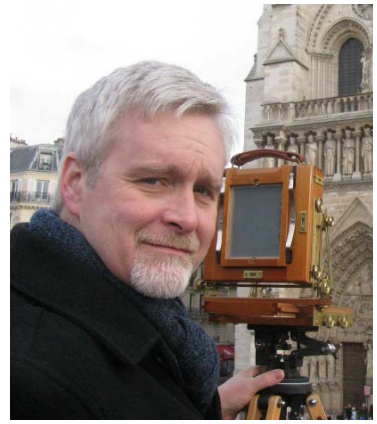
Glenn Teeter, Ph.D.

Surface Analysis Group Manager

National Renewable Energy Laboratory



Education and Training

B.S., Physics, Stetson University, 1992

Ph.D., Physics, University of Texas at Austin, 1999

Professional Experience

2012 – Present **Surface Analysis Group Manager**, National Renewable Energy Laboratory, Golden, CO

- Co-PI for NREL thin-film Cu_2ZnSnS_4 (CZTS) project; played a key role in developing successful three-year proposal to understand fundamental properties of CZTS and develop high-efficiency thin-film CZTS solar cells.
- The NREL Surface Analysis Group is comprised of three Ph.D.-level scientists, two research engineers, and two post-doctoral researchers, and supports research in all core PV research groups at NREL.

2007 – 2012 **Senior Scientist**, National Renewable Energy Laboratory, Golden, CO

- Performed fundamental studies of CZTS thin-film growth kinetics and thermodynamics and developed a manufacturing-friendly process for high quality thin-film CZTS (U.S. Patent awarded 2013).
- Performed x-ray photoelectron spectroscopy (XPS) measurements on as-grown and surface modified CZTS surfaces. Discovered correlation between Fermi-level pinning and near-surface Cu concentration that plays a critical role in determining the conduction-band offset at the CZTS/CdS interface, and hence on device performance.
- Developed instrumentation and software for *in situ* growth monitoring of thin-film CZTS via spectroscopic reflectometry and thermal-desorption mass spectrometry.

2002 – 2007 **Scientist II**, National Renewable Energy Laboratory, Golden, CO

- Designed and built deposition system for thin-film chalcogenide materials that incorporates a novel method for combinatorial synthesis of binary and ternary material systems.
- Key participant in design and construction of NREL surface-analysis cluster tool that integrates a tool for x-ray and ultraviolet photoelectron spectroscopies (XPS/UPS), a scanning Auger electron spectroscopy (AES) tool, a combinatorial chalcogenide deposition system, and an inert gas-purged glovebox.

1999 – 2002 **Postdoctoral Researcher**, Pacific Northwest National Laboratory, Richland, WA

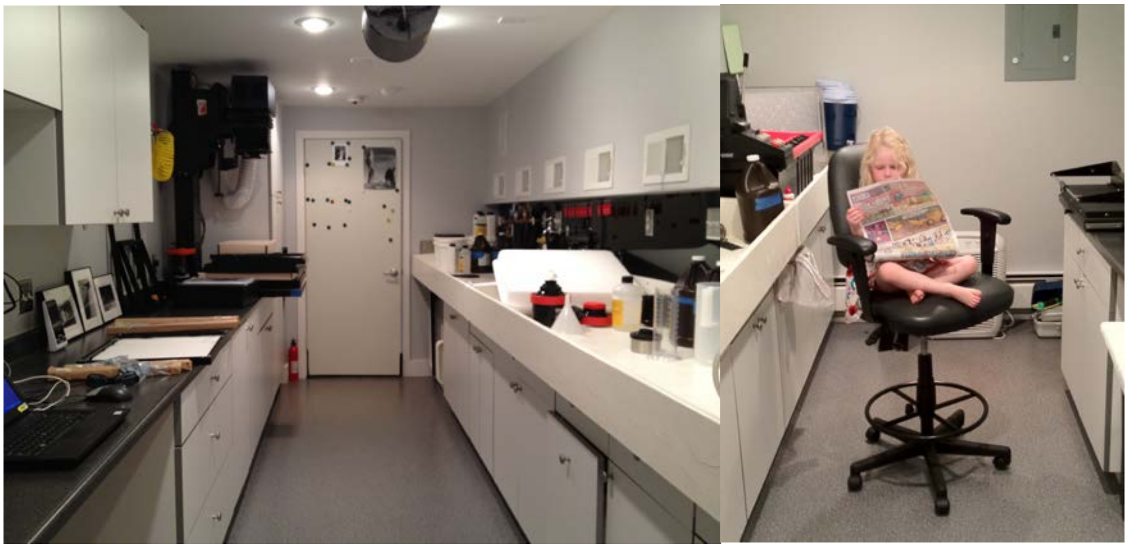
- Developed experimental capability to deposit and thermally process highly porous frozen brines in high vacuum to mimic surface conditions on Jupiter's moon Europa, and gathered data for comparison with the Near-Infrared Mapping Spectrometer (NIMS) instrument on the Galileo spacecraft.

Open Letter to Stetson Physics Majors

It's a tremendous honor to have been chosen as this year's Stetson Physics featured alum. I first visited Stetson as a high school senior, and was given a tour of the campus and Physics Department by a newly minted professor named Kevin Riggs. What impressed me the most was the atmosphere in the department, where teaching was a clear priority, and there seemed to be a strong rapport between students and faculty. It was only after moving on to graduate school at the University of Texas at Austin that I realized how big a difference there could be between a small liberal-arts university like Stetson and a large research university. Some of the highlights of my time at Stetson included the introductory physics course taught by Professor Lick, and the mathematical physics course taught by Professor Jusick. I found both to be challenging and enlightening. Professor Riggs taught a course on computational physics, and this was my first exposure to setting up and solving physics problems on a computer that were too complex to solve analytically. Although it's been many years since I've done research that could be called 'physics' in the traditional sense, the scientific intuition and skill set that I developed at Stetson has been invaluable in my education and professional development.

My wife, Muriel, is a French citizen. We made a trip to Paris for Christmas last year to visit her family, and do a little sigh-seeing on the side. This was the first international trip for our daughter, Chloe, and she had a rough time with the jet lag (see her expression in the photo at the Arc de Triomphe), but we perked her up a little later with hot cocoa and crepes.

I did my graduate work in the Physics Department at the University of Texas at Austin in Professor James Erskine's Surface Science Group. During my time there I learned quite a bit about maintaining and troubleshooting ultra-high vacuum chambers, and worked on a variety of experiments aimed at understanding fundamental properties of single-crystal metal surfaces. We used techniques including Electron Energy Loss Spectroscopy (EELS) and Low-Energy Electron Diffraction (LEED) to characterize and understand differences in atomic-level structure at the surface compared to the bulk, as well as effects of adsorbates and surface roughness on LEED surface-structure determinations. I found this work to be rewarding, but after devoting several years to these very fundamental measurements I became increasingly convinced that I might be better suited to working in an applied technology field. I wanted to pursue a career that aligned well with my world view, which included a growing concern with environmental issues, especially the effects of climate change.



I started developing and printing 35 mm black and white photographs in grad school as a way to de-stress after long hours in the lab. Before long I moved on to large-format photography which I've been doing for about the past 15 years. About five years ago I converted part of our garage into a darkroom. Now I'm in the process of training my new darkroom assistant—that's her perusing the Sunday comics—but it's slow going! (In her defense, she's too short to reach into the sink, and I won't let her play with the 'colored water' in the chemical trays.)

As I moved toward completing my Ph.D., and put more thought into what I wanted to do with my professional life, I began to think seriously about becoming involved in renewable-energy related research. Considering my background in condensed matter physics and surface science, I initially targeted a post-doctoral position to do research related to fuel cells. After completing my Ph.D., I joined Dr. Thomas Orlando's group at Pacific Northwest National Laboratory (PNNL). We intended to set up a project to study the interaction of hydrogen with metal surfaces, with the aim of understanding fundamental mechanisms underlying the operation of hydrogen fuel cells. For a variety of reasons this project did not move forward as hoped, but instead I was fortunate to become involved in a project aimed at interpreting data acquired by the Near-Infrared Mapping Spectrometer (NIMS) on the Galileo spacecraft from Jupiter's moon, Europa. I'd always had an interest in astronomy and planetary science, so this project was both fascinating and a nice break from the work I did in graduate school. A year or so into my post-doctoral appointment, Dr. Orlando moved to another institution, so I switched gears again. I joined Dr. Bruce Kay's group and participated in projects studying, among other things, crystallization kinetics of thin-film supercooled liquids deposited via molecular beams. As I neared the end of my post-doctoral appointment, I decided that what I really wanted to do with my career was to get involved in photovoltaic research, even though this was a bit of stretch considering I had no experience in this area.

I was very fortunate that a position opened up at the National Renewable Energy Laboratory (NREL) at just the right time that was suitable to someone with my background. I joined NREL in early 2002 as a staff scientist Surface Analysis group, a part of the National Center for Photovoltaics (NCPV). Most of my research has focused on various aspects of thin-film PV technologies, including those based on the compound semiconductors CdTe and $CuIn_{1-x}Ga_xSe_2$ (CIGS). Along with my colleagues at NREL, I helped to set up a unique surface-analysis cluster tool geared toward studying interfaces in PV devices. This effort has continued in various stages over the past 10 years or so, and at this point we have a system that includes capabilities for x-ray and ultraviolet photoelectron spectroscopies (XPS/UPS), inverse photoelectron spectroscopy (IPES), scanning Auger electron spectroscopy (AES), scanning tunneling microscopy (STM), low-energy electron diffraction (LEED), and ion scattering spectroscopy (ISS). These analytical tools are coupled by an ultrahigh vacuum transfer system to a chalcogenide molecular beam epitaxy (MBE) tool, as well as a nitrogen-purged glovebox set up for various wet-chemistry based processes. By combining all of these capabilities, especially the ability to deposit, process, and transfer samples to measurement stations under ultrahigh vacuum conditions, we are able to study in detail the formation of critical interfaces in PV devices.

Fly fishing in Rocky Mountain National Park (left), and on Clear Creek near Golden, Colorado (right).

For the past several years, I've been involved in efforts to develop Cu_2ZnSnS_4 (CZTS) and related materials (earth-abundant analogs of CdTe and CIGS). PV devices based on these and other earth-abundant materials are at a relatively early stage of development, so there are many opportunities for novel fundamental and applied studies. These new materials are generally complex, however, if they can be developed to produce PV device efficiencies comparable to existing technologies, then in principle there are no material availability constraints to limit widespread adoption. The ultimate goal of PV research (in my opinion) is to develop a set of low-cost PV technologies that can scaled to the terawatt level, and thereby make a substantial contribution to global energy production.

We took a break while hiking in Grand Teton National Park to do a little fishing in Cascade Creek. The creek turned out to be full of eager and quite hungry little brook trout. I think that if I play my cards right, my budding darkroom assistant will also become my fishing companion. (That water was COLD, but she was a trooper—didn't complain a bit!)