

CRSP

Center for Revolutionary
Solar Photoconversion

update

Summer 2010

CRSP Research Profile

Plasma Sheds Light on Mysteries of PV Efficiency

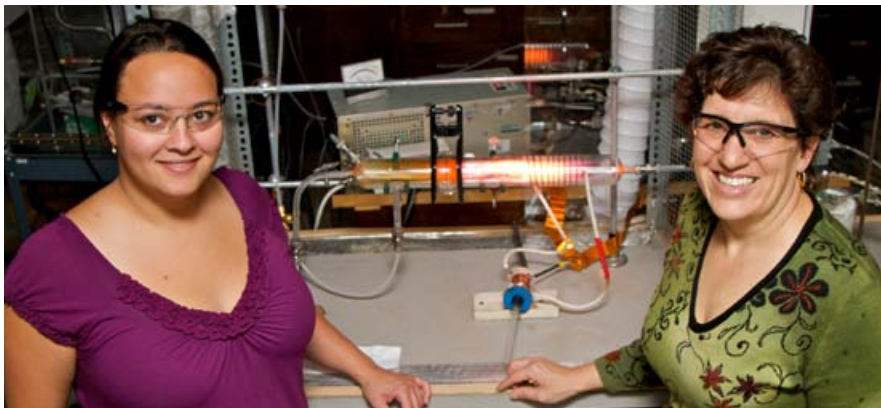
Stars are made of plasma, an ionized gas comprising a complex mixture of gas-phase species. So it's remarkable that CRSP researchers are using plasmas to create photovoltaic (PV) devices that can better convert energy from our own star, the sun, into power we can use here on Earth.

A CRSP research team, made up of researchers from CSU and NREL, has been using plasmas to modify PV materials and improve the interfaces between the layers of materials in thin-film solar cells. The goal is to increase efficiency in PV devices.

Ellen Fisher is an analytical/materials chemist and the project's principle investigator at CSU. "We know we can use plasmas to change materials and get different device results, but we need to know exactly how it works," she says.

The team is developing new materials for solar cells by taking known materials, such as titanium dioxide (TiO_2), and improving their properties. Such improvements include applying plasmas to modify material surfaces to reduce "electron traps." So when photons strike and free up electrons to make electricity, more electrons can flow through the material. The more free-flowing electrons there are, the more electricity is produced relative to the amount of sun exposure.

For example, a promising PV technology is the TiO_2 -based, dye-sensitized solar cell. Such cells can now be produced on a variety of inexpensive substrates, making them ideal for building-integrated PV applications. Each dye cell consists of a photoanode, such as TiO_2 , a dye sensitizer, an electrolyte, and a photocathode. These cells currently have an efficiency of 11%; solid-state dye cells have an efficiency of about 5%. The CRSP team has learned that by using a plasma process on the TiO_2 surface, they may be able to modify the dye/ TiO_2 interface to make it amenable to new dyes, and to boost the overall cell performance.



The CRSP plasma processing project team includes Ina Martin, an analytical chemist at NREL. Her role is to extend the characterization of the modified materials and evaluate the resulting devices under real-world conditions. The rest of the team includes Michael Elliott, a CSU electrochemist with a background in PV device testing; Patrick McCurdy, a CSU staff scientist who specializes in surface science and who helps analyze data; and CSU graduate student Dan Pulsipher, who performs research in the lab.

CRSP has funded the plasma processing project through mid-2010, but the project will need additional funding to continue. Fisher is seeking additional sources of funding, including from the U.S. Department of Energy (DOE), and hopes any further work could be a large component of a new graduate student's thesis.

"The entire world needs to replace fossil fuel energy sources with clean renewable energy," she says. "This project is so interesting because ultimately, it's a part of a worldwide effort and everyone working on PV has different approaches. Collectively, we're bound to find solutions to this very real problem."

Martin concurs, adding, "So much of PV research is a materials science problem. As a scientist, I also find it satisfying to participate in the process of improving materials properties through understanding the gas-phase

Ina Martin (left) and Ellen Fisher are shown in the laboratory with a low-pressure rf plasma reactor. The two chemists work together on a CRSP project that uses plasmas to modify PV materials and improve the interfaces between the layers of materials in thin-film solar cells. Credit: Jeff Shearer.

chemistry, applying these results to PV devices, then using the device performance to determine what additional modifications need to be made to the materials."

To learn more about the project, visit www.chm.colostate.edu/erf/photovoltaics.htm

The Center for Revolutionary Photoconversion (CRSP)

is dedicated to the basic and applied research necessary to create revolutionary new solar energy technologies as well as educational and training opportunities. The research underpins renewable energy technologies, commonly called third-generation solar photon conversion, for the highly efficient and cost-competitive production of both electricity and fuels via direct solar processes. The CRSP participating research institutions are the National Renewable Energy Laboratory (NREL), University of Colorado at Boulder (CU), Colorado State University (CSU), and Colorado School of Mines (CSM).

Lasers Reveal Nature of Interface Surfaces, Processes

As PV materials become thinner and rely on complex material systems, a critical challenge is understanding how the interfaces between semiconductors work. While one CRSP team is using plasma to explore these interfaces (see page 1), another is using an advanced optical technique to unlock the secrets of interface physics.

Charles “Chaz” Teplin of NREL and Charles Rogers of CU are both physicists leading a research team that is using lasers to study how electrons and electron holes move from one material to another in semiconducting interfaces called heterojunctions.

When light is shined on a surface, a small portion is reflected at twice the original frequency. With the help of modern, pulsed lasers, it is possible to collect this “second harmonic generation” or SHG light. The intensity of the SHG light arises only as a result of the interface properties of the materials under illumination. Thus, SHG experiments can monitor interesting interface processes. This interface sensitivity is unusual; most PV measurement techniques sense mainly bulk properties and yield little information about interfaces.

During the course of the research, the team performed SHG experiments on silicon solar

cells and carefully verified that the SHG measurement was truly an interface signal. These results will be the basis of new experiments that will probe how interfaces change under illumination by sunlight, which, in turn, could lead to breakthroughs in efficiency and lower the costs of PV devices.

This interface research, like the plasma process research, has been funded through mid-2010. In the future, Teplin hopes to obtain funding to apply SHG techniques to organic solar cells, which are made of very inexpensive polymers and show promise to dramatically reduce the cost of photovoltaics. These devices are almost entirely controlled by interfaces that separate power-generating charges that are excited by sunlight. This separation frees the electrons to produce electricity, but the process is poorly understood and SHG experiments may provide crucial new insights that would be helpful to device engineers.

Teplin and Rogers work with Howard Branz, an NREL principal scientist. Long He, a CU graduate student, conducts the actual laboratory experiments. Matt Page, a scientist with NREL’s heterojunction research team, provides the samples for study. Together, the team hopes to develop a tool that is useful for every PV technology.

“The combination of fundamental and applied work really appeals to me,” says Teplin. “As a scientist, I want to understand how the devices work, but it’s wonderful to be working on something that will help new PV technologies make it to market.”

Postdoc Research a Critical Success Factor for CRSP

The three research profiles featured in this issue of CRSP Update have a common thread: each one benefits from research contributions by postdoctoral candidates. Postdocs are able to dedicate themselves to specific research assignments, making them an important part of scientific research in general and for CRSP in particular.

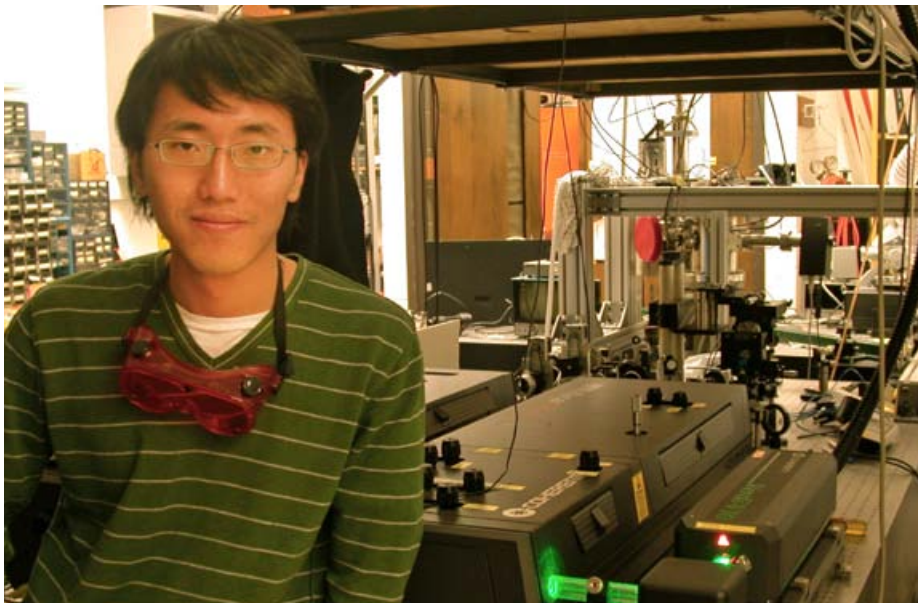
This makes for a two-way street of the best kind. The research laboratories benefit from a tailored, focused research effort, and the postdocs—who earn their coveted positions because they are the most talented among their peers—have an opportunity to work with the world’s leading scientists while advancing their own careers.

Postdocs have strengthened the linkages among CRSP research members. Ina Martin completed her degree at CSU, joining NREL as a postdoc working in thin crystalline-silicon solar cells. She has now moved on to Case Western as an associate professor and is setting up a renewable energy laboratory there. Andrew Herring was an NREL postdoc in electrochemical reduction of carbon dioxide before joining the faculty at CSM. Charles Teplin completed his degree with Chuck Rogers at CU and joined NREL as a postdoc looking at cladding layers for glass. Today, he is a senior scientist at NREL and collaborator in a 2009 CRSP project with Rogers.

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Long He, a graduate student at CU, uses lasers and measures their second harmonic generation light to study how electrons and electron holes move from one material to another in semiconducting interfaces called heterojunctions. Credit: Hsiangsheng Ku.

Harvesting Visible Light for Solar Hydrogen Production

Using hydrogen as a fuel confers a host of benefits. To reap those benefits, one must produce the hydrogen in a clean, renewable way, such as by using the sun's energy to "split" hydrogen from water, which is called photoelectrochemical (PEC) water splitting. That goal is behind this CRSP research project to develop, nanosize, and characterize certain materials—polyoxometallates or POMs.

PEC water splitting is a clean-energy conversion technology that holds much promise, but still has many fundamental barriers, such as stability and efficiency of conversion. These barriers must be addressed before the technology can be put to practical use.

POMs are a large class of inorganic transition metal oxide clusters with many unique properties. They can absorb light, enhance charge separation, and act as catalysts for a variety of reactions. This makes the POMs a good candidate for pairing with titania, the material commonly used as an electrode substrate for water-splitting devices. As an inorganic dye, POMs are inherently more stable than the organic dyes often used in these devices.

This CRSP project draws on the resources of CSM and NREL, and brings several disci-

plines to bear including theoretical modeling, computational analysis, and surface characterization. The principal investigators are John Turner of NREL and Andrew Herring, Mark Lusk, and Thomas Furtak of CSM.

A key member of the research team is S. Kishore Pilli, a postdoc at CSM, who may have had the toughest assignment. "His job was to figure out if the POM absorbs visible light, and if not, work within the design space to make it absorb light," says Andrew Herring.

Part of the challenge was a POM with a silicon atom in the middle of the cluster under study that did not absorb visible light. As a postdoc, Pilli brings a lot of experience with different materials to this work. His eventual achievement was to make the POM cluster heavier by substituting a zinc atom for the silicon, which shifted the activity into the visible so that now it does absorb light.

Mark Furtak subsequently modeled the structure computationally and demonstrated the exact bonding of this "restructured" POM to titania. The CRSP project team has proven how the POM interacts with the titania, both spectroscopically and theoretically, and underscored the importance of optimizing the pH of the POM. More work needs to be done to make the device and ultimately split water, but the project team anticipates that a very robust solar cell could come from this investigation.

"This is a very successful postdoc project," says Herring. "A joint CSM/NREL patent is in the works and five or six research articles will result."

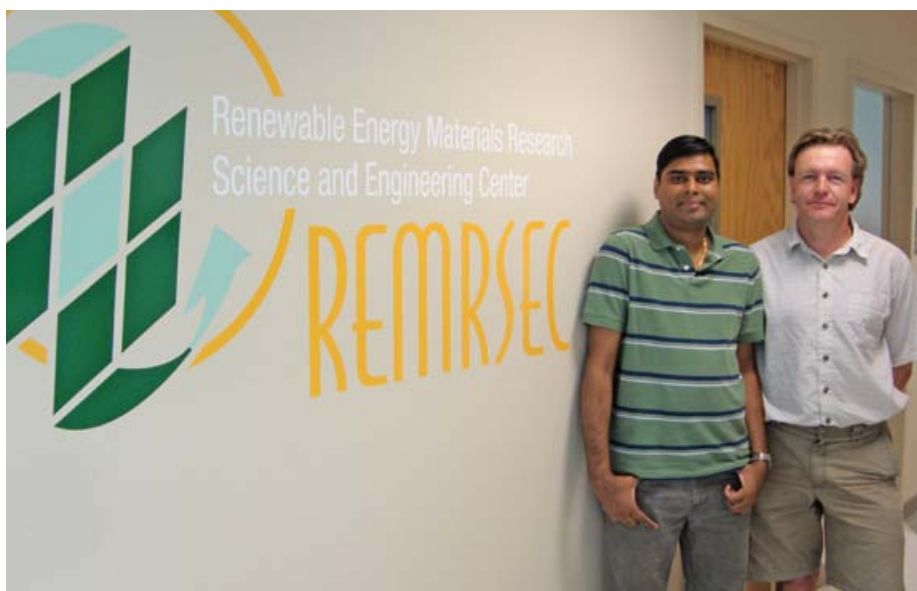
CRSP News & Events

New CRSP Leadership Team—Early in 2010, CRSP welcomed some new members to its leadership team. Craig Taylor of CSM replaced Arthur Nozik of NREL as the CRSP scientific director. John Benner and Kaitlyn VanSant, both of NREL, came onboard as CRSP managing director and associate managing director, respectively, replacing Paul Nelson. Colin Wolden was named a CRSP co-director, representing CSM.

Konarka and CSU Join Forces—A CRSP Sponsored Research Program project pairs Konarka Technologies and CSU in a quest to advance carbon fullerene nanostructures. The project evolved from related work originally funded by CRSP in its inaugural Shared Research Program round of funding in 2009. Konarka develops and manufactures solar plastic films that convert light to energy.

Congratulations to Ascent—A CRSP founding member, Ascent Solar Technologies, won an R&D 100 Award this year. The award is for Ascent's lightweight and flexible CIGS thin-film modules using a plastic substrate for automotive, portable-power, and rooftop applications.

CRSP Annual Meeting—September 13 and 14, 2010, are the dates, and the CSU campus in Fort Collins, Colorado, is the place for the CRSP Annual Meeting. Plans call for presentations by 2009 awardees, an annual dinner, committee reviews of the 20 proposals received for 2010 shared research projects, and other topics to be named later.



S. Kishore Pilli (left) and Andrew Herring of CSM are key contributors to the CRSP project to develop and nanosize a new material for use in a process to produce hydrogen from water using solar energy. Credit: Colorado School of Mines.

Motech Industries

Motech Industries has been in the PV industry for more than 10 years, entering into solar cell production in 1999. Motech is a pioneer in the manufacturing and marketing of high-quality, single- and multi-crystalline silicon solar cells.

Company leaders are dedicated to maintaining Motech's competitive edge with its products and services. For example, Motech has installed and qualified a back-end line for double-printing applications at its high-volume production facility in Tainan, Taiwan. This technology is likely to raise cell efficiency and further optimize solar cell configuration.

Motech is pursuing a vertical integration strategy to drive toward grid parity through operational efficiency, which includes an investment in AE Corp. and the acquisition of GE Energy's solar module assembly

operation in Newark, Delaware. Motech has a major stake in AE Corp. as a strategic partner to supply polysilicon feedstock. AE's fluidized-bed-reactor technology is expected to be more cost effective and to yield higher-purity polysilicon than traditional production technology. As part of the acquisition of GE Energy's module plant, Motech is entrusted to maintain GE's high standards for solar module manufacturing at the existing factory site and assume the responsibility of providing warranty services to GE's existing module clients.

Motech's expanding global business and vertical integration will grow its portfolio of innovation and revolution.

Motech Web site: www.motech.com.tw

Konarka Technologies

Konarka Technologies is a recognized leader in thin-film organic photovoltaic (OPV) technology, a third-generation solar technology that converts available light into affordable, accessible, and renewable energy. The company's flagship product is Konarka Power Plastic®, a lightweight, flexible printed PV plastic that requires less energy to manufacture than traditional solar panels, while being completely recyclable.

Power Plastic can be incorporated into a limitless array of applications—from microelectronics to portable power, and from remote power to building-integrated products. It is being integrated into products such as solar-powered sensors, mobile phone-charging messenger bags, backpacks and camping gear, carport covers that can "trickle charge" an electric vehicle, portable emergency communications systems, and office-powering windows that are embedded with transparent OPV panels.

Konarka redeployed a 250,000-sq² former flagship Polaroid plant in 2008 using experienced staff and existing equipment to make the manufacturing process extremely cost effective and cost efficient. With a one-gigawatt nameplate capacity and the largest manufacturing capability of any thin-film OPV company, Konarka can manufacture Power Plastic up to 60 inches wide in virtually any length.

Konarka is rapidly expanding worldwide markets and supply chains for Power Plastic with sales offices in Europe, Asia, the Middle East, and North America, and additional research facilities in Europe.

Konarka Web site: www.konarka.com



Konarka Technologies' flagship product, Power Plastic, is shown in production. Credit: David White.

CRSP Administration

Executive Board

Scientific Director: Dr. P. Craig Taylor, Renewable Energy Center, CSM.

Co-Directors: John Benner, NREL; Dr. C. Michael Elliot, CSU; Dr. David Jonas, CU; Dr. Colin Wolden, CSM.

Managing Director: John Benner, NREL.

Associate Managing Director: Kaitlyn VanSant, NREL

Advisory Panel

The panel includes one representative from each member company, who play a key role in identifying shared research thrust areas and selecting projects for funding.

Scientific Advisory Board

Dr. Thomas J. Meyer, University of North Carolina at Chapel Hill, chairs this board of external experts; the board's role is to evaluate and monitor the quality of the science performed by CRSP researchers.

CRSP Web site: www.ColoradoCollaboratory.org/crsp

