McCormick

Northwestern Engineering

Chemical and Biological Engineering

Robert R. McCormick School of
Engineering and Applied Science
Northwestern University

FALL 2012

Chemical and Biological Engineering: Two Years, Two Top Teachers

Each year Northwestern recognizes a select group of faculty members across the University who demonstrate outstanding performance in the classroom. In the past two years, the Department of Chemical and Biological Engineering is proud to have had not one, but two, winners of the Charles Deering McCormick Award: in 2012, ***John Torkelson, Walter P. Murphy Professor of Chemical and Biological Engineering and Materials Science and Engineering****; and in 2011,* ***Wesley Burghardt, professor of chemical and biological engineering****. We asked both about their influences, teaching style, and favorite teaching moments.*

WESLEY BURGHARDT

Who has influenced you as a researcher and as a teacher?

In research, the obvious influences are my own research advisers, Tony McHugh at the University of Illinois (now at Lehigh) and Gerry Fuller at Stanford. Prior to initiating research with Tony, I basically viewed professors as people who appeared in front of a classroom a few hours each week; I didn't have much understanding of what else academic life entailed. Then around 10:30 one Friday night, I dropped by my lab to grab something I had forgotten. Tony was still there, leaving me a note about something related to my project. It made a huge impression on me to see that he was so engaged in research (my research, no less!). Working with Tony laid the foundations for my first interest in pursuing an academic career and also started me out in the research directions of polymers and rheology.

At Stanford, I was struck by Gerry's incredible enthusiasm for research. During dinner on my first night as a prospective grad student on a recruiting visit, Gerry flipped over his placemat and started drawing pictures of polymer molecules to explain one of his research projects. One of Gerry's most famous attributes was his "hands-on" approach to research; he was constantly in the lab tinkering with the equipment. I have picked this up, and still enjoy directly participating when my group runs experiments at Argonne.

As for teaching, I was greatly influenced by another Stanford professor, Bud Homsy (now at the University of British Columbia). His lectures were extraordinarily clear and organized, something I have always aspired to. As his TA, Bud gave me numerous opportunities to give lectures when he was traveling, and this sealed my interest in a teaching career.

Describe your teaching style or philosophy.

For me, this is the best job in the world. The opportunity to pursue research of my choosing, while participating in the education of bright students, really can't be beat. I put a lot of work into organizing syllabi, examples, assignments, and exams to reveal the underlying structure of the subject matter. I strive to give very clear lectures, to take advantage of student questions to launch discussions, and have never shied away from substantial homework assign-

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JOHN TORKELSON

Who has influenced you as a researcher and as a teacher?

Two professors at the University of Wisconsin-Madison particularly influenced me as a teacher. Professor Bob Bird was a consummate teacher not only because of his scientific expertise but also because he could communicate effectively with any audience. I saw him speak on the same subject to three groups: an undergraduate student chapter, a graduate department seminar, and a national meeting of scientific leaders. By tailoring his talk to his audience, he made each of the audiences understand more deeply his research motivations and outcomes. Professor Bird taught me that great teaching occurs only when the audience at hand truly learns.

Professor Charles Hill made each student feel like he was teaching directly to him or her. In a class of 30 or 40 students, he emphasized points in his lecture by asking questions directly to students. He did so like a West Point drill instructor, but it still came across as caring and made the point that students should be thinking at all times. I've adapted this approach to fit my personality, which is not that of a West Point drill instructor.

Describe your teaching style or philosophy.

My teaching philosophy begins with the concept of rigor tempered by knowing my audience. In general, Northwestern students are intellectually strong and eager to undertake challenges if those challenges lead to intellectual growth. That growth occurs only if the instruction and course material are delivered at levels appropriate for the backgrounds of the students. It is often necessary to teach a subject very differently in a class dominated by sophomores as compared with a class dominated by graduate students.

Respect for the students is also a cornerstone of my teaching. On the first day of class, I have students complete an information card where they tell me what they would like to learn in the course. Although this input rarely results in a major shift of the course focus, it often influences lecture examples and homework problems to address issues raised by students. I also seek daily, in-class student input. I achieve this by breaking down the faculty-student barrier present in many lecture-based classes by being self-deprecating and both

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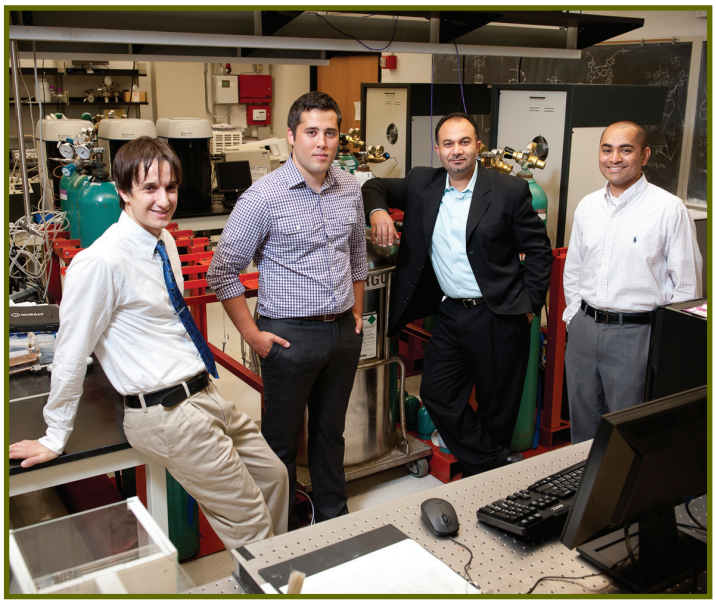
Student Startups NuMat Technologies, SiNode Win Big in Competitions



Members of NuMat Technologies, shown in their lab in the basement of Tech (far left) and meeting with judges at the U.S. Department of Energy National Clean Energy Business Plan Competition in Washington, D.C. (below). The company commercializes technology from the lab of McCormick's Randall Q. Snurr (shown at near left) and Weinberg's Joe Hupp.

With five business plan competitions and more than $1 million in winnings under their belt, Northwestern's NuMat Technologies has enjoyed a tidal wave of success since incorporating in February. The clean-tech company — spun out of research from the labs of chemical and biological engineering's Randall Q. Snurr and chemistry's Joe Hupp – designs high-performance materials that store gases and can be produced on a large scale for industry.

"I don't think anyone in NuMat expected this amount of success," said Chris Wilmer, a PhD candidate in Snurr's lab and NuMat's chief technology officer. "It's unexpected and overwhelming, but in a good way."

NuMat achieved its greatest success to date on June 13, when U.S. Deputy Secretary of Energy Daniel B. Poneman announced the company as the winner of the first-ever U.S. Department of Energy National Clean Energy Business Plan Competition, part of the Obama administration's Startup America Initiative. NuMat bested five other regional-prize-winning clean energy technology teams, including teams from Stanford, Columbia, and MIT, in the national competition in Washington, D.C. The judges — all from venture capital firms — were impressed with NuMat's commercialization idea, go-to market strategy, team plan, environmental benefits, and potential impact on America's clean energy economy. The competition carried a prize of $100,000 in cash and $80,000 worth of in-kind services, including technical, design, and legal assistance. (NuMat had already won more than $1 million in cash and in-kind services in previous competitions, including the Rice Business Plan Competition and a GOOSE Society Investment Prize.)

> "I don't think anyone in NuMat expected this amount of success. It's unexpected and overwhelming, but in a good way."
>
> *Chris Wimer, PhD candidate in chemical and biological engineering and NuMat's chief technology officer*

NuMat's proprietary computational screening tool can rapidly identify and test metal-organic frameworks, a new class of nanostructures for clean fuel storage. The process could fundamentally change the economics of countless gas storage applications, such as natural gas vehicles.

In its short lifetime, NuMat has attracted national media attention from *Fortune* magazine, *Crain's Chicago Business*, and *BusinessWeek*, and had been invited to ring the closing bell at the NASDAQ not once, but twice.

"On behalf of the entire Northwestern community, I couldn't be more proud of NuMat," said Northwestern Vice President for Research Jay Walsh, who attended the event in Washington. "Multidisciplinary teams tackling fundamental societal needs are the lifeblood of a great research university, and I see great potential for Northwestern to continue to innovate at the cutting edge of energy and sustainability research. Several people in Washington asked me who will repeat for Northwestern next year — it's great to have such high expectations."

And the company's rapid growth continues: In July, NuMat and Northwestern were part of a team that won $1.5 million in funding for natural gas vehicle technologies from the U.S. Department of Energy Advanced Research Projects Agency-Energy.

"We all hope that NuMat will become a large, successful company that will solve an important world problem," Wilmer said.

Four Northwestern schools are represented in the company. In addition to Wilmer, the company consists of Ben Hernandez (chief executive officer) and Tabrez Ebrahim (chief operating officer), who are pursuing a JD-MBA, a joint degree from the Kellogg School of Management and the School of Law, and Omar Farha (chief scientific officer) a research associate professor of chemistry in the Weinberg College of Arts and Sciences.

SiNode: An improved li-ion anode

NuMat has not been the only student team from the Department of Chemical and Biological Engineering to fare well in competition recently. SiNode, a business formed by NUVention: Energy students, has also enjoyed success in regional and Northwestern business plan competitions.

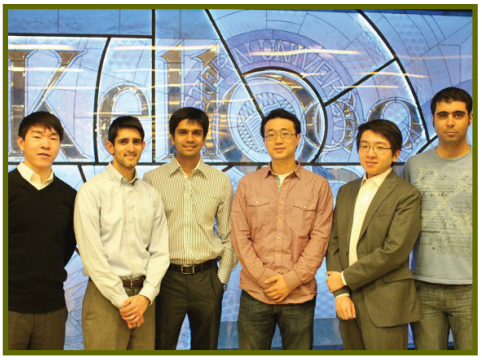
SiNode commercialized an anode for lithium-ion batteries that allows the battery to charge more quickly and hold a charge 10 times longer than current technology. The anode was developed in the lab of Harold Kung, professor of chemical and biological engineering.

Kung's technology utilizes a new method for constructing battery anodes with both graphene sheets and silicon, a combination that allows for a greater number of lithium ions in the electrode, and thus a longer charge. In addition, Kung utilized a chemical oxidation process to create tiny holes in the anode's graphene sheets, which speeds the battery's charging rate by a factor of 10.

SiNode made it to the final round of the student team division of the Clean Energy Challenge 2012 on March 2, and the following month, the team was awarded $3,250 in Shark Tank, a startup competition hosted by the Kellogg Tech Conference and Kellogg Entrepreneurship Club. Ten teams participated in the inaugural Shark Tank competition on April 15, competing for $10,000 in prizes and in-kind services.

"What sets SiNode apart from competing technologies is our ability to obtain drastic improvements in energy capacity (up to 10x) and reduction in charging time (up to 10x), without increasing manufacturing and materials costs," the SiNode team summary stated.

SiNode members include Peter Hamann, Zhenyu Hou, Joshua Lau, Nishit Mehta, Samir Mayekar, Guy Peterson, and Thomas Yue Yang Yu.



Members of SiNode, a business formed in the NUvention: Energy course to commercialize battery technology from the lab of Harold Kung (shown above)

"What sets SiNode apart from competing technologies is our ability to obtain drastic improvements in energy capacity (up to 10x) and reduction in charging time (up to 10x), without increasing manufacturing and materials costs." *SiNode*

Tiny Student-Designed House Displayed at Museum of Science and Industry

Tiny House, a 128-square-foot, zero-net-energy house designed by Northwestern University students and recent alumni, recently enjoyed a stay at Chicago's Museum of Science and Industry (MSI).

The house, completed in 2011 as a tool to promote sustainability and simple living, was displayed at the museum from May 24 to June 7 in conjunction with MSI's "Smart Home: Green + Wired" exhibit, a real, functioning three-story home — one of the "greenest" homes in Chicago.

Throughout the exhibit, Northwestern students were on hand to show off their house, which took two years to design and build. The house can function completely off the grid and comes equipped with a living room, kitchen, bathroom, sleeping loft, storage area, fireplace, and an awning for shade. The house produces its own electricity using solar panels and also collects all of its water through a rainwater catchment system.

Chemical engineering students Molly Baker ('14) and Randy Waymire ('13) arranged the MSI visit, coordinating with museum staff, scheduling tour guides, and organizing transportation for the house from Evanston to the South Side of Chicago.

"The museum-goers were certainly interesting to talk to. They were mostly impressed by how small the house was, and they were infatuated with our 'accordion' cardboard couch," Baker said. "Some were interested in and open to our message, while others simply proclaimed that they could never live in a house so small and looked around in wonder."

The students are hoping to schedule additional showings for Tiny House this fall.

Department News

FACULTY

Luís Amaral gave the opening keynote lecture at NetSci 2012, the annual meeting of the Network Science Society.

Wesley Burghardt and **Randall Q. Snurr** have been elected fellows of the American Association for the Advancement of Science.

Adjunct professor **Roger Guimerà**, a senior researcher at ICREA in Spain, received the inaugural Erdos-Renyi Prize in Network Science, awarded by the Network Science Society during the annual NetSci meeting.

Adjunct professor **Christopher Henry**, a researcher at Argonne National Laboratory, has been named the recipient of the Jay Bailey Young Investigator Award in Metabolic Engineering.

Mike Jewett was invited to attend the DFG-NSF Synthetic Biology Workshop in May to encourage research collaborations between Germany and the United States. Jewett was invited to speak in June at the Six Party Symposia on Synthetic Biology: Synthetic Biology for the Next Generation; the event was hosted by National Academy of Sciences, National Academy of Engineering, Royal Society, Royal Academy of Engineering, Chinese Academy of Sciences, and Chinese Academy of Engineering. Finally, Jewett's article (written with Eric Hodgman) in *Metabolic Engineering*, "Cell-free synthetic biology: Thinking outside the cell," is one of the journal's most downloaded articles.

Mike Jewett and **Josh Leonard** were both awarded 3M Nontenured Faculty Awards.

Justin Notestein will give a keynote lecture at the 2012 Gordon Conference on Catalysis.

Harold and **Mayfair Kung**'s research on "Coking- and Sintering-Resistant Palladium Catalysts Achieved Through Atomic Layer Deposition" was published in March in *Science*.

Eric Masanet received a "Best of 2011" paper award (one of 12 awards out of 1,500 published articles) from *Environmental Science & Technology*, the top-cited journal in environmental sciences.

Julio M. Ottino delivered a plenary lecture at the American Society of Mechanical Engineers meeting entitled "Thinking in a Complex World: Navigating Art, Technology, and Science."

Randy Snurr joined the editorial advisory board of the journal *Chemistry of Materials*. Snurr's paper on metal-organic framework design in *Nature Chemistry* was featured as the cover article.

Keith Tyo and Christina Smolke (Stanford) guest edited a special issue on "Synthetic Biology: New Methodologies and Applications for Metabolic Engineering" that was published in the May issue of the journal *Metabolic Engineering*.

STUDENTS

Andrew Boston, an undergraduate in the Jewett lab, won a McCormick undergraduate summer research grant.

Yunfei Chu, a postdoctoral fellow in Fengqi You's group, was awarded a Young Researcher Award by the Foundations of Computer-Aided Process Operations and Chemical Process Control (FOCAPO/CPC).

Graduate students **Rachel Dudek** (adviser Josh Leonard) and **Mark Duncan** (adviser Bill Miller) were selected as 2012 Robert H. Lurie Comprehensive Cancer Center Malkin Scholars.

Megan Dunham ('12) was the recipient of the 2012 Walter P. Murphy Cooperative Engineering Education Student of the Year award.

Christopher Evans, a graduate student in John Torkelson's group, won the 2012 AkzoNobel Student Award in Applied Polymer Science for his paper and oral presentation, "Dramatic Tunability of Polystyrene Tg via Neighboring Domains: Equivalence of Multilayer Films and Binary Blends."

Northwestern's **iGEM** team, advised by Keith Tyo, Josh Leonard, and Mike Jewett, was awarded first prize in the Natural Sciences category in the Office of the Provost's Undergraduate Research and Arts Exposition.

Three undergraduate ChE students received Summer Undergraduate Research Grants for their independent projects: **Eric Jiang**, "An In Vitro Model of Cancer Cell Migration for Identification of Metastatic Factors" (adviser Lonnie Shea); **Louis Knapp**, "Investigating Tumor Immune Response Dynamics Using Agent Based Simulations" (adviser Joshua Leonard); and **Brianne Knickel**, "Heterogeneity of Macrophage Polarization in Response to Tumor Microenvironment" (adviser Joshua Leonard).

Jessica Perez, a graduate student working with Mike Jewett, was awarded an NSF Graduate Research fellowship.

Michael Reddick, an undergraduate working in Keith Tyo's lab, was awarded an undergraduate research grant at the University of Washington-Madison with Todd Martin.

Sophomore **Rachel Scholes** won a scholarship from the NOAA Ernest F. Hollings Scholarship Program.

Andrew Stine, a graduate student in the Broadbelt lab, was awarded a Department of Energy Computational Science Graduate fellowship.

Divya Venkat (WCAS) was awarded a Weinberg undergraduate research grant for summer research in Keith Tyo's lab.

The research video "High-Density Energy Storage Using Self-Assembled Materials," created by graduate students **Chris Wilmer** and **Patrick Fuller**, received an honorable mention in the 2011 International Science & Engineering Visualization Challenge.

ALUMNI

Stephen Brand (BS '12), currently a graduate student at the California Institute of Technology, was awarded an NSF Graduate Fellowship.

ChBE undergraduate and PhD alum **Fred Koller** was the convocation speaker for McCormick's 2012 professional MS graduation ceremony.

Rodney Priestley (PhD '08), an assistant professor at Princeton University, received a Young Investigator Program award from the Air Force for his work on the characterization of nanostructured polymer films.

Jim Pfaendtner (PhD '07, Broadbelt), an assistant professor at the University of Washington, was awarded an NSF CAREER Award.

Two Grand Challenges Explorations Grants for Global Health

The innovative research of three Northwestern University professors who are making a big difference in the highly promising area of synthetic biology has been recognized with two early-stage discovery awards from Grand Challenges Explorations, an initiative funded by the Bill & Melinda Gates Foundation.

Synthetic biology is the design and construction of new types of biological systems. Synthetic biology researchers at Northwestern are leading a new wave of design-based biological engineering, exploring three major areas: biomolecular networks, cellular devices and therapeutics, and approaches that expand the chemistry of life. The engineers, scientists, and physicians represent three schools — McCormick, Weinberg, and the Feinberg School of Medicine.

The global health projects funded by Gates will focus on creating new compounds to combat malaria and on producing biosensors for low-cost, in-home diagnoses.

The prestigious awards are two of 107 Grand Challenges Explorations (GCE) grants announced in May. The funding supports scientists, researchers, and entrepreneurs worldwide who are testing unconventional ideas that show great promise to improve the health of people in the developing world.

Northwestern now has received a total of three GCE grants as part of the Gates Foundation's call to "Apply Synthetic Biology to Global Health Challenges." To date, only 30 synthetic biology grants have been awarded as part of this initiative, acknowledging Northwestern as being at the forefront of its use to address global health issues.

"The Gates Foundation support allows us to pursue high-risk, high-reward projects that are utilizing cutting-edge techniques to engineer biological systems," said Keith Tyo, an assistant professor of chemical and biological engineering and an investigator on all three grants. "Success on any one of these projects could result in a dramatic improvement in quality of life for millions of suffering people."

Andreas Matouschek, formerly professor of molecular biosciences at Northwestern and now at the University of Texas, and Tyo will develop synthetic compounds that target essential proteins in the Plasmodium parasite for destruction by its own protein degradation mechanisms. This strategy could lead to new treatment modalities as well as small molecule drug development efforts to combat malaria.

Keith Tyo

Joshua Leonard

In the other project, Tyo and Joshua Leonard, an assistant professor of chemical and biological engineering, will work to engineer yeast-based biosensors that identify protein biomarkers in samples like blood and urine. An array of yeast strains could serve as a low-cost, in-home device providing patients with a panel of diagnostics to improve treatment and diagnosis in resource-poor settings.

Each project will receive an 18-month grant of $100,000. Successful projects have an opportunity to receive a second grant of up to $1 million.

"Grand Challenges Explorations encourages individuals worldwide to expand the pipeline of ideas where creative, unorthodox thinking is most urgently needed," said Chris Wilson, director of Global Health Discovery and Translational Sciences at the Bill & Melinda Gates Foundation. "We're excited to provide additional funding for select grantees so that they can continue to advance their idea towards global impact."

Burghardt, *from cover*

ments. Where I have tried to evolve is to utilize new media (instructional media, Internet, YouTube) to add spice to lectures and draw examples from the "real" world.

What have been some of your most memorable teaching moments at McCormick?

There was a day early in my career in which I gave a full lecture with a gaping hole in the seat of my trousers. Helen Elam from our office staff had discreetly passed me a note earlier that day, whispering, "Look at this later." Unfortunately I failed to read the note until I got home that night. (There is a select, privileged group of alumni out there who might remember this.)

More recently, it has been fun to work in-class demonstrations into my undergraduate fluids course. A couple years ago I had assigned a homework problem about a siphon. After a few students came to me with questions, I queried the class and learned that the majority of them had never actually seen a siphon work. This was easily rectified the next day with a couple of buckets of water and some plastic tubing. There are also some simple demonstrations that illustrate some non-intuitive phenomena stemming from the Bernoulli equation that are always a highlight.

Torkelson, *from cover*

asking questions to specific students in an informal, friendly manner and encouraging students to ask me questions about points that they do not understand. This ensures that my classes are interactive and that I become acquainted with each student in class and vice-versa.

What have been some of your most memorable teaching moments at McCormick?

I arrived as a new assistant professor in September 1983, only 10 days before I was to give my first lecture. In those 10 days, I discussed with my teaching assistants and other professors the backgrounds of the students entering my required junior-level Separations class. I was surprised to learn that the students had not received any instruction on a topic known as material and energy balances — essential background for the course material I was to teach. In the first 10 minutes of my first lecture, I confirmed with the students that they had not learned material and energy balances and then informed them that we would take the first four lectures to deliver a condensed, highlights version of a course in material and energy balances. The students responded well to this two-courses-in-one challenge, even with the very heavy workload, because I helped them to understand the critical role of material and energy balances in solving complex problems in chemical engineering and because their self esteem grew during the quarter in proportion to their problem solving skills.

Eric Masanet joins ChBE

The Department of Chemical and Biological Engineering welcomes Eric Masanet, who joined Northwestern in June as an associate professor.

Masanet received his MS in mechanical engineering from McCormick in 1996. He returns to his alma mater after eight years at the University of California, Berkeley, and Lawrence Berkeley National Laboratory, where he led research in industrial energy systems optimization, green design and manufacturing, and life cycle assessment. Through collaborations with the U.S. Department of Energy and Environmental Protection Agency, his research has informed national and regional industrial energy and climate policy.

Using a method called "life-cycle analysis," Masanet studies the environmental impacts for the entire life cycle of products, from manufacturing to consumption to disposal. The goal is to quantify the energy usage, emissions, and environmental effects of current and potential technologies and behaviors to inform smarter manufacturing processes and policies.

"From a sustainability perspective, my research seeks to determine where we are today, where we could be, and the steps we can take to get there," Masanet said. "Putting numbers on potential reduction opportunities is an important first step in designing policy, as these numbers illuminate where design can make a difference, where manufacturing can make a difference, and so on."

Masanet said he is "thrilled" to be returning to McCormick, where he shares an appointment between chemical and biological engineering and mechanical engineering. He also holds an appointment with the Initiative for Sustainability and Energy at Northwestern, where he has supported the launch of a new University-wide certificate in energy and sustainability.

Eric Masanet

Masanet lives in Chicago with his wife, daughter, son, and Labrador retriever and enjoys hiking and backpacking.

"From a sustainability perspective, my research seeks to determine where we are today, where we could be, and the steps we can take to get there."
Eric Masanet

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Designer: Amy Charlson Design

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