



The Conn Center for Renewable Energy Research

The Conn Center for Renewable Energy Research was established at the University of Louisville in 2009 with a legislative mandate to develop a renewable energy research center and generous pledge of support from Hank and Rebecca Conn. The Conn Center mission is to conduct and facilitate R&D on potentially commercializable renewable energy and energy efficiency technologies.

IN THIS ISSUE

Solar panel manufacturing R&D prototyping facility based on glass plates

Thad Druffel, Ph.D., P.E., Solar Manufacturing R&D Theme Leader

Co-op student spotlight: Sam Ellis

Conn Center technology helps AlphaJet make advanced renewable drop-in jet biofuel

UK and UofL researchers find new material for using sunlight to directly split water into hydrogen and oxygen

Delaina Amos, Ph.D., recruited to Chemical Engineering Department

Solar panel manufacturing R&D prototyping facility based on glass plates

The Conn Center has installed a glass plate manufacturing R&D facility for Dye-sensitized solar cell (DSC) technology, an important and potentially low-cost solar cell platform. DSC technology utilizes nanostructured materials involving earth abundant materials mixed with special dyes sandwiched between glass plates to convert light absorption into electric-

ity. DSCs are a relatively new technology that has received considerable interest from university researchers since 1990; in the past few years, DSCs have been translated to building-integratable photovoltaic (BIPV) demonstrations, but remain at prototype scale.

The Conn Center facility consists of a set of manufacturing processes for large area cell prototyping on 6" x 4" glass plates that can be incorporated into a solar panel. Thad Druffel, PhD, PE, Solar Manufactur-

ing R&D Theme Leader at the Conn Center, explains. "This collaborative facility is rare in the US. We apply scientific research innovations to scalable manufacturing platforms, which forces us to consider functionality along with production costs and product quality. We work toward feasibility for commercial applications."

Work at this facility includes research of the dye, paste, scale-up through durability, and translation of these solutions to large area cell manufacturing. The challenges faced to commercialize the DSCs include maintaining efficiency during scale-up and long-term durability of the panels, which this facility is uniquely designed to address.



Glass plate solar cells from the Solar Manufacturing R&D laboratory

A goal of the facility is to produce a consistent, durable DSC module with efficiencies in excess of 10% in the next 5 years. The installed processing equipment at the Conn Center allows researchers to utilize and experiment with all the manufacturing processes for DSC production including aerial deposition, sintering, sealing, electrolyte filling, and glass preparation. Researchers using the facility can produce a glass plate DSC from start to finish quickly.

"These DSCs cost significantly less to produce and at these efficiencies are superior to current technology."

Several of these cells are pictured on page one, including a high voltage cell (upper right) and several designer BIPVs, which incorporate graphic arrangements into the DSC.

Dr. Druffel enables the scale-up of basic and revolutionary innovations alike. For instance, a DOE-EPSCoR funded faculty cluster (ten faculty members at UofL and UK) led by Mahendra Sunkara, PhD, Interim Director of Conn Center, is researching the creation of a novel solar paint involving new nanostructured materials and redox couples toward improving cell efficiency and durability, particularly for BIPVs. The Center's new large-scale prototyping facility for glass plate cell manufacturing R&D will accelerate translation of any potential transformative

discoveries into pre-commercial production readiness.

DSCs are ideally suited for BIPV because they can be incorporated into window constructions, structural components, and interior features. Recent developments have yielded lab scale DSC devices that exceed 13.2% efficiency, which would make this technology competitive with current commercial offerings. Most current solar cells are available for more than \$1/watt; these DSCs cost significantly less to produce and at these efficiencies are superior to current technology.

Marc Thomas, chief executive officer of Dyesol Inc., the regional subsidiary of Dyesol LTD (DYE:ASX) and general manager of the company's global glass effort comments, "The BIPV marketplace represents one of the largest opportunities for DSC technology. Commercial and residential buildings consume a significant amount of electricity, which can be offset by the usage of PV-enabled glass and metal-based building products, rather than standard building materials. Much of the cost of the base material, glass or metal, and installation is already accounted for in the construction cost of the building, and the remaining cost is for the active PV components, thus lowering the levelized cost of energy (LOCE)." He adds, "We are pleased to be associated with ongoing research at the University of Louisville. Dr. Druffel brings an excellent blend of commer-

cial and research orientated focus to this institution."

The Conn Center collaborates with industry and universities to research new materials and designs for renewable energy commercialization.

Thad Druffel, PhD, PE, Solar Manufacturing R&D Theme Leader

Dr. Thad Druffel is a Research Engineer at the Conn Center and Solar Manufacturing R&D Theme Leader. He is focused on scalable manufacturing of photovoltaics and other renewable energy production and storage solutions. Thad's primary research is to investigate utilization of nanocomposites on wide area flexible substrates with intended applications in solar energy via roll-to-roll deposition techniques. He has 20 publications and patent applications related to this research in photonic applications of thin film nanocomposites.

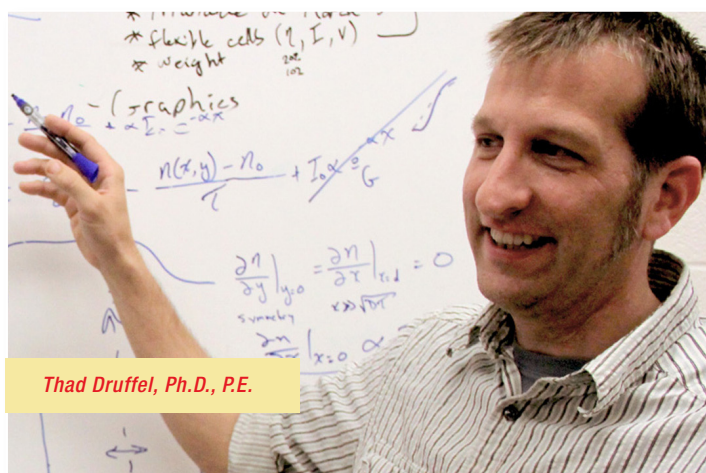
Thad has commercialized numerous products and was the architect of the nanoCLEAR product, which was awarded a TechBriefs Nano50 Award in 2006. He is experienced

as the principal investigator in grants from the National Science Foundation, Department of Energy, and the State of Kentucky as well as industry sponsored research, with total funding over \$1M. His background includes research and development topics in both Mechanical and Chemical Engineering and he has been involved in projects ranging from solar and water facilities in Africa to corporate research and development of cutting edge technologies.

The Conn Center collaborates with industry and universities to research new materials and designs. We invite and encourage research groups throughout the region to utilize the Solar Manufacturing R&D Laboratory. Dr. Druffel can be reached at 502/852-2265 or at thad.druffel@ouisville.edu.

Co-op student spotlight: Sam Ellis

Sam Ellis is a Mechanical Engineering junior from Louisville KY. He is a co-op student in the Conn Center Solar Manufacturing R&D Laboratory with Dr. Thad Druffel. Sam is focused on



Thad Druffel, Ph.D., P.E.

developing glass plate solar cell prototyping processes for Dye Sensitized Solar Cells (DSCs). This includes learning industrial screen printing techniques, working out automation issues, solving electrolyte seal issues, and creating a nice flow to the manufacturing process. Sam explains, "The hands on work I do here is way more fun than number crunching. I am able to design, test, and build solar cells every week."



Sam explains how this co-op experience has had a positive effect on his education. "It's schoolwork, but I'm learning by working through all the issues of process design and implementation with a great mentor and excellent fellow researchers from all over the world." As a high school student, Sam's dream job was to work in a national lab conducting some kind of solar energy research, but it seemed like a distant goal. Now, in just over two years since starting at UofL, he is working in the Conn Center labs in a field of great interest to him creating solutions to real world challenges. Sam also put this knowledge to work during the 2011 MRW

Solar Flight Competition. "I would recommend a co-op at the Conn Center to those interested in renewable energy, or those who want to work with really intelligent people on important issues. There are a lot of options here," he notes. "I have gained great experience working in a research lab, which introduced me to new technologies and helped me develop numerous problem solving skills that I might not have learned in the classroom." Sam still hopes to work in a national lab or in research and development for a company at the conclusion of his studies at UofL, but feels better prepared to be successful after his Conn Center research co-op experience.

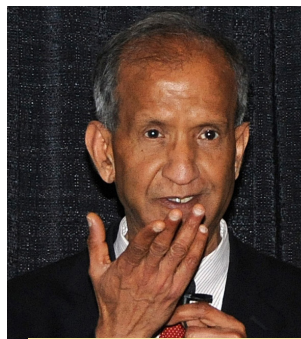
Conn Center technology helps AlphaJet make advanced renewable drop-in jet biofuel

A method developed at the Conn Center has enabled San Francisco-based AlphaJet Inc. to license a way to make jet biofuel economically from renewable products such as plant oils and animal fat. Paul Ratnasamy, PhD, a former senior research scientist at UofL who now serves as the company's chief science officer, patented the process in 2010. AlphaJet recently announced it had successfully demonstrated its method of using a catalyst to remove oxygen from feedstocks; this method could cut costs because it doesn't rely on large amounts of hydrogen from fossil-fuel refineries to do the

job, freeing companies from the need to locate production facilities near refineries.

"Development of this technology and its licensing to AlphaJet advance University of Louisville goals to discover solutions to societal problems and to translate these into commercial practice," said Thomas Starr, PhD, Associate Dean for Research at UofL's J.B. Speed School of Engineering, where the Conn Center is based.

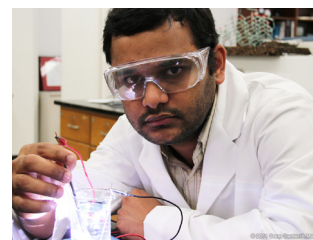
AlphaJet, a collaborative venture between SynGest Inc. and Unitel Technologies Inc., announced it will collaborate with Honeywell to accelerate commercialization of renewable "drop-in" biofuels. Demand for "drop-in" fuels is high because using them would not require extensive and expensive retooling of existing engines or changes to fuel delivery or storage methods. Biofuel sources could include algae, seeds, vegetables and fats from animal-processing plants. A 2009 grant from the Kentucky Renewable Energy Consortium helped fund initial research by Ratnasamy and Conn Center Director Mahendra Sunkara



Paul Ratnasamy, Ph.D.

for the biofuels process. The Kentucky Pollution Prevention Center, also based at UofL's Speed School of Engineering, administers the consortium grant program.

For information on AlphaJet, contact CEO Jack Oswald at 415-986-8300 or joswald@alphajet.com.



UK and UofL researchers find new material for using sunlight to directly split water into hydrogen and oxygen

Hydrogen has been touted as the energy carrier of the future. However, current production methods use carbon based natural gas or expensive and energy intensive water electrolysis, which maintains the carbon footprint in the process. Solar water splitting is a clean, inexpensive and carbon free process for hydrogen generation which can be used to produce electricity using fuel cells. Photoelectrochemical (PEC) water splitting involves the generation of electron hole pairs by a semiconductor material upon illumination with sunlight. Electrons go to the counter electrode and holes to the semiconductor surface where they drive the complimentary water splitting reactions.

A water splitting reaction requires a potential of about 1.2 V (1.7 after accounting for the system losses). The solar spectrum has maximum energy in the 1.7-2.2 eV range. Hence, the semiconductor should have the band gap in this region to absorb maximum sunlight. Also, the bands of the semiconductor should straddle the hydrogen and oxygen reaction potentials for spontaneous splitting. Apart from these criteria, the material should be able to conduct the generated charge carriers fast enough to prevent them from recombining before they reach the electrodes and carry out the reactions.

"This is the first time that a simple & easy to produce alloy has been shown to be one of the best candidate materials for PEC water splitting."

To date none of the materials investigated satisfy all the criteria for water splitting. In most cases, either the band gap is not right or the bands are not straddling. Using state-of-the-art theoretical computations, Drs. Madhu Menon and R. Michael Sheetz at the Center for Computational Sciences at UK and Dr. Mahendra Sunkara and his former graduate student, Chandrashekhara Pendyala, PhD, at the Conn Center for Renewable Energy Research at UofL have demonstrated that an inexpensive alloy obtained by 2% substitution of antimony (Sb) in gallium

nitride (GaN) has all the right ingredients for enabling solar light energy to split water into hydrogen and oxygen.

Although pure GaN has a very large band gap and, therefore, is unsuitable for solar energy applications, the UK and UofL team found that an introduction of a very small amount of Sb results in drastic reduction in the band gap. What is even more intriguing is that the bands of this alloy exhibit perfect alignment, i.e., straddle the hydrogen and oxygen reaction potentials; a key requirement for spontaneous water splitting. To be precise, about 2% antimony in the GaSbN alloy would give a 2 eV direct band gap with both the valence and conduction bands straddling the water splitting reaction potentials.

This is the first time that a simple and easy to produce alloy has been shown to be one of the best candidate materials for PEC water splitting. Their work has appeared in a recent issue of Physical Review Journal (R. M. Sheetz et al., Phys. Rev. B84, 075304 (2011)). This work was funded by the US Department of Energy.

**Delaina Amos, PhD,
recruited to Chemical
Engineering Department**

The Conn Center welcomes Dr. Delaina A. Amos, Associate Professor in Chemical Engineering. Dr. Amos is an experienced research scientist

and leader with over ten years of accomplishments in the areas of inks, materials, formulation, materials incorporation, and product development at the Eastman Kodak Company. Her research focuses on the characterization of polymeric molecules and their interaction with polyelectrolytes and surfactants at interfaces and in solution. Specifically, she examines the role of surfactant structure, solubilize location, and molecular interactions in the formation of swollen micelles for environmental, biological, pharmaceutical, and other novel applications. Her current research interests involve novel uses of colloidal materials, quantum dots, polyelectrolytes, inkjet materials, and thin film deposition for renewable energy and display applications such as solid-state lighting, dye-sensitized solar cells, and color writable electronic displays. Her research at the Conn Center has implications for the Center's roll-to-roll manufacturing R&D on solar cells, particularly in the rapid deposition of photovoltaic-active layers.



Dr. Amos received her doctorate in Chemical Engineering in 1996 from the University of California-Berkeley, where she

researched the modeling and characterization of aqueous micellar surfactant solutions. She holds an MS in Chemical Engineering from UC-Berkeley (1992) and a BS in Chemical Engineering from the University of Virginia (1989). She served as a Senior Research Scientist and Research Associate at the Eastman Kodak Company in Rochester NY for thirteen years, during which time she specialized in the development of inks, dispersions, and other advanced materials for new product implementations. Delaina joined the UofL Speed School of Engineering in 2010. She enjoys problem solving, research, and taking on new challenges. One of her passions is mentoring and working with diverse students, particularly women.

UPCOMING FEATURES

Anaerobic digester R&D facilities and UofL's biogas project

Jagannadh Satyavolu, Ph.D., Biofuels/Biomass Conversion Theme Leader

NSF SOLAR grant funding

Conn Center roll-to-roll manufacturing facility

DOE-EPSCoR cluster grant funding

Jinjun Liu, Ph.D., Assistant Professor of Chemistry to utilize ultrafast transient absorption spectroscopy facility at Conn Center