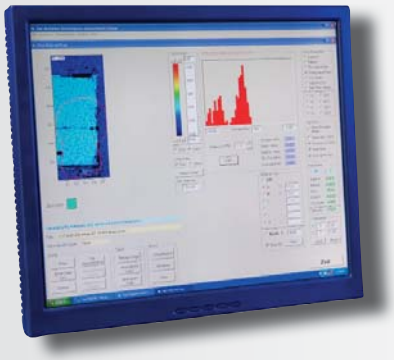
# 2-MGE Ellipsometer

## Optical Anisotropy Factor Measurement System

The Hinds Instruments 2-MGE Ellipsometer is a normal-incidence polarization reflection microscope for measuring the Mueller matrix of a sample. It has been developed to evaluate the Optical Anisotropy Factor (OPTAF) of Pyrocarbon layers of TRISO nuclear fuel. The system is designed and built on the principles described in the paper by Dr. G. E. Jellison Jr. et al entitled "Normal-incidence generalized ellipsometer using the two-modulator generalized ellipsometry microscope (2-MGEM)". This ellipsometer is a significant breakthrough; it is faster, more accurate and collects considerably more data than previous optical anisotropy measurement techniques.

The system is built around two Hinds Instruments Series I Photoelastic Modulators (PEMs). Hinds Instruments is the world's leading developer of scientific and industrial instruments and technologies based on the principles of PEM polarization modulation. The PEM is used in a wide range of high sensitivity photonic measurement equipment for both research and industrial applications.

The 2-MGE Ellipsometer measures changes in the polarization state of light that is reflected off the individual layers of a TRISO fuel particle. The system utilizes a high precision positioning stage and has a measurement spot size of ~5 µm to collect thousands of points on each fuel particle being measured. The linear diattenuation, linear retardation and reflective intensity of each sample point are calculated and reported by the automated software. These parameters are then used to calculate the OPTAF determination for each of the Pyrocarbon layers (IPyC and OPyC).



The Hinds Instruments 2-MGE Ellipsometer is composed of four main components:

- Main Scanning Module
- Master Electrical Enclosure
- Light Source
- Computer System

The system can be easily adapted to a variety of glove box arrangements for containing contaminated sample materials. Research and development software as well custom production software packages are available.

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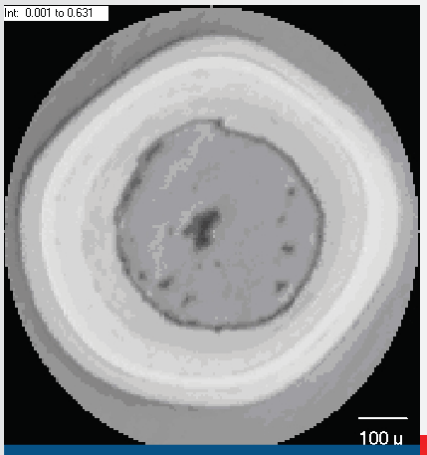
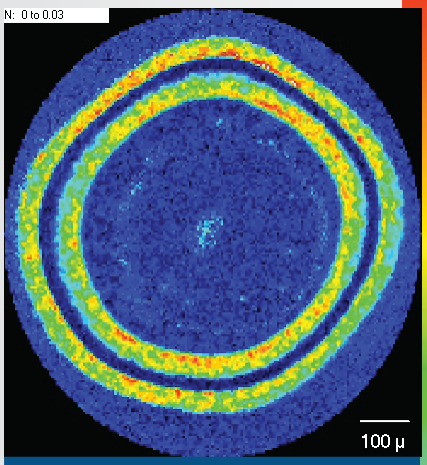



TRISO CROSS-SECTION

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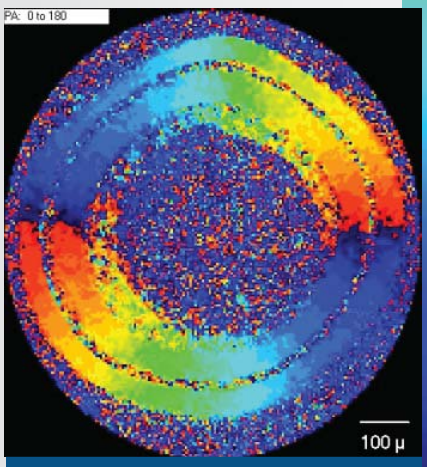


DIRECTION OF PRINCIPLE AXIS γ

The 2-MGE Ellipsometer technology can also be used to evaluate other demanding optical surface characterization needs for materials such as crystals, carbon compounds and surface deposition films. Contact Hinds Instruments for more information and to discuss your specific measurement needs.

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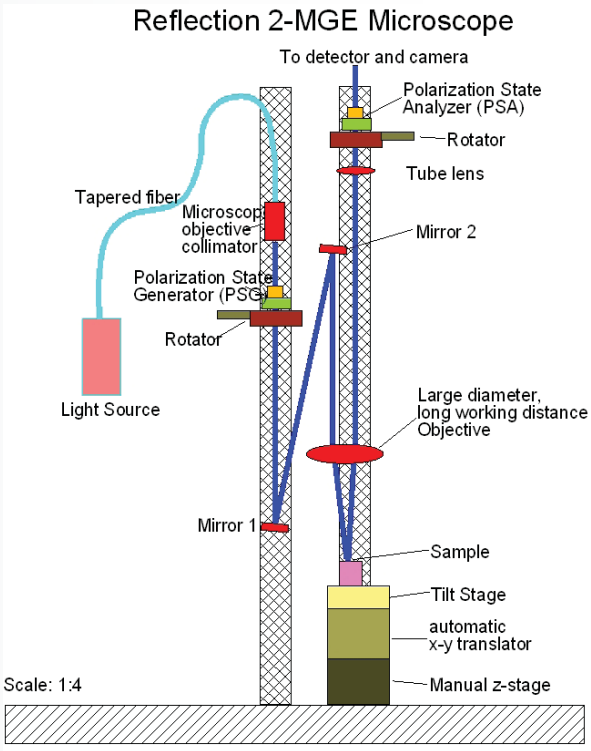


Color scale used: Minimum is black, Maximum is red.

Top left: Gray-scale image of the reflected light from a cross-section of a TRISO nuclear fuel particle. The kernel (which contains the radioactive material) has been removed and replaced with back-filled epoxy. The additional 4 layers, going from the kernel to the outside of the particle, are 1) buffer, 2) inner pyrocarbon (IPyC), 3) silicon carbide (SiC), and 4) outer pyrocarbon (OPyC).

Middle left: A map of the diattenuation of the TRISO cross-section shown. The scale is N=0 (black) to N=0.03 (red), with average error <0.001 at each point. The IPyC and OPyC are clearly identified by the large diattenuation.

Bottom left: A map of the direction of the principal axis γ of the diattenuation of the TRISO particle, using the scale γ=0° (black) to γ=180° (red). The direction γ is roughly perpendicular to the radius in both the IPyC and OPyC layers.

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