



FALL 2017

# COLUMNS

Chemical and Biomolecular Engineering  
A. James Clark School of Engineering  
[www.chbe.umd.edu](http://www.chbe.umd.edu)

## **Cheaper, Faster, Longer Lasting** **What Magnesium Iodine Battery Chemistry Can Offer**

Dear Alumni and Friends of the Department of Chemical and Biomolecular Engineering,

I would like to welcome you to the Fall 2017 edition of our newsletter. I am very humbled and excited to be back in the Department of Chemical and Biomolecular Engineering, and look forward to a productive tenure as the new Chair. In this issue you can read about exciting transformative research carried out in our Department. From longer-lasting rechargeable batteries, to more efficient methods of converting natural gas, improved models to describe cellular membranes, and bioinspired multi-layer polymer capsule architectures, our faculty and students continue to work toward bettering the world through chemical and biomolecular engineering innovation.



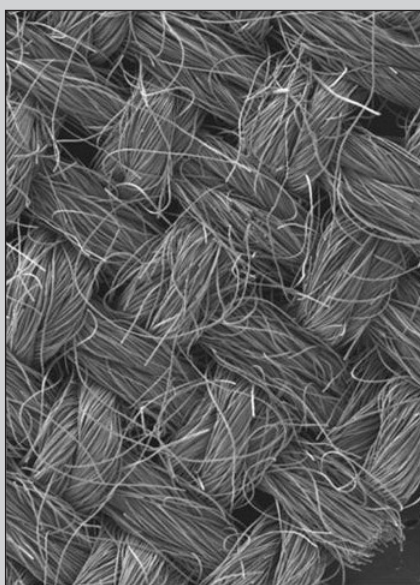
Thank you for taking time to read our newsletter and letting us share some of the interesting things going on in the CHBE Department. I would also like to thank our donors for their gifts, both large and small. Your gifts make a tremendous impact on the department, our faculty and students.

Sincerely,

Peter Kofinas  
Professor and Chair,  
UMD Chemical and Biomolecular Engineering

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ChBE researchers... For the full story, see  
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## Cheaper, Faster, Longer-Lasting: What Magnesium-Iodine Battery Chemistry Can Offer

Can you image how cumbersome the world would be without batteries? Devoid of any moving parts, batteries convert chemical energy into electricity, making everyday life more expedient. Rechargeable lithium-ion batteries power our daily lives, from cell phones, to computers, and even electric vehicles. Batteries provide numerous benefits, but are not without disadvantages. Lengthy charging times and short overall battery life, for example, can be a burden.

**Chunsheng Wang**, a Professor within the University of Maryland Department of Chemical and Biomolecular Engineering, and his team have developed an alternative to current technology. This new battery chemistry is based on the coupling of a magnesium cathode and an iodine anode. Magnesium batteries have the potential for much higher energy density – roughly 10 times current technology – however, development of rechargeable magnesium batteries has been slowed due to a lack of a compatible cathode. A higher energy density would translate into longer battery life, which would save consumers money in the long run.

“Our mission is to make rechargeable batteries that are cheaper, recharge faster and last longer than what is currently available to consumers,” said ChBE Ph.D. Candidate **Tao Gao** (pictured above). “Research of magnesium batteries has been ongoing for the last decade, and one of the biggest challenges is decreasing the recharge time, to hours, rather than days.”

Dr. Wang’s research group approached this issue by combining iodine with magnesium.

Iodine is soluble, and it becomes a solid after discharge, quite unlike the solid-state reaction in lithium-ion batteries. This two-phase, liquid-solid reaction is significantly faster than a pure solid reaction.

“In our research, we have demonstrated that the magnesium/iodine battery can be recharged within 5 min,” said Gao. “This is very important for the direction of next generation battery chemistry because it dramatically decreases the charging time while significantly increasing the energy stored in the battery.” Gao and the

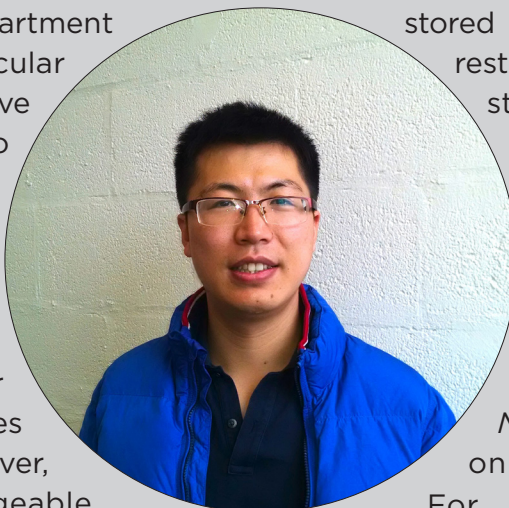
rest of the team are currently studying the effects of temperature on this battery, to ensure that it can be used in all climates, and under all conditions, regardless of application.

This research was published in *Nature Communications* on January 10, 2017.

For additional information:

Huajun Tian, Tao Gao, Xiaogang Li, Xiwen Wang, Chao Luo, Xiulin Fan, Chongyin Yang, Liumin Suo, Zhaohui Ma, Weiqiang Han and Chunsheng Wang. “High power rechargeable magnesium/iodine battery chemistry,” *Nature Communications* 8, 14083. DOI: 10.1038/ncomms14083.

Since the publishing of this research, Wang’s group has published a supplemental paper in *Angewandte Chemie* (August, 2017) addressing the capacity fading problem of a rechargeable magnesium-sulfite battery, which boasts one of the highest energy densities yet achieved. For additional information, DOI: 10.1002/anie.201708241.



## ChBE Research Team Develops Cleaner, More Efficient Method of Converting Natural Gas into More Valuable Materials

One of the world's most heavily utilized energy resources is natural gas, accounting for roughly 20% of the world's energy supply. Natural gas, which is generally odorless and devoid of color, is composed of multiple compounds, primarily methane. When directly released into the atmosphere – as opposed to being burnt – during the fracking process (i.e. shale gas), or the transport of coal, for example, methane becomes a dangerous, greenhouse gas, trapping heat in the Earth's atmosphere and contributing to global warming. If methane could be harnessed in form of longer hydrocarbons and even in liquid form, it would be easier to transport and less likely to increase pollution.

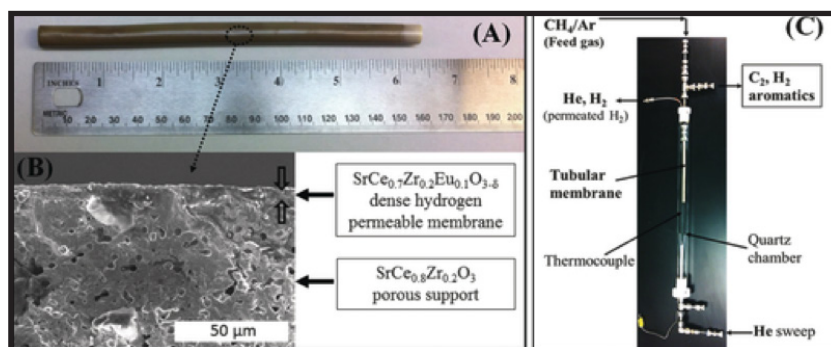
To that end, researchers at the University of Maryland are developing a method of converting methane to other valued-added materials, such as C2 hydrocarbons (e.g., acetylene, ethylene, ethane) and higher hydrocarbons such as aromatics (e.g., benzene and naphthalene). Current converters use a catalytic oxidation process to make these hydrocarbon materials but generate harmful CO and CO<sub>2</sub> chemicals. This research group, led by Department of Chemical and Biomolecular Engineering (ChBE) Professors **Dongxia Liu** and **Eric Wachsman**, has created a single-step converter: a hydrogen-permeable tubular membrane reactor via non-oxidative methane conversion to harness these chemicals from methane.

“The route for this one step process is limited by the thermodynamics of the reaction, which

can be circumvented by using a membrane reactor,” said **Mann Sakbodin**, a ChBE graduate student and first author on the research paper. “By combining a membrane reactor and a catalyst, we can improve the methane utilization and maximize the product yields.”

The reactor, which is the size of a drinking straw, is patented, metal oxide ceramic material, thermally stable, hydrogen-permeable and very strong. This mechanism has the ability to do both chemical separation and reaction simultaneously – it removes the hydrogen

component of the products, and pushes it through the reactor, driving methane into more value-added hydrocarbon materials.



The group is currently in the process of extending the capabilities of the membrane reactor system. Specifically, they're looking at using different 'sweep gases' (e.g. helium, dual production on both feed and sweep sides), and optimizing the system to maximize the product capability. The hope is to commercialize the product, sell it to oil companies, for example, in the near future.

This research entitled, “Hydrogen-Permeable Tubular Membrane Reactor: Promoting Conversion and Product Selectivity for Non-Oxidative Activation of Methane over an Fe@SiO<sub>2</sub>,” was published in *Angewandte Chemie* in November, 2016 (DOI: 10.1002/anie.201609991).



## Research Offers Insight into Structure of Cellular Membrane

All living things, regardless of size, be it human, animal or plant, are made up of cells: the so-called ‘building blocks of life.’ Each cell is made up of cytoplasm, the inner material, and the outer plasma membrane, which acts as a protective barrier. The structure of a cell’s plasma membrane consists of lipids and proteins, which vary across organisms. This protein/lipid make-up sends signals from cell-to-cell and defines, for example, how flexible it may be, and how permeable; thus, how susceptible a cell may be to viruses, or drug molecules, for example. Molecular dynamics computer simulations are now being used to study lipids and proteins as they provide a more comprehensive look at plasma membranes and their abilities. **Jeffrey Klauda**, an Associate Professor in the University

of Maryland Department of Chemical and Biomolecular Engineering, and his team have developed a computer simulation of a soybean plasma membrane. To date, soy membranes have not been often studied using computational methods. The hope is that this research will be useful in future projects geared towards the engineering of bio-chemicals and fuels, pharmaceuticals, etc.

In this field, “we have the ability to simulate and probe biologically relevant membranes,” Klauda told the American Institute of Physics. “If you want to understand the structure of a membrane, you really need to include the diversity that exists in biology.”

This research, entitled “Simulations of simple linoleic acid-containing lipid membranes

and models for the soybean plasma membranes” (doi: 10.1063/1.4983655), was published in the *Journal of Chemical Physics* on June 7, 2017. Klauda’s research team includes first author **Xiaohong Zhuang** (who completed her Ph.D. in Dec. ’16) and Anna Ou. Ou was a student at Montgomery Blair High School while this research was being conducted.

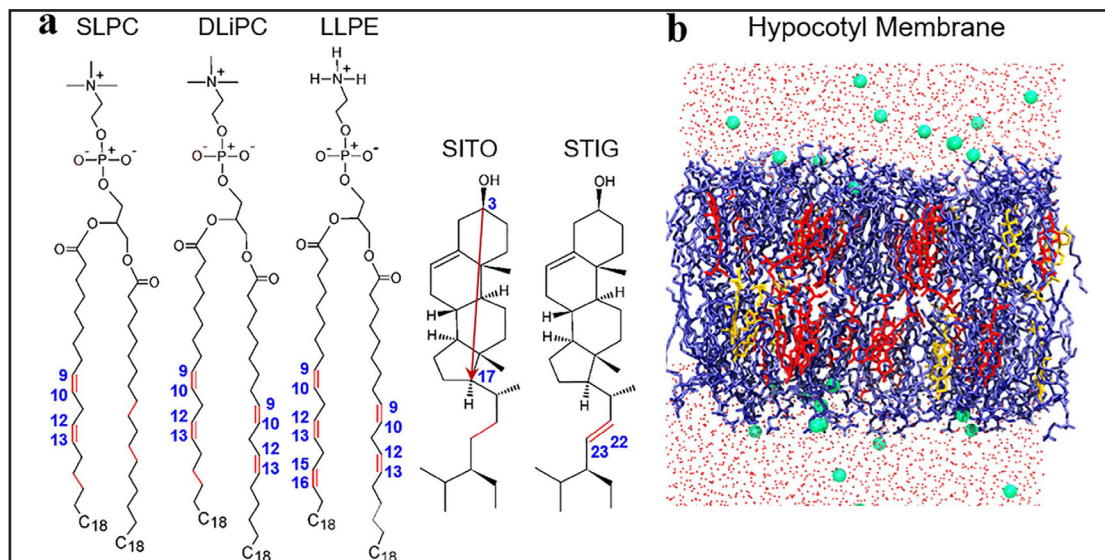


FIG 1: (a) Chemical structure of glycerol phospholipids of SLPC, DLiPC, and 1-linoleoyl-2-linolenoyl-snglycero-3-phosphoethanolamine (LLPE, 18:2/18:3) and sterol lipids of  $\beta$ -sitosterol (SITO), stigmasterol (STIG). The red arrow indicates the C3-C17 vector used to calculate the tilting angle of sterol. The positions of the double bond carbons, C3 and C17, in  $\beta$ -sitosterol are shown in blue texts. The relevant bond differences in glycerol phospholipids and sterol lipids are shown in red. (b) The snapshot of the hypocotyl at the end of the simulation. The glycerol phospholipids are shown in blue line; sitosterol and stigmasterol are shown in red and yellow lines, respectively, water is shown in red dots, and the potassium ions are shown in green sphere.



## Eric Wachsman Appointed Director of New Energy Institute

On August 14, 2017, state and university leaders gathered at the University of Maryland (UMD) campus to officially launch the Maryland Energy Innovation Institute (MEI<sup>2</sup>). The Institute, created by the state to turn research breakthroughs by Maryland academic institutions into commercial, clean energy solutions, “is a collaboration between UMD and the Maryland Clean Energy Center, which has been a really important part of the state’s strategy for consistency in our clean energy policies,” said U.S. Senator for Maryland Chris Van Hollen at the launch. “More than 100 [UMD] faculty have been involved already in developing breakthrough technologies in the areas of solar, wind, energy efficiency, and battery and fuel cell technology, and [the University] will expand those efforts with the launch of this institute.”

Indeed, MEI<sup>2</sup> is a partnership between the University of Maryland Energy Research Center (UMERC), directed by Professor **Eric Wachsman**, and the state’s Maryland Clean Energy Center (MCEC), directed by Katherine Magruder. It will be housed within UMD’s A. James Clark School of Engineering and directed by Dr. Wachsman. MEI<sup>2</sup> received \$7.5 million in state funding earlier this year and will seek to bolster economic jobs in the clean energy industry sector in Maryland, as well as promote the deployment of clean energy technology throughout the state.

“The availability of clean and affordable energy remains one of our greatest societal challenges,” said Dr. Wachsman. “While the University of Maryland Energy Research Center has been a leader in developing the technologies necessary to address this challenge, the creation of the Maryland Energy Innovation Institute will now enable the translation of those advanced energy technologies into commercial products, which is the critical next step for this research to truly benefit society.”

Professor Wachsman, a California native and Stanford University graduate, holds dual appointments in the UMD Departments of Chemical and Biomolecular Engineering and Materials Science and Engineering. He is the editor-in-chief of the International Journal of Ionics, a fellow of the Electrochemical Society, and was recently elected to the World Academy of Ceramics. Dr. Wachsman has devoted his career to the development of energy conservation research, devices and technology. Moreover, the U.S. Department of Energy recently awarded him and MSE Professor **Liangbing Hu** grant money to advance their innovative battery research and technology (see [https://go.umd.edu/DOE\\_battery500](https://go.umd.edu/DOE_battery500)) in the hopes of reducing carbon emissions.

Indeed, “the pivot to fossil fuels started here in Maryland. The first gas lamps in North America turned on in Baltimore almost 200 years ago exactly,” said Maryland State Senator Richard Madaleno. “So, isn’t it fitting that the pivot to the next generation of energy also happens in Maryland?” For additional information on the MEI<sup>2</sup>, please visit <https://energy.umd.edu>.



Photo above (left to right): UMD President Wallace Loh, MEI<sup>2</sup> Director Eric Wachsman, and Clark School of Engineering Dean Darryll Pines at the MEI<sup>2</sup> grand opening ceremony.

## ChBE Researchers Develop ‘Inside-out’ Technique for Creating Multi-Layer Polymer Capsules

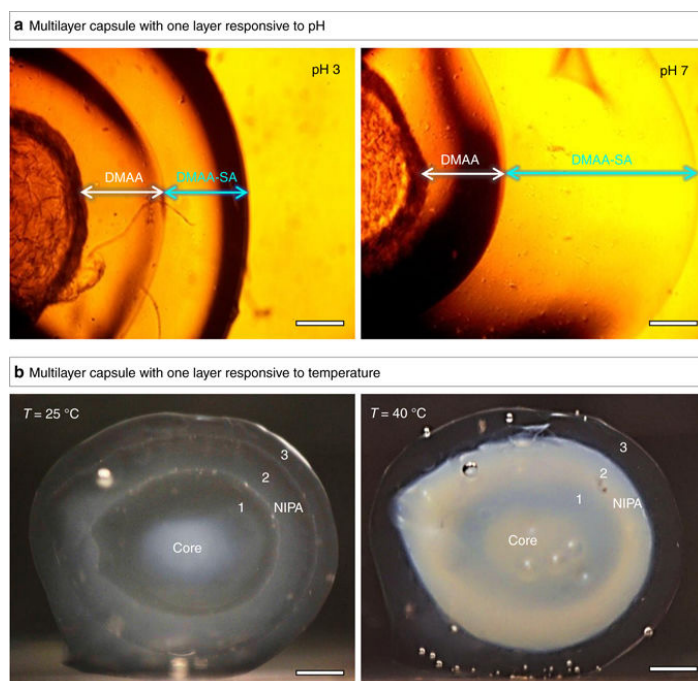
The structure of natural materials is inspiring the development of innovative technology more and more often these days. For example, the ribbed design of Speedo’s FastSkin swimwear is inspired by the scales of shark skin. Lockheed Martin created a new rotor for their Samarai UAV motivated in part by the swirl of maple seeds. In the University of Maryland (UMD) Department of Chemical and Biomolecular Engineering (ChBE), researchers have drawn inspiration from layered materials found in nature – onions, castor beans, eggs and the discs in our spinal column, to name a few – to design multi-layered polymer capsules. Such capsules could serve numerous purposes, especially in the pharmaceutical industry as containers for delivering drugs.

In their research, ChBE Professor **Srinivasa Raghavan** and his PhD Student, **Brady Zarket** (Ph.D. ‘17), have invented a technique where they begin with a small gelatinous bead and then grow layers of different polymers around this bead. Each layer is grown by immersing the core in a solution of monomers, which polymerize around the core in a minute or so. The process is repeated multiple times to form an onion-like capsule with multiple concentric layers, each of a unique chemical composition. Interestingly, each layer grows ‘inside-out’, ie, the growth starts at the core and extends outward, with the thickness depending on the amount of molecules called ‘initiators’ that are present in the core. According to Raghavan, “the beauty of this technique is that we can control the growth of each layer – so we can decide what the layer is made of and how thick it is. This is something that cannot be done by any existing method.”

As an example of the technique’s versatility, the researchers created a capsule in which one of the layers is made from polysodium acrylate (SA) – a polymer used in disposable diapers due to its ability to swell and absorb water. The swelling of this polymer is dependent on the pH of the surrounding water – it swells much more at normal pH rather than in acidic water. Accordingly, the SA-bearing layer in their onion-like capsule exhibits a dramatic change in its thickness with a change in pH, as shown in the figure to the right.

The overall goal of Raghavan’s lab is to create novel materials that act as the basis for new technologies. The hope in this particular research is that this robust technique – a method of inducing growth from the inside out – will be instrumental for creating other layered materials that may be useful in various areas, eg, tissue engineering. This research was published in Nature Communications in August, 2017.

For additional information: Zarket, B. C., & Raghavan, S. R. (2017, August 4). Onion-like multilayered polymer capsules synthesized by a bioinspired inside-out technique. Nature Communications, 8 (193). doi: 10.1038/s41467-017-00077-7.





## UMD Team Chases Solar-Powered Victory, Led by ChBE Professor Raymond Adomaitis



Two years. Ten contests. One solar-powered house. The Department of Energy's Solar Decathlon is a biennial outreach competition that challenges student teams from universities around the world to design and build a house powered entirely by the sun.

The University of Maryland's (UMD) 2017 Solar Decathlon team will put their design and smart energy innovations to the test this fall in Denver, Colorado, in the hopes of winning first place for the second time (the first time was in 2011). Named *reACT* for "resilient Adaptive Climate Technology," UMD's entry is a modular design inspired by American Indian culture. The team's range of disciplines - from engineering to architecture and environmental science to communications - helped diversify the house's innovations.

Engineering team members - led by ChBE Professor, **Raymond Adomaitis**; **Michael Binder**, a lecturer from the School of Architecture, Planning and Preservation (MAPP); and **Garth Rockcastle**,

a former MAPP Professor and Dean - have been making sure the house maximizes solar power, minimizes water usage and waste, and is informed by climate data. The focal point of the house is a centralized courtyard where residents can experience a community feel, interact with the earth and air, and have direct access to mechanical facilities (run via SMART technology). What sets UMD's entry apart from the rest of the competition is the automated systems of the home that are already live. Online, viewers can see how the house would perform in current environmental conditions. Check it out at: [go.umd.edu/virtual](http://go.umd.edu/virtual)

This goal of the project is to educate both students and the public about environmentally friendly, money-saving opportunities offered by clean energy solutions, in addition to offering students a unique opportunity to prepare for their post-graduation careers.

Go Terps!!!





## Taylor Woehl Will Use Funding to Study NanoTechnology

**Taylor Woehl**, a ChBE assistant professor, is the recipient of the Ralph E. Power Junior Faculty Enhancement Award for the 2017-2018 academic year, granted by the Oak Ridge Associate Universities (ORAU) consortium as a means of supplementing the research and professional growth of young faculty members. According to the proposal, Woehl's research will "investigate the effects of mesoscale properties (particle size and interparticle separation) on the stability of d-PtNi ORR electrocatalysts using liquid cell transmission electron microscopy (TEM)," which will offer clean energy technology for automobiles.

Additionally, Woehl and colleague **Bruce Yu**, a professor of Pharmaceutical Sciences at the University of Maryland Baltimore (UMB), received a 2017 Research and Innovation Seed Grant for their proposal entitled, "Noninvasive and Direct Imaging Methods for Characterizing Protein Aggregates in Biologics." The research will fill gaps in protein-based drug technology; specifically, it will assess the stability of therapeutic proteins and provide new on-line and at-line process analytical technology. Woehl, who completed his Ph.D. in chemical engineering at UC Davis, joined the Department in 2016.



## Anisimov Named Distinguished University Professor

**Mikhail Anisimov**, a ChBE professor with a joint appointment in the Institute for Physical Science and Technology (IPST), has been named a University of Maryland (UMD) Distinguished University Professor, the most prestigious internal honor on the campus. Anisimov began at UMD as a visiting professor in 1994 and became an affiliate professor in 1996. He's been a full-time ChBE and IPST faculty member since 2002. Anisimov's research interests are in mesoscopic and nanoscale thermodynamics, critical phenomena and phase transitions in soft matter. His current research includes supercooled water, self-assembly of small molecules in aqueous solutions, and the effect of fluctuations on the behavior of smooth interfaces. His research in these areas earned him the Touloukian Award in 2015, which is given once every three years for outstanding contributions to thermophysical properties, as well as a USMD Regents' Faculty Award for Excellence in Research, Scholarship, and Creative Activity (2015). Anisimov is also celebrated with fellows in the American Institute of Chemical Engineers, American Physical Society, American Association for the Advancement of Science, International Academy of Refrigeration, and the Newtonian Society.



## ChBE 101 Students Participate in Student-Mentoring, Program Implemented by Lecturer Deborah Goldberg

Students transferring to the University of Maryland (UMD) from two-year community colleges are required to take ChBE 101 during the summer semester, but many find the intensive six-week course overwhelming. These students, all new to campus, typically look at a challenging transition period.

“As an advisor, I saw many of my transfer advisees struggling with this transition, which extended into struggling in the fall semester,” said ChBE lecturer **Deborah Goldberg**. “I thought that having an upperclassmen mentor, particularly one who also transferred from community college, would really help to ease the transition. Advice is much more impactful coming from a student who recently went through the process.”

The summer cohort also includes internal UMD transfers and students who need to re-take the class. Goldberg figured these populations, too, could benefit from an upperclassmen mentor, so she went about putting the program into action. By the end of the spring semester, eight senior mentor volunteers were identified: **Soliver Fusi, Deiaa Harraz, Brendan Hensel, Tanya Kiryutina, Ricky Morales, Nina Uchida, Hanchu Wang** and **Samantha Weaver**.

The program kicked off over the summer

semester with a ‘panel discussion’ class, during which the mentors introduced themselves and offered 35 incoming students advice on how to study for exams, fitting in as a non-traditional student, the importance of study groups, and the psychological aspects of succeeding in such a challenging major. After the event, new students were matched with a peer mentor. Throughout the rest of the summer, the groups met multiple times to discuss student progress. Social engagements also became the norm, and several friendships developed as a result.

ChBE rising senior and volunteer mentor, **Nina Uchida**, suggested more interaction between the upper and lower classmen would also be beneficial. “The transition as a transfer student last year into the summer ChBE program was tough for me,” she said. “I personally would have benefited from having a peer mentor who had been through the same experience, and could offer support and advice. I think the summer program was successful, and I am looking forward to keeping in touch with my mentees in the upcoming academic year!”

The program received highly positive feedback overall. When asked in an anonymous survey, “What was your favorite part of the mentoring program?”, student responses had a similar theme. For example: [“It really helped to reduce the anxiety for summer class. The mentors are survivors, and it made me believe that I, too, can do this.”](#)

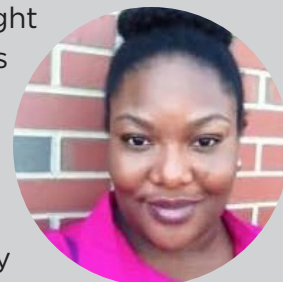
Goldberg intends to offer the program again during the 2017/2018 academic year. “All new chemical engineering students can benefit from a mentor who has ‘been there/done that’ and succeeded,” she said. “It also provides a great leadership opportunity for upper-class students and fosters departmental community. I’m excited to see how we can improve the pilot program over time to best serve student needs.”





## ChBE Alumna Receives Fullbright Scholarship

**Ezinne Achinivu** (B.S. '10) has recently become a Fullbright Scholar. The Fullbright Program seeks to increase mutual understanding between U.S. representatives and other countries via the exchange of people, knowledge and skills. Achinivu was selected to work in Reims, France, in the field of biotechnology and bioprocessing. While studying at UMD, she participated in undergraduate research, advised by former ChBE Professor and Chair, Dr. **Sheryl Ehrman**, where she developed a foundation in performing rigorous, multidisciplinary research with a focus on computational chemistry and drug delivery. Achinivu's extracurricular activities included membership in the Society of Women Engineers where she worked to promote engineering education amongst middle and high school students. In 2014, she received a Ph.D. in chemical and biomolecular engineering from NC State University.



"My thesis focused on developing a sustainable technique for processing waste biomass into high value bioproducts," said Achinivu. "In France, my team and I will develop processes for extracting high value compounds, such as mustard bran and canola seeds, for use in cosmetics. I will contribute my skills in bioprocess development to effectively extract the biomaterials of interest and develop formulations for a potential product to be commercialized." Achinivu's fellowship commenced September 1, 2017.

## ChBE Alumnus Hunts Down Pathogens in the Gut

A global team of synthetic biologists and bioengineers is taking their fight against antibiotic-resistant bacteria to a new front - the gut. UMD ChBE alumnus **Matthew Wook Chang** (Ph.D. '03) and a team of researchers from the National University of Singapore, Cornell University, and UMD's Fischell Department of Bioengineering are on a mission to train bacteria to prey on pathogens in the gastrointestinal (GI) tract.

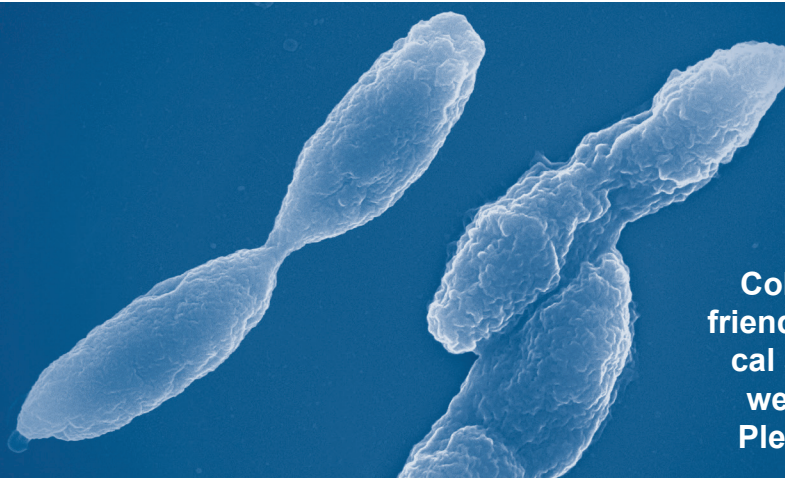
"Our work represents a potential novel antimicrobial strategy where probiotics are reprogrammed to prevent and treat target diseases," said Chang, an associate professor at the National University of Singapore's Department of Biochemistry. "Using an infection as a testbed, we demonstrated the prophylactic and therapeutic efficacy of reprogrammed probiotics against a human pathogen in animals."

Chang has previously developed a probiotic strain of *E. coli* to respond to *P. aeruginosa* by seeking it and manufacturing a targeted antibiotic protein. In this most recent effort, Chang collaborated with UMD and Cornell University

researchers to engineer *E. coli* to destroy *P. aeruginosa* by honing the targeting functions as well as the means to get the drug - pyocin - to the *P. aeruginosa* bacterium. The group demonstrated this concept in both nematode worm and mice models. While the engineered *E. coli* strain demonstrated an ability to sense the *P. aeruginosa* pathogen and accelerate bacterial clearance from the gut in both model systems, Chang and his team employed an anti-biofilm enzyme, dispersin B (DspB), to aid in wiping out the pathogen completely. Chang's team eliminated the infecting bacteria from mice and also used the engineered *E. coli* strain as a prophylactic to prevent *P. aeruginosa* colonization.

For additional info: In Young Hwang, Elvin Koh, Adison Wong, John C. March, William E. Bentley, Yung Seng Lee & Matthew W. Chang. "Engineered probiotic *Escherichia coli* can eliminate and prevent *Pseudomonas aeruginosa* gut infection in animal models," *Nature Communications* 8, 15028. DOI:10.1038/ncomms15028

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