Featured Researcher

Dr. Robert Collins

There are only a handful of researchers with the vast ellipsometry experience of Professor Robert Collins. He has designed, built, improved, measured, and analyzed data from spectroscopic ellipsometers since 1982, with many groundbreaking discoveries along the way. In fact, he is the only author to have three chapters in the Handbook of Ellipsometry[1]. His first ellipsometry experience came at Standard Oil, where he started with a manual "null" principle ellipsometer to get a "hands-on" feeling for the ellipsometric technique. He soon moved to an automatic rotating analyzer spectroscopic ellipsometer patterned after David Aspnes' original design of 1975.[2] The instrument Collins developed was also used for real-time measurements at a single-wavelength, which yields "psi-delta trajectories." He developed and worked with these ellipsometers for some years before moving to Penn State in 1988.

Rob and Linda's unique home with integrated shingles incorporating flexible triple-junction a-Si:H and a-SiGe:H PV materials on stainless steel foil. A stack of three thin film solar cells, each with different bandgap, enables light collection over a broader range of solar wavelengths than possible with a single semiconductor. This home generates its own electricity from sunlight.

At Penn State, Professor Collins collaborated with Professor Vedam and a number of excellent students and postdocs to develop a number of multichannel ellipsometers. Real-time single-wavelength ellipsometry has its limitations in evaluating thin film growth mechanisms. To study such mechanisms in greater depth, accounting for the significant variability in the optical functions depending on processing, real-time spectroscopic measurements were critical. With support from a "Presidential Young Investigator Award" in 1989 from the National Science Foundation, Professor Collins built and applied the first multichannel instrument based on a rotating polarizer ellipsometer (RPE) design. This offered a simple design using a common ellipsometry approach, which allowed his research to concentrate on the multichannel methodology. Photodiode arrays had never been implemented in an ellipsometer. He addressed major issues such as phase shift in calibration, image lag, and stray light in the spectrograph.[3]

To improve both accuracy and precision, the next major multichannel development involved a rotating compensator ellipsometer (RCE) design. This allowed accurate measurements of psi and delta over their full range, including the handedness of the polarization (Ψ: 0°-90°, Δ: 0°-360°), along with depolarization measurements in real-time.[4] The final step in this progression was to add a second rotating compensator. This allowed measurements of the full Mueller-matrix to help determine anisotropy in real-time.[5]

The primary application area that has been the focus of Professor Collins' research goes back to before his work with ellipsometry at Standard Oil. As an undergraduate at Clark University, Collins had projects on both solar thermal collectors and thin film photovoltaics. When he proceeded to Harvard University to get his Ph.D. in Applied Physics, he studied the photoluminescence of amorphous silicon thin films. This background was perfect for his first job at Standard Oil in Cleveland, Ohio, where real-time ellipsometry was used to study the growth of amorphous silicon thin films for solar cells.

His interest in renewable energy continues to present day. Professor Collins is currently at the University of Toledo, where he leads a large research group of students and postdocs studying 2nd and 3rd generation photovoltaics (PV).

Those outside the PV community often ask "Why Toledo, Ohio?". Actually, the current state-of-the-art in thin film PV technology originated at the University of Toledo, developed by glass industry pioneers who had a vision of coating float glass not only with low-emissivity transparent conductors, but also with a semiconductor for PV power generation. Ultimately, CdTe was selected and this technology now provides the lowest manufacturing costs in the industry, at $0.85/Watt. Today, 60% of the U.S. PV production occurs

within 100 miles of Toledo, thanks to FirstSolar (CdTe) and Unisolar (a-Si:H).

The University of Toledo is right at the heart of PV innovation. Professor Collins has helped build the Wright Center for Photovoltaics Innovation and Commercialization, which includes state-of-the-art equipment for fabricating 2nd and 3rd generation PV cells and modules. They use insights from real-time spectroscopic ellipsometry, among other techniques, to better understand thin film processing steps and the optical properties of PV devices. This advanced facility is currently home to eight Woollam Company spectroscopic ellipsometers covering the spectral range from 193nm in the ultraviolet to 33µm in the infrared.

Professor Collins currently has 12 students and 2 Postdocs, all of which get an in-depth education of both PV and ellipsometry. Each student gets a chance to (i) make solar cells, (ii) measure them in real-time with SE, and (iii) measure them ex situ with SE for correlation with quantum efficiency - all of which provides better understanding of the origins of high PV performance. Great students can be a very rewarding part of the job as Professor. There have been many noteworthy students through the years and it is extremely satisfying to see successful output from former students. Ilsin An and Hiro Fujiwara both worked with Professor Collins at Penn State. Both have gone on to write textbooks on ellipsometry - Ilsin An in Korean and Hiro Fujiwara in Japanese (later translated into English). Another important role for students is to gain exposure at conferences including the Materials Research Society (MRS) and IEEE Photovoltaics Specialists meetings. Of course the ICSE ellipsometry conference is important and his entire group will be in Albany this May to present their latest research.

The ICSE is one of Professor Collins' favorite conferences - especially the fourth, which was held in Stockholm. He mentions the combination of "...a great location. Hans, Mathias, Uwe and team did a great job, and I was pleased not to be an organizer - so I could sit back and enjoy all the technical presentations."

In his free-time, Professor Collins and wife Linda like to enjoy the natural world, its geology, plants, and animals. They enjoy backpacking trips of a week or more deep into the wilderness where they can also partake in another favorite pastime of nature photography. Their favorite destinations are the national parks of the Canadian Rocky Mountains where one can backpack for a week in solitude. It is always exciting to hear Professor Collins' stories involving run-ins with wildlife along the trails - which can include an abundance of rattlesnakes and baby bear cubs with their moms in spring - always sure to get the heart pumping!

For more information on Professor Collins' research areas, please check out the following references or the following web-site: http://astro1.panet.utoledo.edu/~rcollins/collins.htm

Professor Collins with his 8-day backpack and photo gear during a hike in Banff National Park, Canada

References:

[1] R. W. Collins and A. S. Ferlauto, "Optical Physics of Materials"; R. W. Collins, I. An, and C. Chen, "Rotating Polarizer and Analyzer Ellipsometry"; and R. W. Collins and A. S. Ferlauto, "Multichannel Ellipsometry", in: *Handbook of Ellipsometry*, edited by H. G. Tompkins and E. A. Irene, (William Andrew, Norwich, NY, 2005).

[2] D. E. Aspnes and A. A. Studna, *Appl. Opt.*, **14**, 220 (1975).

[3] R. W. Collins "Automatic Rotating Element Ellipsometers, Calibration, Operation, and Real Time Applications", *Review of Scientific Instruments* **61**, 2029-2062 (1990).

[4] J. Lee, P. I. Rovira, I. An, and R. W. Collins, "Rotating Compensator Multichannel Ellipsometry: Applications for Real Time Stokes Vector Spectroscopy of Surfaces and Films", *Review of Scientific Instruments* **69**, 1800-1810 (1998).

[5] J. Lee, J. Koh, and R. W. Collins, "Dual Rotating-Compensator Multichannel Ellipsometer: Instrument Development for High-Speed Mueller Matrix Spectroscopy of Surfaces and Thin Films", *Review of Scientific Instruments* **72**, 1742-1754 (2001).