College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

SPRING 2023 NEWSLETTER

CHEMICAL AND BIOLOGICAL ENGINEERING

A STEP FORWARD

State-of-the-art instructional space, new faculty and cutting-edge research are enhancing our excellence

Greetings from Madison!

Our newsletter cover features CBE undergraduates Abby Larson and Ryan Peters participating in CBE 324: *Transport Phenomena Lab*. Based on Bird, Stewart, Lightfoot and Klingenberg's *Introductory Transport Phenomena*, students learn how transport theory can be directly applied to engineering experiments. In this photo, they are getting ready to run water through a pipe and valve section that they assembled themselves. The lab is currently occupying a smaller, temporary space on the fourth floor of Engineering Hall, as construction continues to progress in B103, our exciting new instructional lab space.

We are happy to report that the project is on schedule. We are concurrently constructing a state-of-the-art bioresearch lab on the third floor of Engineering Hall, and we are greeted by the sounds of construction on an almost-daily basis. We continue to look for partners that can help us outfit our labs so that we can uniquely prepare our students for their chemical engineering careers. Please see the additional information on this page to learn how you can partner with us on these landmark projects.

If you're interested in more information (and photos!) of our lab renovation, and to find out what's new in CBE, please watch the fall 2022 town hall recording on our YouTube channel (UW-Madison CBE). The recording also features the groundbreaking research of Assistant Professor Marcel Schreier and his group in electrocatalysis for energy storage and sustainable chemical synthesis.

We are excited to welcome our newest faculty members: Whitney Loo and Rose Cersonsky. Whitney's research focuses on polymers, soft materials, nanomaterials and sustainability. Rose brings to us her research expertise in molecular modeling and simulation, applied mathematics and machine learning.

In May, we will be graduating 80 chemical engineers. As is the case with all of our distinguished alumni, we'll eagerly follow the exciting career paths of these future engineers.

We are always interested in hearing about you and your many accomplishments since graduating. If you have news or stories you would like to share (potentially for inclusion in future newsletters), please email us at che@che.wisc.edu.

On, Wisconsin!

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Renovation update

If all goes well, our new instructional space, B103 Engineering Hall, will be ready for students in time for Summer Lab 2023 and our new bioresearch lab will be ready for a new generation of researchers. The renovations need more support, and opportunities to contribute to the projects are still available. Be part of CBE's next chapter!

Naming opportunities for equipment remain, starting at $50,000. Donors who contribute $1,000 will be recognized in a physical display in the renovated lab—but we appreciate contributions of any size. All donors will be recognized in a digital display in the newly renovated space.

To learn more or make a gift, contact:
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Cersonsky will use machine learning to understand colloids and nanoparticles, which could improve drug delivery and plastic sustainability.

FOCUS ON NEW FACULTY

Rose Cersonsky is taking machine learning to the nanoscale

Over the last decade, machine learning has revolutionized how we model materials at the atomic scale: With the help of powerful algorithms, researchers can quickly model new materials or simulate interactions that would have taken months or even years of work using previous techniques.

Even though machine learning approaches at the atomic level have matured over the past few decades, that isn't true at larger scales; the same caliber of tools and techniques is not available for larger materials building blocks, like colloids, or large molecules held in suspension. "Working at both the nanoscale and the atomistic scale has shown me the disparity between machine learning applications and methodologies between the two scales," says Rose Cersonsky, who started as an assistant professor in January 2023. "What my lab is going to focus on first and foremost is learning what we can apply from the atomistic community to accelerate our understanding and our abilities at the colloidal and nanoscale."

Cersonsky grew up in Connecticut and received a bachelor's degree in materials science and a minor in computer science from the University of Connecticut. She earned her PhD at the University of Michigan studying macromolecular science and engineering. There, Cersonsky earned renown for her work studying photonic structures—crystallographic patterns responsible for the beautiful colors in chameleons and many species of butterflies—that can be targeted with nanoparticle self-assembly.

After her PhD, she joined the Laboratory of Computational Science and Modeling at the École Polytechnique Fédérale de Lausanne, Switzerland, as a postdoctoral researcher, working on machine learning methods for atomistic simulations, for the next three years. During her postdoctoral work, Cersonsky developed and implemented multiple machine learning methodologies and applied them to further the understanding of molecular crystallization, an important process in applications including drug stabilization and biological processes.

In Madison, she hopes to bring all of her research interests together and investigate new directions. "Colloids and nanoparticles are not the same as atoms and often do not behave like atoms," she says. "We will pursue how can we apply a mathematically rigorous machine learning infrastructure to large particles in a way that helps us to understand them better and to design them better. My group will first focus on figuring out how we represent shapes and particle design in these models."

Cersonsky says her work, which is primarily computational, will illuminate the properties of many macromolecules, including polymers (extremely long, complex molecular chains that make up things like plastic) and biomolecules. She believes this work will complement research on plastic sustainability and nanoscale drug delivery systems by other faculty in CBE. "We are in a climate crisis and we really need to think about the ways in which we produce and use materials," she says.

Cersonsky is also excited about other types of collaboration. At Connecticut and Michigan, she led public outreach programs to foster inclusivity in science for grade school, high school and college students. She hopes to continue those efforts at UW-Madison, and also hopes to get back into her personal hobby: musical theater. "I love the intricacy and the cooperation of a music production. It just takes so many pieces," she says. "When you have an amazing set design and cast and music director and everything works together … it is almost transcendental."

Graduate student Beichen Liu (left) and postdoctoral scholar Wenxiao Guo (right) are key collaborators on Matthew Gebbie's (center) NSF CAREER Award project.

Gebbie's CAREER Award is a catalyst for electrochemical CO2 recycling

Carbon recycling, or using electrochemistry to power a carbon dioxide reduction reaction that turns carbon dioxide into carbon monoxide, could be an important tactic for combating climate change. Not only does the process use up excess carbon dioxide, it reduces the need for chemical precursors derived from fossil fuels.

While researchers have studied the carbon dioxide reduction reaction for several decades, it is still not feasible at an industrial scale. But Conway Assistant Professor Matthew Gebbie hopes that he can use a National Science Foundation CAREER award to fine-tune the electrolytes used in carbon dioxide reduction reactions to improve their speed and efficiency.

Electrochemical devices are composed of two electrodes—a cathode and an anode—separated by an electrolyte, or an ion-rich substance that's usually a liquid. At the surface of these electrodes, ions from the electrolyte tend to collect and self-assemble, creating a region called the electric double layer. While most prior research in electrocatalysis focused primarily on how the structures and properties of electrodes influence reactivity, recent research by Gebbie and others has shown that the structures and concentrations of ions in electrolytes can cause the electric double layer to grow thinner or thicker and switch from ordered to disordered. That has major impacts on reactivity.

In his CAREER Award project, Gebbie and his students will investigate how collective ion assembly at the electric double layer influences the carbon dioxide reduction reaction and the electrochemical properties of interfaces. In particular, Gebbie and his students want to figure out how to use electrolytes to tune the double layer environment to promote the carbon dioxide to carbon monoxide reaction and limit other competing reactions, like hydrogen evolution, which has been one of the major difficulties in optimizing electrochemical carbon dioxide recycling. "Bringing together emerging concepts and tools from colloid and interface science to evaluate our hypotheses and reveal new insights into nanostructured electric double layers could make a big impact in the field of catalysis that extends well beyond carbon dioxide electrochemistry," he says.

Gebbie also recently received an Army Research Office early career grant to research ionic liquid electrolytes for new battery chemistries.

New technique increases understanding of electrochemical interfaces

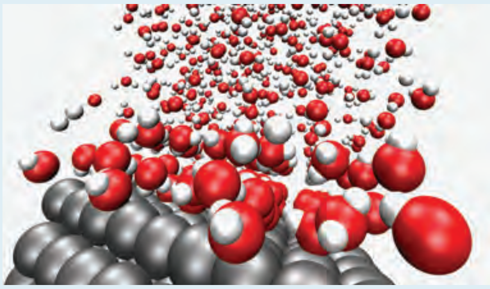
Manos Mavrikakis, the Ernest Micek Distinguished Chair, James A. Dumesic Professor and Vilas Distinguished Achievement Professor, and PhD student Alex von Rueden are part of a team that has pioneered a noninvasive way of measuring an important but difficult to determine variable in electrochemical interfaces.

In electrochemical devices, like fuel cells or electrolyzers, engineers often fine-tune electrode catalysts to boost their durability and reactivity. However, at the interface where the electrode and electrolyte meet, an electric field forms that can polarize the electrode surface and nearby molecules, impacting the devices' chemical reactions.

Applying a potential to the electrode can counteract this polarization, but determining that "potential of zero charge" is very difficult. Using a platinum electrode and water-based electrolyte interface as a model system, a team at Cornell University developed an optical method using laser pulses that determines the potential of zero charge without disturbing the system.

At UW-Madison, Mavrikakis and von Rueden then used theoretical modeling to better understand the finding and predict the potential of zero charge of the platinum-water interface and the interfacial water structure under different conditions. They identified one structure in particular to model, demonstrating how water molecules at the platinum surface rearrange as the electrode potential moves above and below the potential of zero charge.

Mavrikakis says the team's optical technique and modeling approach could be applied to many other electrodes, including different metals and metal oxides. In fact, the researchers' future work will target electrodes made of earth-abundant materials, which are less costly than platinum, for energy applications.



The UW-Madison team used theoretical modeling to predict the potential of zero charge in a platinum-water interface. White spheres represent hydrogen atoms, red represents oxygen and the grey spheres represent platinum. Submitted image.

Drying process could be key step in the development of life

Graduate student Hayley Boigenzahn has investigated how a drying environment may have enabled amino acids to bond together, forming the building blocks of early life.

One-hundred fifty years ago, Charles Darwin speculated that life likely originated in a warm little pond. There, chemical reactions and the odd lightning strike led to chains of amino acids that, over time, became more and more complex until the beginnings of life emerged.

Ever since, researchers have investigated this type of pre-life or "prebiotic" chemistry, trying to figure out the chemical pathways that led from a pool filled with simple amino acids to bacteria, redwood trees and people. In a recent paper in the journal *Origins of Life and Evolution of Biospheres*, PhD student Hayley Boigenzahn and Vilas Distinguished Achievement Professor John Yin explain how one of the potentially crucial early steps on the path of life could have happened.

"We know amino acids are the building blocks of proteins and proteins are essential for life," says Yin. "In prebiotic chemistry, it's long been a question of how we could get these things to form bonds and strings in a manner that might eventually lead to a living cell. The question is hard because the particular chemistry involved is one that tends to fail in the presence of water."

In her experiment, Boigenzahn investigated whether it's possible these amino acids could have come together during periods of environmental change—for instance, as a pool of water evaporated. In the presence of a chemical activator, these amino acids could bond together into peptides, or short chains of amino acids.

To study how amino acids might form bonds during the drying process, Boigenzahn created solutions of the amino acid glycine and trimetaphosphate, an activator that is naturally created during volcanic processes. Using a heater to evaporate the solution, Boigenzahn watched what happened to the amino acids over 24 hours.

What she found was a two-stage process. In the first stage, when the pH of the solution was alkaline, the glycine combined into two-molecule units called dimers, which also produced protons, making the pH of the solution neutral. In the second stage, as evaporation took place, the dimers began to bond together to form longer peptide chains, called oligoglycine. It's easy to imagine a scenario in which amino acids in a volcanically warmed hot spring containing an activator first combine into dimers then form into longer chains of amino acids as the chemistry changes, over time forming enzymes and the beginnings of metabolism.

So why are chemical engineers studying the origins of life? Yin says understanding the chemistry could lead to DNA-based information storage and other novel technologies.

Schreier wins prestigious Packard Fellowship

Richard H. Soit Assistant Professor Marcel Schreier was one of 20 early-career scientists from across the United States selected as a 2022 Packard Fellow for Science and Engineering.

Each fellow receives a grant of $875,000 over five years; Schreier's lab focuses on electrocatalysis, developing methods to use electricity to drive transformations in chemicals. Schreier is interested in developing ways of using electricity, which can be sourced from renewable resources like wind and solar, to power chemical conversions sustainably to achieve a circular economy with net-zero-carbon emissions. In particular, he and his students study electrochemical interfaces at the molecular level to better understand how electric fields can drive these transformations.

Schreier is UW-Madison's 18th Packard Fellowship winner. He also recently received funding from the Scialog: Negative Emission Science initiative, for a multi-institution team project to capture the greenhouse gas methane.

Marcel Schreier and his students, including Alex Zielinski (right), are developing ways to use clean energy to create chemicals and store electricity.

AIChE introduces students to the wide world of chemical engineering

AIChE student chapter members recently gathered for an industry night to hear about the role of chemical engineers at NorthStar Medical Radioisotopes based in Beloit, Wisconsin.

During his first semester on campus, Alex Bloemendal went to an industry presentation hosted by the student chapter of AIChE, the professional organization for chemical engineers. While the Saint Paul, Minnesota, native knew he was interested in chemical engineering, he wasn't aware of just how wide-ranging the discipline was. In fact, he was blown away by the presenter, Cargill. "They talked about their agricultural roots and how they love farmers," says Bloemendal. "I was like, 'Wow.' I didn't know chemical engineers worked in the food realm—and I knew I wanted to be there."

The next year at a career fair, he approached Cargill, eventually doing an eight-month co-op. Now, the senior is close to starting a full-time position with the company. That's exactly the type of relationship the UW-Madison AIChE chapter, celebrating its 100th anniversary this year, hopes to foster. It's also one reason Bloemendal decided to give back to the organization by becoming co-president.

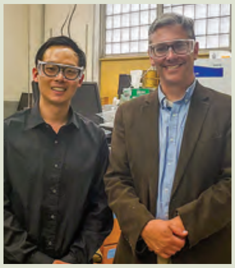
The UW-Madison chapter of AIChE hopes to offer some guidance to students about their future careers, as well as camaraderie. The organization's flagship events are its industry nights. About half a dozen times per semester, the students bring in industry representatives to talk about their companies and the types of opportunities they provide for chemical engineers. Over the last few years, that has included major firms like Georgia Pacific, Amcor, Genentech, PepsiCo, Honeywell, Marathon, Johnson Controls, Cargill and others.

Sophomore Adam Malmstrom, AIChE's other co-president, says that the organization also offers professional development events, like resume writing and job interview clinics, as well as social events, which have included pumpkin carving and bowling. The organization is participating in AIChE's Chem-E-Car competition, in which teams build a model car powered by a chemical energy source.

Recently, the organization also sharpened its focus on diversity. Last fall, the UW-Madison student chapter won the 90-Day Equity Challenge sponsored by parent organization AIChE. The group's winning initiative included organizing a weekly student study session, which ultimately included a higher percentage of women than other events, and even led to a new board member.

Bloemendal says the student org plans to continue that effort. "I want to make sure our commitment to equity continues, and it starts with our board," he says. "Our board represents people of different backgrounds, genders and beliefs. So we're very cognizant of encouraging people to run for positions on the board that they may not have thought of before."

Co-presidents Alex Bloemendal (left) and Adam Malmstrom (right) are recruiting a more diverse, engaged membership base to the UW-Madison student chapter of AIChE.



The review paper is a way to get new students and researchers ready to tackle the plastic recycling problem.

"Recyclopedia" will bring researchers up to speed on plastic waste recycling

A paper in the journal *Green Chemistry* led by postdoctoral researcher Houqian Li and Richard L. Antoine Professor George Huber is a veritable "recyclopedia" that will provide researchers a valuable resource as they develop new techniques and strategies for recycling plastic waste.

More than 100 pages long, the paper details the current state of the plastics recycling industry and includes primers on mechanical and chemical recycling techniques and other emerging technologies. It also includes discussions of landfills, emerging methods for sorting plastic waste, the chemical supply chain for plastics, economic analysis of the industry and many other aspects of the recycling process.

In recent years, efforts to decarbonize the economy have highlighted the problem with waste plastics. Only about 10% of the 380 million tons of plastics produced each year is recycled globally, with 8% of those downcycled into less valuable materials. Only 2% of plastic is recycled into "virgin" feedstock, which is used for closed-loop recycling.

That has driven strong interest in improving recycling techniques and developing new methods for transforming waste plastic back into useable, high-quality products. "There's a whole complex science that goes into making any type of plastic material you look at," says Huber. "It's designed to get the consumer to buy the product, not to optimize recycling."

The review paper lays out the issues in plastics recycling and discusses emerging technologies for recycling. Among them are chemical recycling techniques under study at UW-Madison, including STRAP (solvent-targeted recovery and precipitation) a way to catalytically separate multilayer plastics, and pyrolysis, a technique in which heat is used to break waste plastic down into an oil.

Department News

Professor Emeritus James Dumesic was one of 16 UW-Madison researchers on the Clarivate *Web of Science* Highly Cited Researchers list for 2022. The list honors authors ranked in the top 1% of cited papers.

Two CBE alumni were elected to the National Academy of Engineering's 2023 class of members. Leo H. Chiang (BSChE '97), a researcher at Dow, was cited for contributions to process data analytics and its applications to process monitoring and for continuous improvement in the chemical industry. James Rekoske (BSChE '88; MSChE '91) currently at Ecolab, was cited for leadership in development and implementation of petrochemicals, renewable fuel, alternative energy and water conservation technologies.

Vilas Distinguished Achievement Professor John Yin is part of a $3 million, five-year National Institutes of Health multi-institution grant to build a "digital twin" of the urinary tract to enable new research into health issues of the urinary tract.

Joshua Dietrich, PhD student working with Karen and William Monfre Professor Brian Pfleger, was one of five winners of the flash talk session at the Energy Research Showcase hosted by the Wisconsin Energy Institute.

Getting cheesy in CBE

During their experiment, Karjala and Chen learned multiple factors can affect the yield and texture of cheese.

In the 2022 Summer Lab, partners Margaret Shen and Katie Karjala worked on a cheesemaking experiment in which they tested different kinds of milk and coagulates to determine which combination would give the highest yield. In addition, they tested cheese textures to determine how fat content and aging affect texture.

According to Shen, their results showed they could help cheese manufacturers everywhere to find a more efficiently processed cheese, using the coagulant that results in the highest yield. Additionally, cheese manufacturers could use the texture analysis information to manipulate the softness or hardness of the cheese depending on consumer preferences. "The final results demonstrated that higher-fat-content milks result in softer cheese and that longer aging results in harder cheese," says Shen, who graduated with her bachelor's degree in summer 2022.

Karjala's favorite part of the project included the ultrafiltration experiment, where the two passed milk through a filter to remove water and increase the protein concentration of the product. The December 2022 graduate is pursuing opportunities in the food industry.

CBE grads receive College of Engineering alumni awards

In the fall of 2022, the College of Engineering honored its outstanding alumni. We asked CBE's recipients about their time at UW-Madison.

David Hemker (MSChE '85) received a Distinguished Achievement Award. He served as senior vice president and chief technology officer of Lam Research Corporation, a supplier of fabrication equipment and services to the semiconductor industry.

How did you choose chemical engineering? I was intending to be a chemistry major. At registration, there was a catalog that listed every possible major. I turned to the page for chemistry but on the facing page it listed chemical engineering, and that sounded interesting. I asked my dad what the difference was; he said a chemist typically works in a lab and a chemical engineer solves problems on a scale that people care about. In hindsight, I realize that my electrical engineering father had subtly pushed me toward engineering.

Of what accomplishments are you most proud? Every advanced semiconductor chip that is made today (at least part of it), I had a little bit to do with its fabrication. I think I have more than 100 worldwide patents, and really, the part that made it fun was assembling the team; to have a lot of smart, talented people who are driven to the same goal is satisfying.

Kevin Yttre (BSChE '03) received an Early Career Achievement Award. Yttre is president of Milwaukee-based Grace Matthews, a firm specializing in mergers and acquisitions in the chemical and materials science industry.

How did your experience at UW-Madison influence your career path? The problem-solving skills that were instilled in us in the chemical engineering program were phenomenal. I use those skills every day of my life. I still spend 100% of my time focused on the chemical industry, but my expertise has shifted to be more financial-service-oriented rather than more technical.

What was your favorite class? Summer Lab. During that course, it truly feels like you're working from seven in the morning till midnight for five straight weeks. At the time, it was very challenging, but you just needed to find a way to get through it. After completing the course, students leave with a confidence that they can manage through anything. I think it's a great way to wrap up the undergrad program. If there's a class I would take again, it would be that one.

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Graduate student helps develop Africa's first COVID-19 vaccine

Liz Appelt, a fourth-year PhD candidate advised by Howard Curler Distinguished Professor and R. Byron Bird Department Chair Eric Shusta, had long wanted to tie together her interests in global health and engineering. That's why she sought an internship at Afrigen Biologics and Vaccines—the first vaccine and biologics biotechnology company on the African continent. It was part of a technology transfer hub developing Africa's first COVID-19 mRNA vaccine.

After a year of travel restrictions, Appelt made it to South Africa in summer 2022 and found herself quickly immersed in Afrigen's COVID-19 vaccine projects. Due to delays, Afrigen's approximately 40 employees had only a few months to get their vaccine ready for animal and clinical trials.

The small team worked quickly and in parallel to develop manufacturing capacity and perform R&D on the vaccine itself. Their location made things even more difficult; much-needed, highly specialized instruments, and sometimes commonly used items, would take months to arrive, while others would arrive broken after traveling thousands of miles. "South Africa has really incredible scientists and biomedical engineers," Appelt says, "but suppliers aren't nearby and resources aren't readily available."

Appelt, who had five years of industry experience under her belt from working at a biotechnology startup after finishing her undergraduate degree at Northwestern University, says that she was primed for the work. In three months, she helped start Afrigen's analytical development group, learned the company's techniques for mRNA in vitro transcription and liposome encapsulation, worked on documentation and compliance with the South African Health Products Regulatory Authority (similar to the FDA in the United States) and helped validate the manufacturing facility.

Liz Appelt's industry experience and academic training made her an ideal intern for Afrigen Biologics. Photo credit: Laura Vanderploeg, Department of Biochemistry. Submitted photo.

Now back in the United States, Appelt is once again thinking about doing research at a small biotechnology company after she wraps up her PhD research. "I had asked the question, 'How can I put engineering in a global health perspective?'," Appelt says. "This internship made me realize that there is a career path for me in bridging chemical engineering and global health."