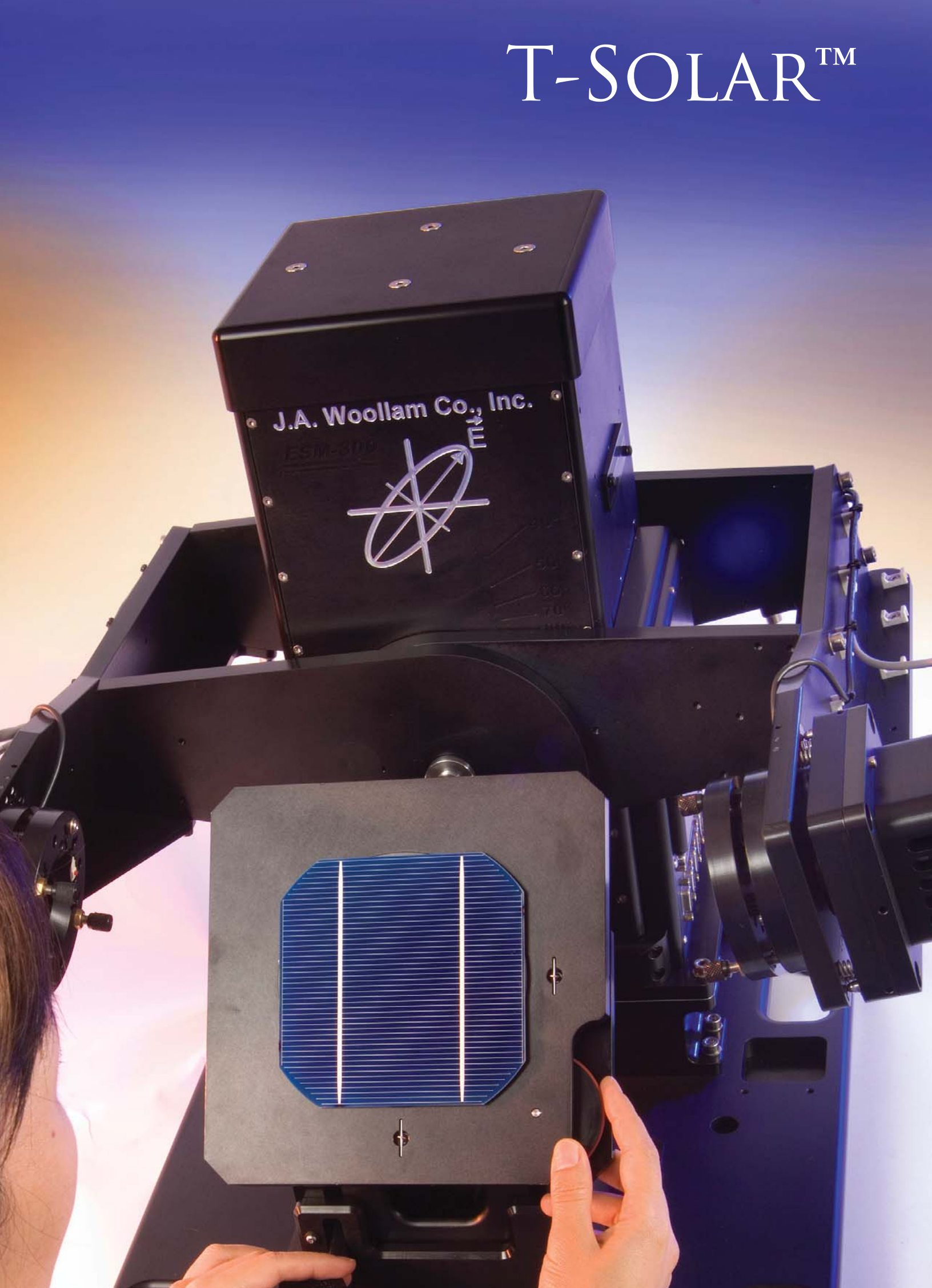
T-Solar™



System Overview

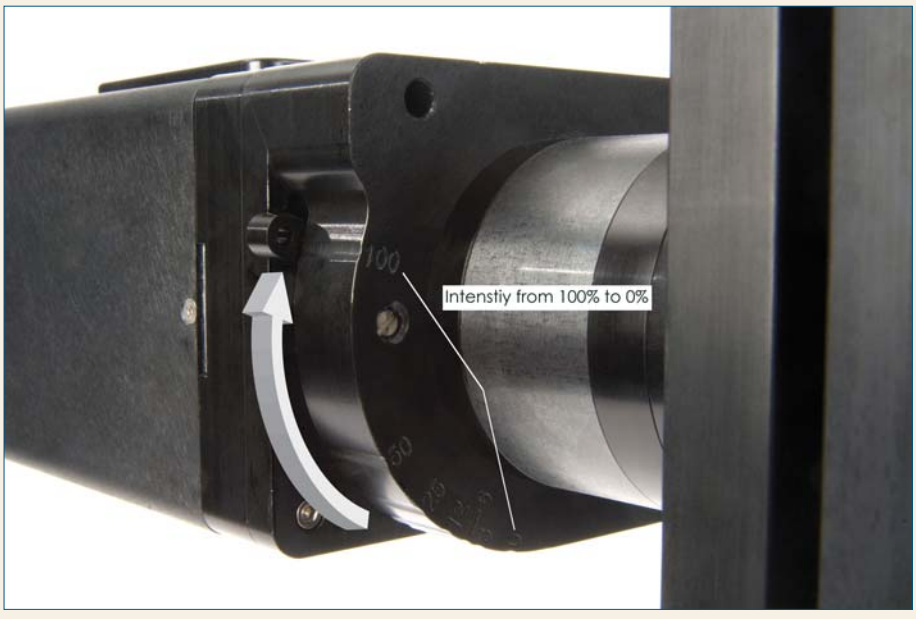
The T-Solar™ system combines the best photovoltaic measurement technology into a single system designed specifically for textured samples. Based on the established M-2000® rotating compensator spectroscopic ellipsometer, the T-Solar measures hundreds of wavelength across the UV-Visible-NIR. To improve performance on rough, textured surfaces that significantly reduce reflected signal, the T-Solar combines a special High-Intensity Lamp source with our new Intensity-Optimizer*. The T-Solar is perfect for characterizing AR coatings on etched silicon surfaces. In addition, the T-Solar features an adjustable tilt-rotation-stage*, which is required to align the pyramid structures of alkaline-etched monocrystalline surfaces[1].

* Patent-pending

[1] J. Sun et al., "Characterizing AntiReflection Coatings on textured Mono-Crystalline Silicon with Spectroscopic Ellipsometry", submitted to IEEE 34th PVSC Proc., 2009.

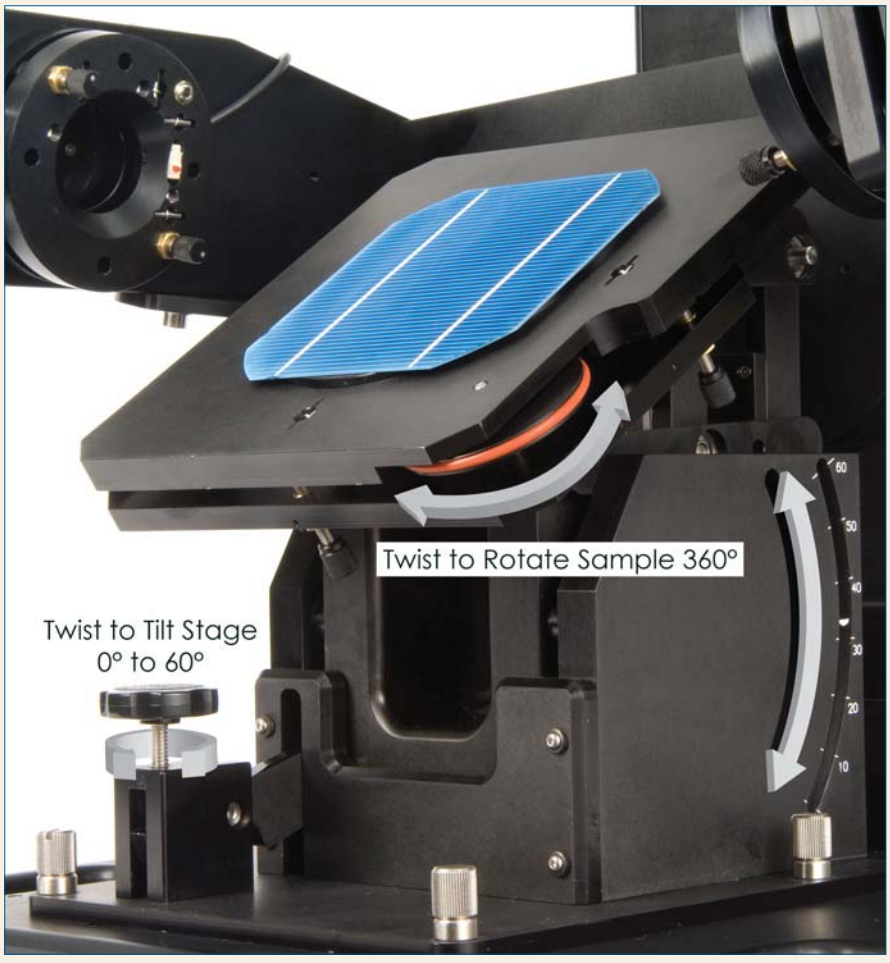
PV Applications:

- Textured Mono- and Multi-crystalline Substrates
- AR Coatings (SiN_x, AlN_x...)
- Transparent Conductive Oxides
  - ITO
  - ZnO_x
  - doped SnO_2
  - AZO
- a-Si, µc-Si, poly-Si
- CdTe, CdS, CIGS
- Organic PV Materials
- Dye Sensitized Films



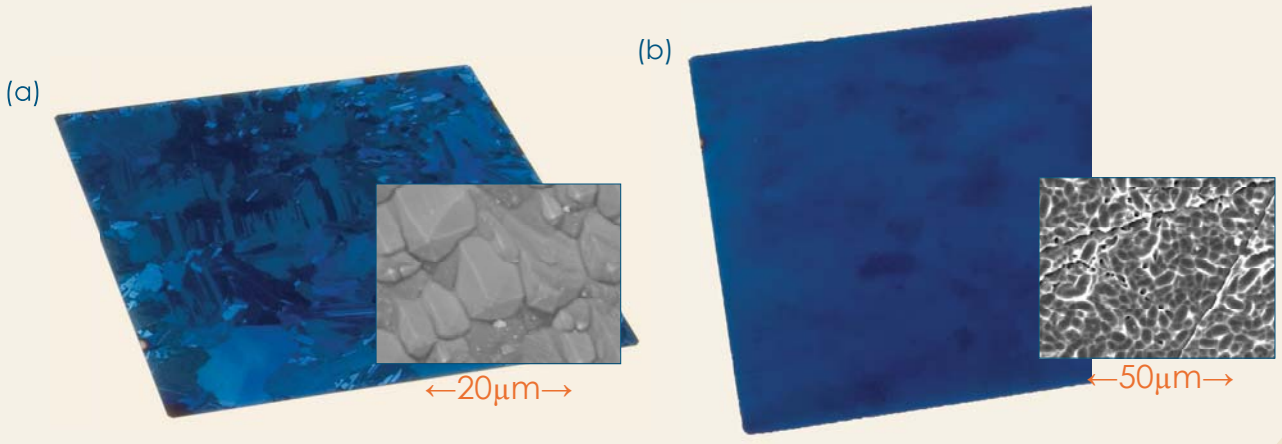
The Intensity-Optimizer* allows convenient control of measurement signal to match the ideal range for any sample. Very useful when switching between metal, glass, and even textured substrates that will have a large variation in reflected signal.

T-Solar™ Sample Stage is fully adjustable for textured, pyramidal surfaces. Tilt and rotate sample to align pyramid facets with ellipsometer probe-beam.



T-Solar Measurements

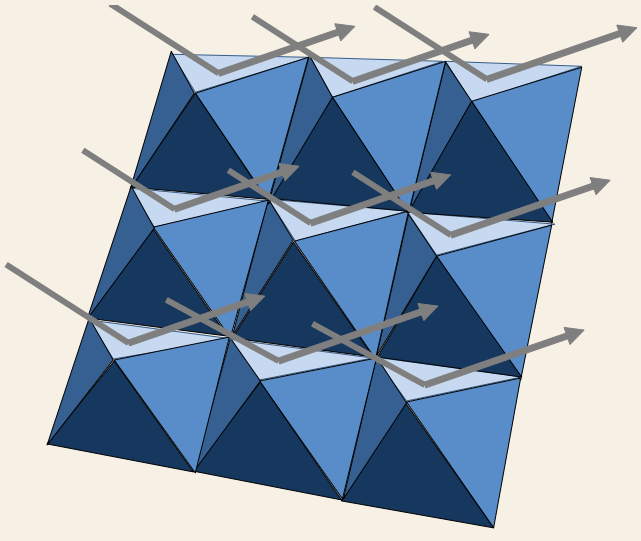
The T-Solar system was specifically designed to measure AR coatings on textured substrates, such as those shown below. Both the texturing and AR coating work to suppress reflection from the surface - making optical characterization challenging.



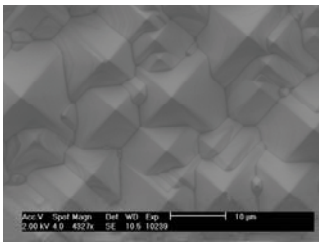
Examples of textured surfaces, coated with single-layer SiN_x as AR coating.

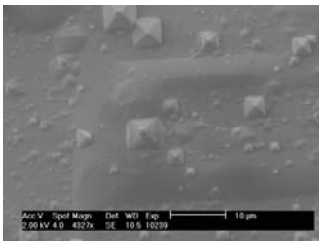
Alkaline-etched Monocrystalline Si

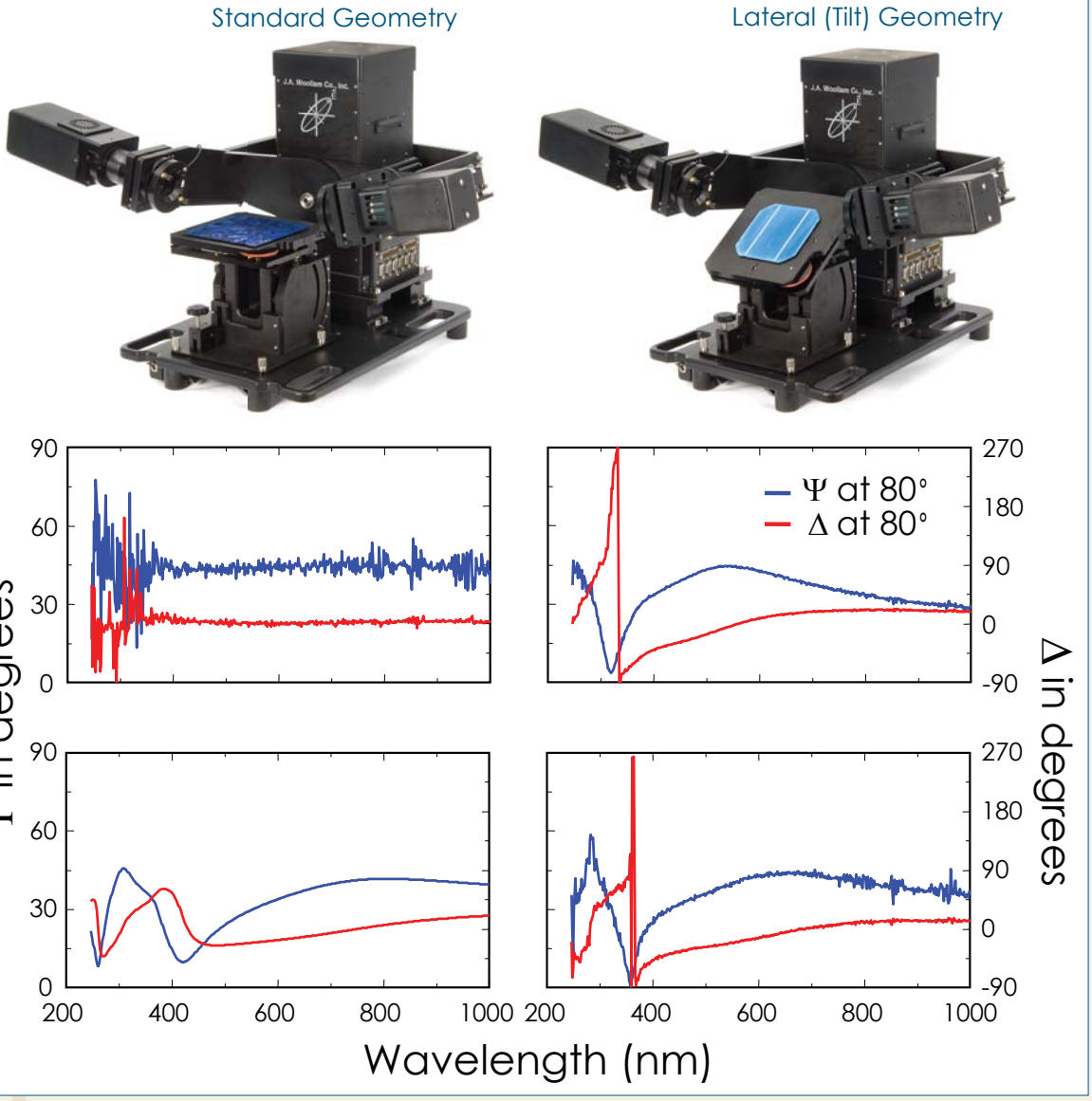
The texturing produced from alkaline etch of monocrystalline silicon has a regular pattern of pyramids that etch along specified directions of the silicon crystal. To measure this regular pattern of pyramids requires the special T-Solar measurement geometry. With the T-Solar, the sample stage can be tilted (and rotated) from the Standard Geometry to align the pyramids with the probe beam used for measurement.



*patent-pending.



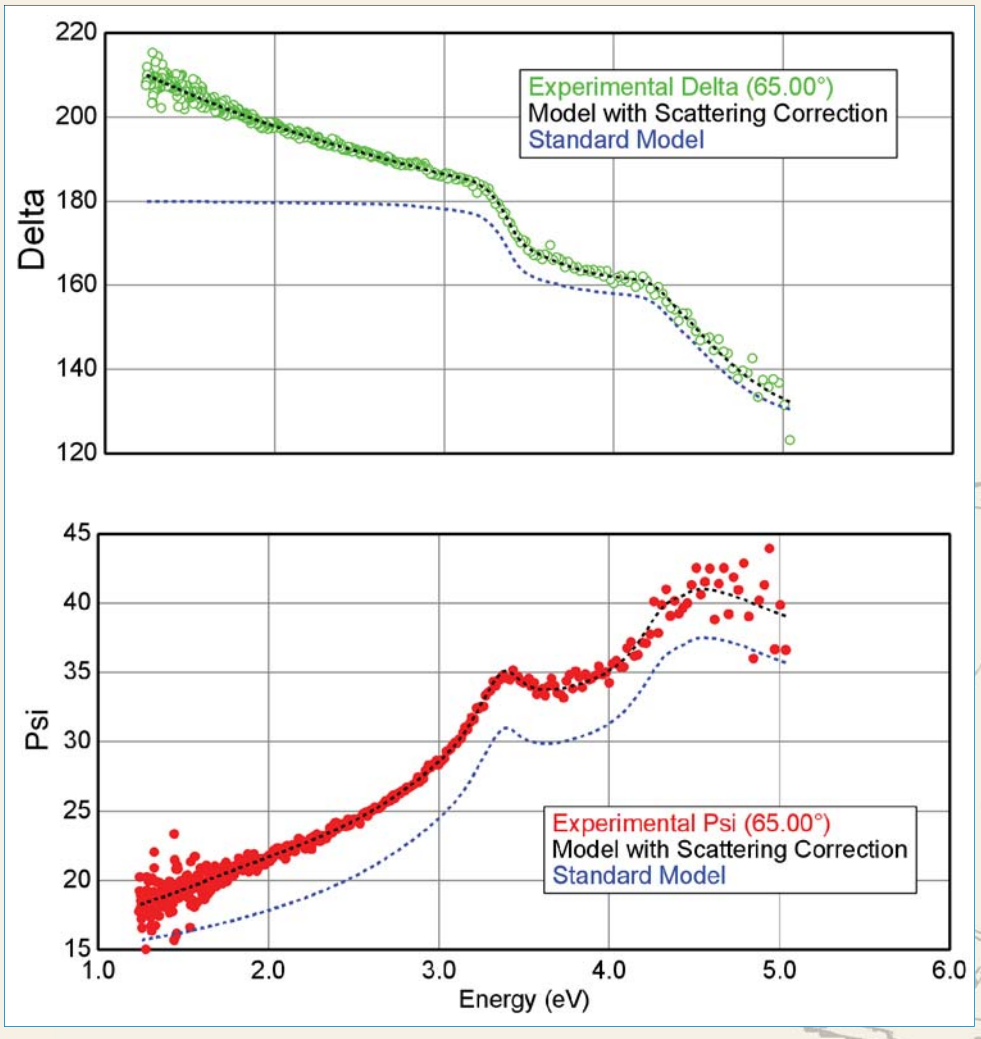




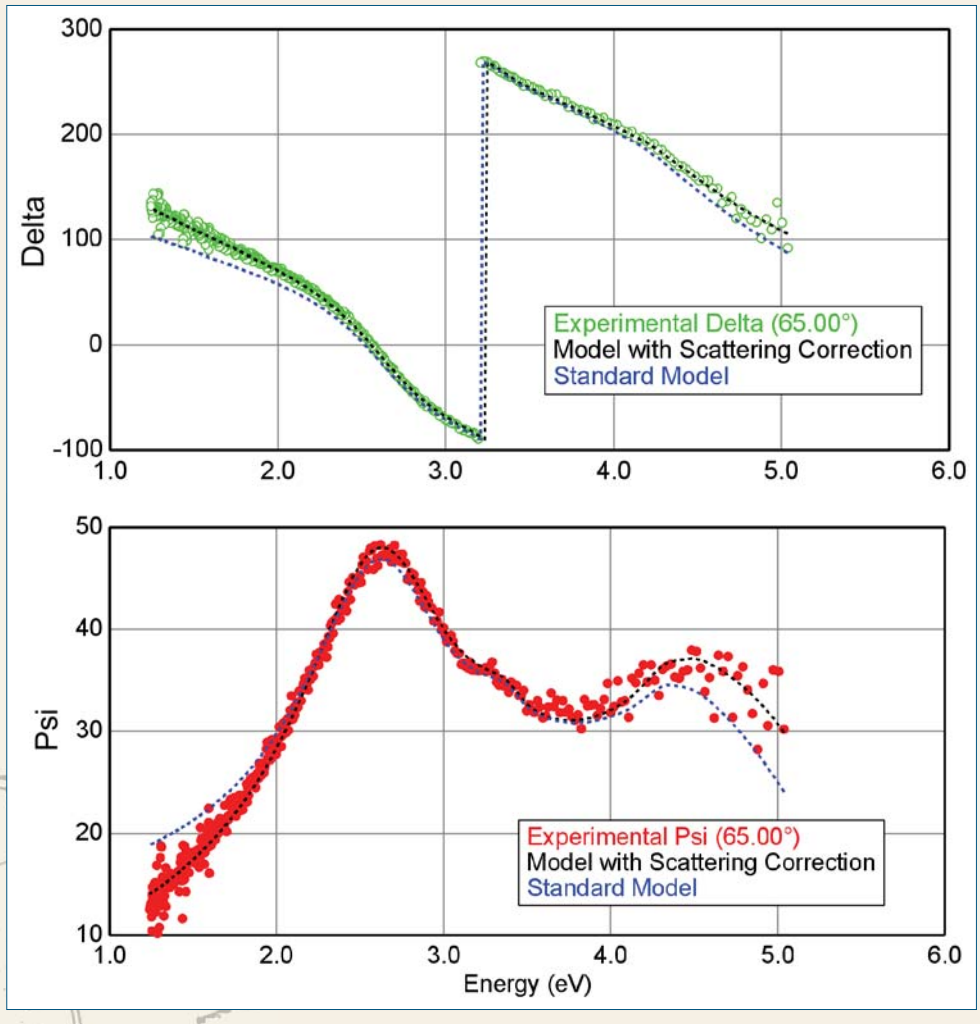
The measurement configuration can be moved from standard geometry (for samples dominated by flat regions) to the Lateral (Tilt) Geometry for samples with textured pyramid surfaces. As shown in the figure, the data are very noisy due to lack of signal if the wrong geometry is measured. The T-Solar provides flexibility to measure in any geometry needed for textured and non-textured surfaces.

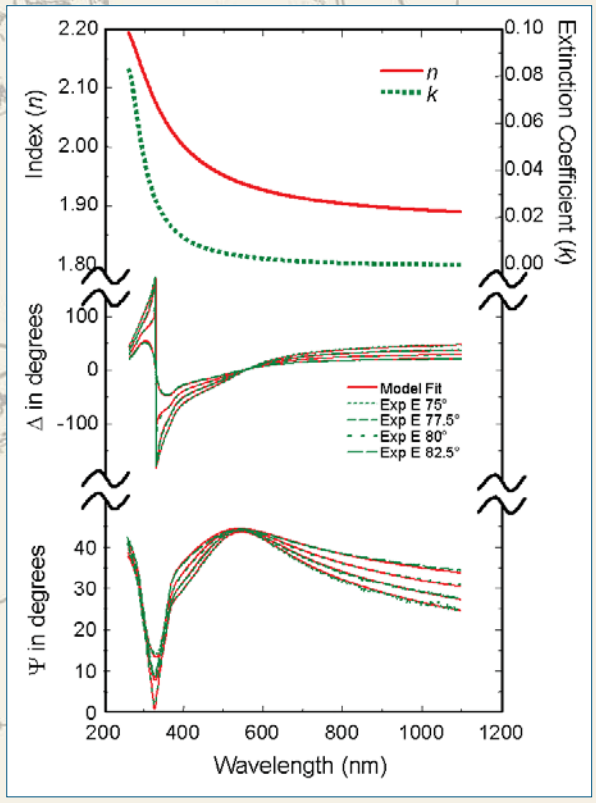
Modeling

Monocrystalline Silicon substrate measured on T-Solar. Standard Model does not reproduce the effects from pyramid structure and needs to be supplemented by scattering "factor" to correctly reproduce the Experimental Data.



T-Solar data from AR coating on textured Monocrystalline silicon are also corrected to match the effects from rough, textured surface.





Measured data and corresponding model fit for a single-layer AR coating on multi-crystalline silicon. Resulting optical constants for the AR coating are also shown.

Even with the optimized intensity, the low reflectivity from textured surfaces push measurements to very oblique angles.

Specifications

Ellipsometer Technology:

M-2000® with Rotating Compensator Technology

Base Options:

- Manual Angle or Automated Angle
- 45° to 90°
- Horizontal Sample for standard measurement.
- Special Tilt (0°-60°) and Rotation for Mono-crystalline Textured Surfaces

Wavelength Range:

245nm to 1000nm, approximately 470 total wavelengths

Detection System:

CCD detector for simultaneous collection of all wavelengths.

Measurement Time:

All wavelengths collected in less than 1 second. However, longer averaging (up to 20 seconds) is necessary for the low-light conditions of most textured solar cells.

Intensity Optimizer:

Patented method to manually adjust the measurement beam intensity. Adjust to match both rough and smooth surfaces.

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