improvement over contact systems, such as prism couplers.

#### **Enhanced Versatility for Single- and Multi-Layer Stacks**

Multi-angle reflectometry accommodates film thicknesses from 50 nm to 150 µm, covering thicker films typically encountered in planar waveguides. The same mechanical design supports the optional addition of a spectroscopic ellipsometer, comprising an additional polarizer and compensator, to extend compatibility to ultrathin films like monolayers or bare substrates. Combining simultaneous multi-angle reflectometry and spectroscopic ellipsometry with Bruker's DPSD technique enables accurate and repeatable thickness measurements, since the model can separate the effects of thickness and optical properties variations. A proprietary dispersion formula, based on a quantum mechanical model and satisfying Kramers-Kronig relations, further deconvolutes contributions of refractive index and thickness for multi-thin layer stacks. Supported by fast data collection and processing times, FilmTek 4000 is ideal for product line monitoring, process evolution, and quality control of advanced films.



DPSD plot comparing 5  $\mu$ m SiO<sub>2</sub> on Si to 5  $\mu$ m Si<sub>3</sub>N<sub>4</sub> on Si.



Index of refraction as a function of temperature, showing high accuracy.

#### Fully Automated, High-Throughput In-Line Metrology

FilmTek 4000 enables 300 mm wafers to be loaded and measured automatically, with results uploaded to the host network for real-time process control. Wafer handling from FOUP or cassette to stage is quick with accurate stage placement. Pattern matching, using PatMax from Cognex, improves stage accuracy to within less than a micron. Fully automated beam alignment, calibration, and focusing ensure the tool provides consistently accurate results without necessitating user input. Data processing is fast and easy, with a typical processing time of a few seconds or less per point. FilmTek 4000 is uniquely equipped to be fully integrated into in-line production for refractive index and film thickness metrology.





600 nm Si<sub>3</sub>N<sub>4</sub> (CVD)

Silicon Substrate

Multilayer thickness results for  $Si_3N_4$  on CVD  $Si_3N_{4'}$  showcasing applications in Si photonics.

#### FilmTek 4000 Specifications

Measurement Function	Index of refraction <i>n</i> and extinction coefficient <i>k</i> , film thicknesses <i>t</i> , roughness, crystallinity
Film Thickness Range	0 Å to 150 μm
Film Thickness Accuracy	$\pm 1.5$ Å for NIST traceable standard oxide 5000 Å to 1 $\mu m$
Film Thickness Precision (1ơ)	5 μm Oxide ( <i>t,n</i> ): 2 Å / 0.00002
Spectral Range	400 nm to 1700 nm
Spectral Resolution	Visible: 0.3 nm; NIR: 2 nm
Measurement Spot Size	1 mm (normal incidence); 2 mm (70°)
Light Source	Regulated halogen lamp and optional NIR source
Detector Type	2048 pixel Sony linear CCD array; 512 pixel cooled Hamamatsu InGaAs CCD array (NIR)
Wafer Handling	Brooks or Bruker's internal handling solutions
Automated Stage	150 mm to 300 mm
MeasurementTime	<5 s per site

#### **Bruker Nano Surfaces and Metrology**

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