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TRANSPORT

Department of Chemical & Biomolecular Engineering • Fall 2014

GRABOW WINS DOE EARLY CAREER AWARD AND ROBERTSON WINS NSF CAREER AWARD

(turn page for more on Robertson's CAREER Award) >>

PROFESSOR DISCOVERING

NEW CATALYSTS FOR BIO-OIL SYNTHESIS WITH DOE EARLY CAREER AWARD

Assistant professor **Lars Grabow** won a five-year, $750,000 Early Career Award from the U.S. Department of Energy (DOE) to investigate the use of catalysts – substances that speed up chemical reactions – to effectively remove oxygen from bio-oils in a process called hydrodeoxygenation.

According to Grabow, there's one big hurdle for bio-oil to overcome before it can become a realistic replacement for petroleum: its high oxygen content. Bio-oil is notoriously difficult to work with as a result of these high oxygen levels, which lower its energy content and make the oil extremely viscous, acidic and unstable. In order for bio-oil to be refined into a more stable form of fuel – such as the fuel you put into your car – researchers need to develop safe and efficient methods of removing oxygen from bio-oil. This is where Grabow steps in.

Hydrodeoxygenation of bio-oil involves the use of pressurized hydrogen to remove oxygen in the form of water. Grabow noted that the process of hydrodeoxygenation is very similar to the well-established catalytic process of hydrodesulfurization, which is used by petroleum refineries across the world to remove sulfur from natural gas and other refined petroleum products.

"What we propose is to look at both the chemistries of hydrodesulfurization and hydrodeoxygenization and find similarities at the atomic scale so we hopefully can translate existing knowledge from the hydrodesulfurization field and apply it to hydrodeoxygenation," explained Grabow. "This will speed up the discovery of catalysts for hydrodeoxygenation and enable widespread use of biomass as feedstock for fuel or chemicals."

By relating these two processes and translating lessons learned from hydrodesulfurization so they can be applied to hydrodeoxygenation, Grabow hopes they might bypass "a lot of time consuming trial and error testing" and effectively speed up the discovery process for the right catalytic converters for hydrodeoxygenation. Grabow's chunk of this research project focuses on using computational methods to simulate reactions that take place during the upgrade of bio-oil so his research team can make predictions on which materials might be good catalysts for this type of reaction.

The DOE has a strong interest in advancing this biomass conversion technology, setting the goal that biofuels should be replacing about 30 percent of all fossil-derived fuels by 2025, with biochemicals replacing about 25 percent of all petroleum-derived chemicals by 2025.

PROFESSOR DEVELOPING PLASTICS FROM PLANTS THROUGH NSF CAREER GRANT

Megan Robertson, assistant professor of chemical and biomolecular engineering, received a $500,000 grant from the National Science Foundation's CAREER Award program to develop plant-based plastics and rubbers. CAREER Awards are designed to help faculty in the early stages of their research launch long-term, successful labs. They are widely considered one of the most prestigious grants given to young investigators.

With the funds, Robertson will use vegetable oils like soybean oil, palm kernel oil and linseed oil to develop new polymers. Polymers are long, chain-like molecules made up of repeating units. They are the key component of rubbers and plastics encountered in everyday life.

Today, most polymers are made from petroleum. This can present some issues, said Robertson, such as fluctuations in pricing and undesired environmental impacts related to processing the petroleum oils. Another issue, and one that is possibly most serious in the long term, is the limited nature of fossil fuels.

"People have been innovating with polymers that are primarily derived from petroleum over the last 100 years. We've learned a lot during that time, but in the end, petroleum is a finite resource. Are we going to run out of petroleum today? No, but we need to start thinking about this now, because it could take a long time to develop the same diversity in materials from plant-derived polymers that we currently have in petroleum-derived polymers," said Robertson.

One of the challenges in developing good vegetable oil polymers is their chemical structure. Polymers that have desirable mechanical properties tend to contain individual molecules that are intertwined, similar to noodles in a bowl of spaghetti. This entanglement gives them many of their best characteristics, like high strength.

The polymers that Robertson is developing from vegetable oils, though, have long strands of carbon coming off the side of each repeat unit in the polymer chain. These strands limit how much the individual polymer chains intertwine with one another. As a result, these polymers from vegetable oils are typically weaker than their petroleum counterparts. Robertson, then, will explore ways to create vegetable oil polymers that are more fully entangled, and therefore have better mechanical properties. Ultimately, Robertson is aiming to create new materials that have properties that are even better than commercially available petroleum-derived materials.

PROFESSOR PUBLISHES DEFINITIVE EVIDENCE ON ZEOLITE GROWTH IN SCIENCE MAGAZINE

Zeolites play an important role in your day to day life. These crystalline materials are used as adsorbents and catalysts in a variety of chemical processes, spanning applications from gasoline production to additives for laundry detergent – not to mention thousands of other commercial and consumer products. But despite their importance, the way zeolites grow is surprisingly not well understood, and methods to synthesize zeolites have been largely ad hoc.

That is until now. **Jeff Rimer**, the Ernest J. and Barbara M. Henley Assistant Professor of chemical and biomolecular engineering, has published an article in Science Magazine that outlines an in situ method for visualizing the growth of zeolites through the use of instrumentation that permits measurements to be performed at realistic synthesis conditions.

Typically, a powerful imaging tool called Atomic Force Microscopy (AFM) has been used as an ex situ technique to visualize the topography of zeolites after they have grown, from which inferences can be made regarding the mechanism of growth. However, AFM is traditionally used at or near room temperature, and zeolites typically grow at temperatures ranging from 80 to 100 degrees Celsius. Moreover, researchers could only image zeolites for very short periods of time using AFM because of lateral drift, or the tendency for the area being imaged to gradually shift out of the frame.

To bypass these two obstacles, Rimer teamed up with a company called Asylum Research to design a liquid cell that would allow them to use AFM to image zeolite surface growth at much higher temperatures. They also worked together to create a new software suite that accounts for lateral drift while using AFM to continuously image the surface of zeolite crystals. This so-called “drift correlation” software automatically accounts for lateral drift by shifting the view so the same surface area is being imaged every time, allowing researchers to scan zeolite surfaces for up to 48 hours.

Together, these two advancements in AFM technology from Rimer’s group will allow researchers to study zeolite growth in situ and to elucidate the pathways of crystallization for the first time ever.
Using the novel liquid cell and AFM imaging software, Rimer was able to conclusively answer what he calls a “25-year-old-question” about how zeolites form in his article. Researchers have been scratching their heads for over two decades over the role of tiny silica nanoparticles which are present during the entire process of zeolite growth. Until now, researchers have wondered exactly what role, if any, these silica particles play in the growth of zeolites. Rimer’s group tracked the deposition of silica particles on the surface of the crystal, revealing a highly dynamic process in which silica nanoparticles attach to the surface and rearrange themselves into the underlying crystal.

However, Rimer said that there is still much to be revealed about these particles. “We don’t quite understand their structure or how they evolve over time,” he said. But one thing is for sure: using the novel AFM instrumentation from Rimer’s group, researchers will now be able to study zeolite growth and the role silica nanoparticle precursors play in this process with a level of detail never before possible.

PROFESSOR MAKES DEVICE FABRICATION EASIER, THANKS TO NSF GRANT

Ernest J. and Barbara M. Henley Assistant Professor **Gila Stein** won a $279,411, three-year grant from the National Science Foundation to build models that can explain the complex physical and chemical reactions that take place in lithography systems used for device fabrication.

The semiconductor industry relies on the lithography process to produce nearly all electronic device components – yet, very little is understood about the physics and chemistry underlying the complex chemical reactions required for semiconductor patterning.

Stein wants to change this by researching materials called chemically amplified resists, which are systems wherein a polymer is blended with a catalyst and then a chemical reaction is used to form the patterns for semiconductor devices. Her collaborator on this project is Manolis Doxastakis, a materials scientist and simulations expert at Argonne National Laboratory.

“These are the materials that are used to pattern semiconductor devices, like the chips in your computer. As computers become faster and faster, it’s because you’re shrinking the size of all the little devices that go into those integrated circuits, like the microprocessors and memory chips,” Stein said. “So, if you want to be able to pattern things that are very, very small, you need to have really good control over the reactions that create those patterns.”

The bulk of Stein’s research will involve performing very simple experiments with chemically amplified resists, interpreting the results of those experiments, and then building models to predict how those same materials will perform under much more complex circumstances – such as at the industrial scale. Having such a model in place would be a homerun for the semiconductor industry, as the time needed to evaluate materials and optimize their processing would be vastly reduced.

If all goes perfectly to plan, Stein said this model could be implemented into semiconductor manufacturing processes immediately, taking out much of the guess work with semiconductor patterning at the nanoscale.

DIAGNOSING DISEASES WITH SMARTPHONES

Smartphones are capable of giving us directions when we're lost, sending photos and videos to our friends in mere seconds, and even helping us find the best burger joint in a three-mile radius. But thanks to UH Cullen College of Engineering researchers, smartphones may soon be boasting another very important function: diagnosing diseases in real time.

The researchers are developing a disease diagnostic system that offers results that could be read using only a smartphone and a $20 lens attachment.

The system is the brainchild of **Jiming Bao**, assistant professor of electrical and computer engineering, and **Richard Willson**, Huffington-Woestemeyer Professor of chemical and biomolecular engineering. It was created through grants from the National Institutes of Health and The Welch Foundation, and was recently featured in ACS Photonics.

This new device, like essentially all diagnostic tools, relies on specific chemical interactions that form between something that causes a disease – a virus or bacteria, for example – and a molecule that bonds with that one thing only, like a disease-fighting antibody. The trick is finding a way to detect these chemical interactions quickly, cheaply and easily. The solution proposed by these professors involves a simple glass slide and a thin film of gold with thousands of holes poked in it.

◀ *Richard Willson*

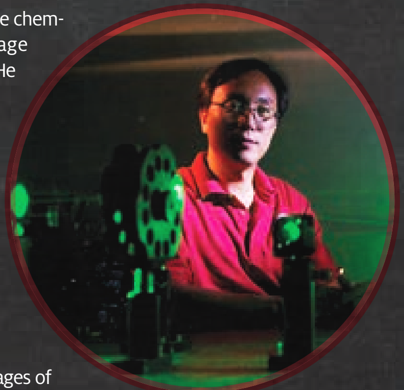
This task starts with Bao, who takes a standard glass slide that is covered in a light-sensitive material known as a photoresist. He uses lasers to create a fishnet pattern on the photoresist, which is then developed and washed away. The spots surrounded by intersecting laser lines – the 'holes' in the fishnet – remain covered, basically forming pillars of photoresist.

Next, he exposes the slide to evaporated gold, which attaches to the photoresist and the surrounding clean glass surface. Bao then performs a procedure called lift-off, which essentially washes away the photoresist pillars and the gold film attached to them.

The end result is a glass slide covered by a film of gold with ordered rows and columns of transparent holes where light can pass through.

Willson and Bao's device diagnoses an illness by blocking light with a disease-antibody bond – plus a few additional ingredients.

Willson tackles this part of the project by attaching disease antibodies to the holes' surface, then flowing a biological sample over the slide. If the sample contains the bacteria or virus being sought out, it will bond with the antibody in the holes. This alone, though, isn't big enough to block the light. Willson then flows a second round of antibodies that bond with the bacteria over the slide. Attached to these antibodies are enzymes that produce silver particles when exposed to certain chemicals. With this second set of antibodies now attached to any bacteria that are in the holes, Willson exposes the entire system to the chemicals that encourage silver production. He then rinses off the slide. Thanks to chemical properties of the gold, the silver particles in the holes will remain in place, completely blocking light from getting through.



▲ *Jiming Bao*

One of the advantages of this system is that its results can be read with very simple tools. A basic microscope used in elementary school classrooms, Willson said, provides enough light and enough magnification to show whether holes are blocked. With a few small tweaks, a similar reading could almost certainly be made with a phone's camera, flash and an attachable lens.

This technique, then, promises an affordable system with readouts that are easy to interpret. "Some of the more advanced diagnostic systems need $200,000 worth of instrumentation to read the results," said Willson. "With this, you can add $20 to a phone you already have and you're done."

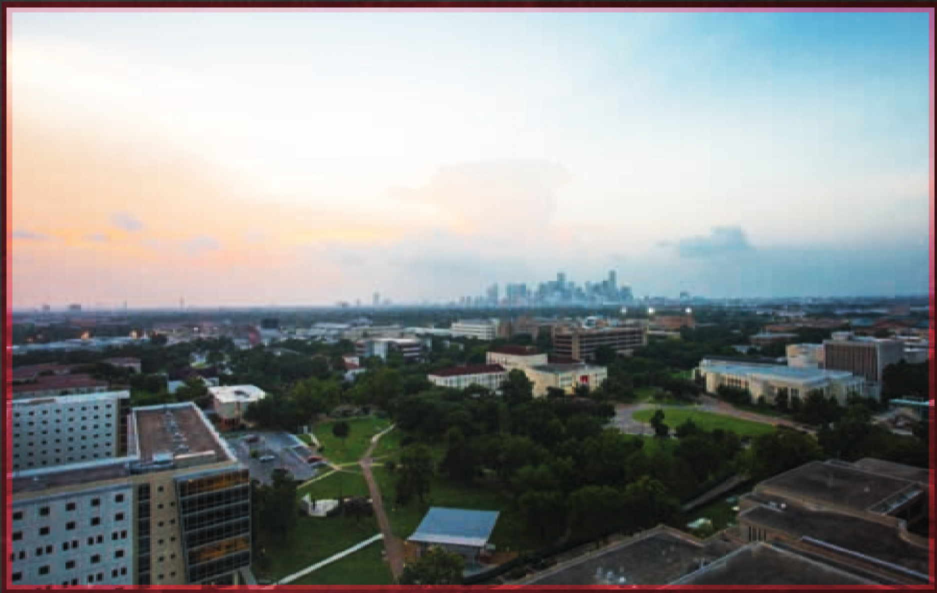
GROUNDBREAKING CEREMONY FOR NEW ENGINEERING BUILDING TO BE HELD IN OCTOBER

As the University of Houston expands each year, so does the Cullen College of Engineering; the college itself expects to double over the next 10 years, welcoming more than 4,000 new students and 50 new faculty members by 2025. To accommodate this explosive growth, UH is constructing a new Multidisciplinary Research and Engineering Building (MREB), which will stand between the engineering complex and Calhoun Lofts in the footprint of the now-demolished "Y" building.

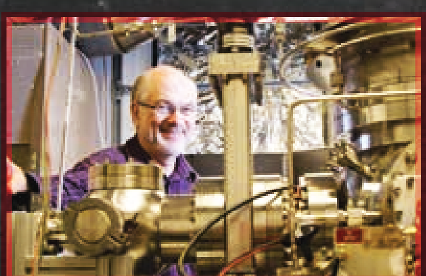
The Cullen College is thrilled to announce that the fundraising goal of $10 million for this new building has officially been met. In honor of this exciting achievement and the upcoming construction of the MREB, the Cullen College will host a groundbreaking ceremony on Monday, October 6 at 10 a.m. Alumni, donors, friends, faculty, staff and students are welcome to attend and celebrate this milestone for both the college and the university.

The MREB is expected to help generate approximately $36 million in research funding annually for the Cullen College of Engineering and to promote an approximate $612 million increase in annual economic activity in Houston alone. It will also allow UH to add more than 250 talented graduate students and hire new National Academy of Engineering faculty.

Construction on the MREB will commence in November with scheduled completion in summer of 2016.



PLASMA ETCHING ARTICLE TOPS JOURNAL'S "MOST READ" LIST FOR MONTHS



A paper co-written by a University of Houston Cullen College of Engineering professor has stayed at or near the top of the Journal of Vacuum Science and Technology's "Most Read" list since last fall.

"Plasma Etching: Yesterday, Today, and Tomorrow," was authored by professor of chemical and biomolecular engineering **Vincent Donnelly**, along with Avinoam Kornblit, a consultant and former colleague of Donnelly's at Bell Labs. It appeared in JVST's 60th anniversary issue in September of last year.

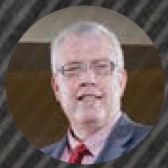
The piece provides an overview of plasma etching, a method of using chemical reactions to selectively remove very small amounts from the surface of a material in very precise patterns. It is an essential step in the creation of integrated circuits. "Every cell phone, every computer, uses integrated circuits that were built with plasma etching," Donnelly said.

One reason this paper has proven so popular, Donnelly said, is that no good overview of the field of plasma etching exists. In fact, when teaching students about plasma etching, he himself has been frustrated by the lack of such a resource. There is clearly a demand from many quarters for an overview of the topic. "I've gotten a lot of feedback from people in industry in particular who've said they really appreciated the article," Donnelly said.

▲ *Vincent Donnelly*

FACULTY ACCOLADES

Michael Harold was elected as fellow of the American Institute of Chemical Engineers (AIChE).



Tom Holley won the Society of Petroleum Engineers (SPE) Gulf Coast Regional Distinguished Achievement Award for Petroleum Engineering Faculty.

Jeff Rimer won a research excellence award in the assistant professor category from the University of Houston.

Ramanan Krishnamoorti won a research excellence award in the full professor category from the University of Houston.

CULLEN COLLEGE PLAYING KEY ROLE IN OFFSHORE ENERGY SAFETY INSTITUTE

No one disputes that offshore energy development carries environmental risks. Through its involvement in the new Ocean Energy Safety Institute (OESI), the UH Cullen College of Engineering will play a key role in ensuring the safety of offshore energy production for years to come.

The institute is a partnership of UH, Texas A&M University and the University of Texas at Austin. The three schools recently won a competitive five-year, $5 million grant from the Department of the Interior's Bureau of Safety and Environmental Enforcement to establish the institute. Its mission is vital: Serve as a platform for communications and research among government, academia and industry in the field of offshore energy.

"The institute itself is going to act as a liaison between industry, regulators and the creators of the best available technologies in terms of safety and feasibility," said Ramanan Krishnamoorti, professor of petroleum engineering and chemical and biomolecular engineering at the college and Chief Energy Officer for the University of Houston. "These technologies are going to come out of places like the Cullen College of Engineering. The college is a critical player in bringing cutting-edge academic research to subsea applications, where technology is rapidly evolving."

As home to the only subsea engineering program in the United States, the Cullen College is an established leader in offshore energy education, Krishnamoorti noted. Through this program, students learn about the design and maintenance of the equipment and infrastructure used in the underwater portion of offshore petroleum exploration and drilling. The program began offering a master's degree this fall and already has more than 48 M.S. students, on top of roughly 160 certificate students.

The college's involvement in the institute should help these technologies find their way to real-world use more quickly, Krishnamoorti said. By providing a platform for partnerships with industry, researchers will have easy access to input and guidance from companies in the offshore sector. Likewise, Cullen College faculty members will be able to present their work to industry members on a regular basis thanks to their involvement with the institute.

Such partnerships will help bring the college some well-deserved recognition for its contributions in the offshore sector, added Joseph W. Tedesco, Elizabeth D. Rockwell Dean and Professor of the Cullen College.

"Offshore resources are going to contribute significantly to energy production in the years to come. The Ocean Energy Safety Institute will play a key role in safely and efficiently developing these resources," he said. "I'm proud that our researchers are so prominently involved in this initiative and I look forward to seeing their advances adopted by companies in this sector."

STUDENT NEWS

SENIOR RESEARCHER, PH.D. STUDENT RECOGNIZED FOR SHALE RESEARCH

Dan Coleff, a senior researcher with the Cullen College's petroleum engineering program and Geology Ph.D. candidate at UH, has been recognized for his work to develop artificial mudrocks that match the properties of shale.

Coleff won the award for the best poster presentation at a recent meeting of the Society of Sedimentary Geology's Gulf Coast Section. His poster outlined research he is conducting with Michael Myers, a professor of petroleum engineering at UH.

One of the challenges to better understanding shale is that there just isn't much actual shale rock available for study. Most rock core samples are taken from traditional reservoirs, which don't offer much shale. Since taking a core sample is extremely expensive, few pure shale cores are available.

Coleff and Myers are working to create artificial mudrocks that match the properties of shale. In doing so, they hope to provide researchers in industry and academia with an easy and affordable shale alternative to use in their own experiments.

CHEM-E-CAR TEAM TAKES 2ND AT REGIONALS

The University of Houston Chem-E-Car Team is well on its way to creating a tradition of supremacy in the Cullen College of Engineering. Fresh off their third place win at last November's national Chem-E-Car competition, the team opened up the 2014 competition season with a bang, placing second at regionals in College Station. They will advance to the national competition this winter.

The Chem-E-Car competition is sponsored annually by the American Institute of Chemical Engineers. Teams must construct a car powered solely through chemical reactions that can haul a certain load several meters. However, the specific load and distance are not known until the competition day. At the regional competition, cars hauled 770 milliliters of water over a distance of 70 feet. The UH car's motor is powered by a battery cell and stopped by an iodine clock reaction.

CHEMICAL ENGINEERING STUDENTS AWARDED FOR POSTERS AT SOUTHWEST CATALYSIS SOCIETY SYMPOSIUM

Three chemical and biomolecular engineering Ph.D. students swept the Spring Symposium of the Southwest Catalysis Society's poster contest month on the UH campus. Matthew Oleksiak, Manjesh Kumar and Tayebeh Hamzehlouyan received top honors for their posters, "Controlling Crystal Polymorphism in Organice-Free Synthesis of Zeolites," "Tuning the Physicochemical Properties of Zeolite Catalysts Through Molecular Design," and "Experimental and Kinetic Study of SO_2 Oxidation on a Pt/γ-Al_2O_3 Catalyst," respectively.

The Southwest Catalysis Society is a branch of the North American Catalysis Society, a group focused on promoting and encouraging the growth and development of the science of catalysis. Oleksiak and Kumar both worked with chemical and biomolecular engineering professor Jeff Rimer as their advisor. Hamzehlouyan worked with faculty advisor Bill Epling.

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MEET CONNOR FERNANDEZ,

a chemical and biomolecular engineering student who won this year's Outstanding Junior award from the UH Cullen College of Engineering. Fernandez transferred to UH after completing his freshman year at Lone Star College. At the time, Fernandez said, he wasn't sure what the future held for his career: "I was good at math, I was good at science, so I stuck with it." It wasn't until Fernandez made the move to UH that he found the program best suited to his goals. "I always had an inkling to go to UH, but when I decided I wanted to be a chemical engineering student, I looked up the curriculum, and the curriculum is renowned around the country for being one of the best chemical engineering departments. That was my last major driving factor." This summer, Fernandez began a process engineering internship with Styrolution, the global leader in styrene monomer, polystyrene and styrenic specialties. He wants to explore the possibilities of getting his MBA after college, and sees himself going into process engineering as a career.

YOUR SUPPORT MATTERS TO STUDENTS LIKE CONNOR!

Gifts to the UH department of chemical and biomolecular engineering help fund much-needed scholarships for students, renovations to our labs and facilities, and the activities of our student organizations. Thank you for continually helping us meet these needs!

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