Director Jinsang Kim’s Message

Dear Alumni and Friends,

Greetings, all! I hope you have been enjoying the beginning of your summer. We have much to share since last semester.

This year’s admissions season was very successful. We are pleased to announce that we will be welcoming 15 new students (9 Ph.D. and 6 Master’s) to the program in September. Several beneficial changes to the prospective graduate student visit days were introduced, including a faculty-hosted dinner, alumni discussions of their Macro experience, a new faculty meeting sign-up procedure, and additional individual meetings with representatives from various research groups. We appreciate the current Macro students for their sincere efforts to recruit students of remarkable quality during the visit days. A special thanks goes out to Professors Zhan Chen and Kenichi Kuroda for their hard work in reviewing over 80 applications.

Macro students have continued their excellent research developments, outreach contributions, and other efforts to make Macro a warm, close-knit program beyond just academics. This newsletter includes articles about that research as well as some of the accolades our program has received, highlighted by Da Seul Yang receiving the prestigious Rackham Predoctoral Fellowship, Yingying Zeng’s selection as a Barbour Scholar, and Rose Cersonsky winning the Biointerfaces Institute Student Innovator Award. We have continued to build upon our relationships with industry partners. In May, PPG representatives visited for a professional development event, and it was recently announced that Taeyong Ahn, Weijie Feng, Yanan Gong, Shamalee Goonetilleke, and Alyssa Travitz are the recipients of 3M Summer Fellowships. We are grateful for our partners’ continued support of our program!

In January, we welcomed the return of Professor Ayyalusamy Ramamoorthy to the Macro program. Rams is a Professor of Chemistry and Biophysics in the College of Literature, Science, and the Arts. His...
Director’s Message (Continued from Page 1)

research group focuses on the development of solid-state NMR and its applications to non-soluble, non-crystalline chemical and biological solids. Rams previously served the Macro program from 1996-2002 and we are delighted to have him back.

We would also like to acknowledge Professor Timothy Scott for his outstanding contributions to the Macro program. Tim will be leaving us to join the Chemical Engineering department of his alma mater, Monash University in Australia. Over the past seven years, Professor Scott has developed excellent research programs, provided valuable education, and served as a faculty advisor for the ACS POLY/PMSE Student Chapter. The latter saw him working closely with our students to help with networking and career development opportunities, and under his guidance our student chapter has been recognized by the ACS POLY/PMSE with the Award for Best Student Chapter. Though we are deeply saddened by his departure, we wish him the best in his future endeavors.

In an effort to continuously improve the Macro program, we recently completed a holistic review with Rackham Graduate School and hosted our first faculty retreat in May. The retreat provided the perfect opportunity to discuss the results of the review and revisit a host of topics: the qualifying exam, Macro 800, the symposium, the Charles G. Overberger International Prize, recruitment, increasing the program’s visibility, and the expansion of the master’s program, among other things.

Planning is underway for the 43rd Annual Macro Symposium, which will be held on October 23rd and 24th, 2019. We are pleased to welcome Professor Kenneth B. Wagener to the symposium as the recipient of the ACS POLY Overberger International Prize. Professor Wagener is the George B. Butler Professor of Polymer Chemistry at the University of Florida and is well-known for his pioneering development of the acyclic diene metathesis (ADMET) reaction used worldwide, a truly new polymerization reaction which came about via his astute observation of the mechanistic needs to achieve high molecular weights in this polycondensation reaction. Ken achieved international renown for this work, which has had profound influence and is now used by groups in academia and industry around the world.”

Professor Timothy Scott Accepts Position at Monash University

Professor Timothy Scott has accepted a position in the Chemical Engineering department at Monash University in Melbourne, Australia. Tim has been a professor of Chemical Engineering and Macromolecular Science and Engineering since 2011. He most recently served as a member of the Macro Executive Committee and faculty advisor for the ACS POLY/PMSE Student Chapter. We wish Professor Scott all the best for this exciting new opportunity!

Overberger Prize Awarded to Kenneth B. Wagener

Macro is pleased to announce that the 2019 Charles G. Overberger International Prize has been awarded to Kenneth B. Wagener, the George B. Butler Professor of Polymer Chemistry and Director of the Center for Macromolecular Science and Engineering at the University of Florida.

Nominees noted that Professor Wagener is best known for “pioneering the ADMET (acyclic diene metathesis) reaction used worldwide, a truly new polymerization reaction which came about via his astute observation of the mechanistic needs to achieve high molecular weights in this polycondensation reaction. Ken achieved international renown for this work, which has had profound influence and is now used by groups in academia and industry around the world.”

Professor Wagener will be honored at the Overberger Award Symposium at the ACS Fall National Meeting in addition to the Macro Annual Symposium. Past honorees are Craig Hawker (2017), Krzysztof Matyjaszewski (2015), James McGrath (2013), and Yoshio Okamoto (2011).

PPG Professional Development Event

In May, Macro hosted PPG for a professional development seminar that provided students with valuable resume and interview preparation. Following the seminar, students met one-on-one with PPG representatives to review resumes and practice their interviewing skills. A special thank you to Se Ryeon Lee, Justin Martin, and Betsy Brown-Tseng from PPG!

Save the Date

The 43rd Annual Macro Symposium will be held October 23-24, 2019. More information will be coming soon at macro.engin.umich.edu/symposium.
3D Printing 100 Times Faster with Light
Kate McAlpine, Michigan Engineering

Rather than building up plastic filaments layer by layer, a new approach to 3D printing lifts complex shapes from a vat of liquid at up to 100 times faster than conventional 3D printing processes, University of Michigan researchers have shown.

3D printing could change the game for relatively small manufacturing jobs, producing fewer than 10,000 identical items, because it would mean that the objects could be made without the need for a mold costing upwards of $10,000. But the most familiar form of 3D printing, which is sort of like building 3D objects with a series of 1D lines, hasn’t been able to fill that gap on typical production timescales of a week or two.

“Using conventional approaches, that’s not really attainable unless you have hundreds of machines,” said Timothy Scott, an associate professor of chemical engineering and macromolecular science and engineering at U-M, who co-led the development of the new 3D printing approach with Mark Burns, the T.C. Chang Professor of Engineering at U-M.

Their method solidifies the liquid resin using two lights to control where the resin hardens—and where it stays fluid. This enables the team to solidify the resin in more sophisticated patterns. They can make a 3D bas-relief in a single shot rather than in a series of 1D lines or 2D cross-sections. Their printing demonstrations include a lattice, a toy boat and a block M.

“It’s one of the first true 3D printers ever made,” said Burns.

But the true 3D approach is no mere stunt—it was necessary to overcome the limitations of earlier vat-printing efforts. Namely, the resin tends to solidify on the window that the light shines through, stopping the print job just as it gets started. By creating a relatively large region where no solidification occurs, thicker resins—potentially with strengthening powder additives—can be used to produce more durable objects. The method also bests the structural integrity of filament 3D printing, as those objects have weak points at the interfaces between layers.

“You can get much tougher, much more wear-resistant materials,” said Scott. An earlier solution to the solidification-on-window problem was a window that lets oxygen through. The oxygen penetrates into the resin and halts the solidification near the window, leaving a film of fluid that will allow the newly printed surface to be pulled away.

But because this gap is only about as thick as a piece of transparent tape, the resin must be very runny to flow fast enough into the tiny gap between the newly-solidified object and the window as the part is pulled up. This has limited vat printing to small, customized products that will be treated relatively gently, such as dental devices and shoe insoles.

By replacing the oxygen with a second light to halt solidification, the Michigan team can produce a much larger gap between the object and the window—millimeters thick—allowing resin to flow in thousands of times faster.

The key to success is the chemistry of the resin. In conventional systems, there is only one reaction. A photoactivator hardens the resin wherever light shines. In the Michigan system, there is also a photoinhibitor, which responds to a different wavelength of light. Rather than merely controlling solidification in a 2D plane, as current vat-printing techniques do, the Michigan team can pattern the two kinds of light to harden the resin at essentially any 3D place near the illumination window.

The University of Michigan has filed three patent applications to protect the multiple inventive aspects of the approach, and Scott is preparing to launch a startup company.

A paper describing this research is published in Science Advances, titled, “Rapid, continuous additive manufacturing by volumetric polymerization inhibition patterning.”

Burns is also a professor of chemical engineering and biomedical engineering.
Ice-proofing Big Structures with a “Beautiful Demonstration of Mechanics”

Gabe Cherry, Michigan Engineering

A new class of coatings that sheds ice effortlessly from even large surfaces has moved researchers closer to their decades-long goal of ice-proofing cargo ships, airplanes, power lines and other large structures.

The spray-on coatings, developed at the University of Michigan, cause ice to fall away from structures—regardless of their size—with just the force of a light breeze, or often the weight of the ice itself. A paper on the research is published in Science.

In a test on a mock power line, the coating shed ice immediately.

The researchers overcame a major limitation of previous ice-repellent coatings—while they worked well on small areas, researchers found in field testing that they didn’t shed ice from very large surfaces as effectively as they had hoped. That’s an issue, since ice tends to cause the biggest problems on the biggest surfaces—sapping efficiency, jeopardizing safety and necessitating costly removal.

They cleared this hurdle with a “beautiful demonstration of mechanics.” Anish Tuteja, an associate professor in the U-M Department of Materials Science and Engineering and Macromolecular Science and Engineering, described how he and his colleagues turned to a property that isn’t well-known in icing research.

“For decades, coating research has focused on lowering adhesion strength—the force per unit area required to tear a sheet of ice from a surface,” said Tuteja. “The problem with this strategy is that the larger the sheet of ice, the more force is required. We found that we were bumping up against the limits of low adhesion strength, and our coatings became ineffective once the surface area got large enough.”

The new coatings solve the problem by introducing a second strategy: low interfacial toughness, abbreviated LIT. Surfaces with low interfacial toughness encourage cracks to form between ice and the surface. And unlike breaking an ice sheet’s surface adhesion, which requires tearing the entire sheet free, a crack only breaks the surface free along its leading edge. Once that crack starts, it can quickly spread across the entire iced surface, regardless of its size.

“Imagine pulling a rug across a floor,” said Michael Thouless, the Janine Johnson Weins Professor of Engineering in mechanical engineering. “The larger the rug, the harder it is to move. You are resisted by the strength of the entire interface between the rug and floor. The frictional force is analogous to the interfacial strength. But now imagine there’s a wrinkle in that rug. It’s easy to keep pushing that wrinkle across the rug, regardless of how big the rug is. The resistance to propagating the wrinkle is analogous to the interfacial toughness that resists the propagation of a crack.”

Thouless explains that the concept of interfacial toughness is well known in the field of fracture mechanics, where it underpins the mechanics of products like laminated surfaces and adhesive-based aircraft joints. But until now, it hadn’t been applied in ice mitigation. The advance came when Thouless learned of Tuteja’s previous coatings work and saw an opportunity.

“Traditionally, fracture mechanics researchers only care about interfacial toughness, and ice mitigation researchers often only care about interfacial strength,” Thouless said. “But both parameters are important for understanding adhesion.

“I pointed out to Anish that if we were to test increasing lengths of ice, he would find the failure load would rise while interfacial strength was important, but then plateau once toughness became important. Anish and his students tried the experiments and ended up with a really beautiful demonstration of the mechanics, and a new concept for ice adhesion.”

To test the idea, Tuteja’s team used a technique he honed during previous coating research, which breaks with the traditional materials science “mix-and-see” approach. By mapping out the fundamental properties of a vast library of substances and adding interfacial toughness as well as adhesion strength to the equation, they were able to mathematically predict the properties of a coating without the need to physically test each one. This enabled them to concoct a wide variety of combinations, each with a specifically tailored balance between interfacial toughness and adhesion strength.

They tested a variety of coatings on large surfaces—a rigid aluminum sheet approximately 3 feet square, and a flexible aluminum piece approximately one inch wide and 3 feet long, to mimic a power line. On every surface, ice fell off immediately due to its own weight. It stuck fast, however, to the control surfaces, which were identical in size—one was uncoated and another was coated with an earlier icephobic coating.

The team’s next step is to improve its durability of the LIT coatings. Tuteja explains that LIT coatings tend to be thin and hard, unlike the thick, rubbery coatings that are designed for low adhesion strength. Making the thin coatings durable can be a challenge, but Tuteja is confident that the team will be able to dial in the right mix of interfacial toughness, adhesion strength and modulus for a variety of applications.

“The advantage of designing coatings based on their fundamental mathematical properties is that you don’t end up with just one coating,” he said. “You get more of a recipe, and you can then adjust that recipe to create a variety of slightly different coatings for different applications.”

The paper is titled “Low Interfacial-Toughness Materials for Effective large-Scale De-Icing.” In addition to Tuteja and Thouless, the team included U-M macromolecular science and engineering graduate researcher Abhishek Dhyani and former U-M materials science and engineering PhD student Kevin Golovin. The research was funded by the Office of Naval Research, the Air Force Office of Scientific Research, the National Science Foundation and the Nanomanufacturing program (grant #1351412), and the U-M College of Engineering MTRAC Transportation program.
A Step Toward Recovering Reproduction in Girls who Survive Childhood Cancer

James Lynch, Michigan Engineering

Leukemia treatments often leave girls infertile, but a procedure developed by researchers at the University of Michigan working with mice is a step toward restoring their ability to be biological mothers.

Ovarian follicles are the “nests” that carry eggs and support them to grow and become viable. The researchers demonstrated that they could dramatically improve the rate at which follicles develop mature eggs by surrounding the follicles with adipose-derived adult stem cells in a 3D scaffold that mimics the environment of the ovary. Adipose-derived stem cells can be obtained from readily available fat tissue in adults.

The researchers point out that utilizing this approach in women is a ways off, but it could offer hope for many.

“Once a patient is cancer-free and they want biologically-related children, we hope we’ll be able to take their ovarian follicles, grow them in vitro and obtain healthy eggs for these young, otherwise healthy women,” said Ariella Shikanov, an associate professor of biomedical engineering and macromolecular science and engineering at U-M.

The described approach increased follicle survival from less than 5% to between 42% and 86% depending on the size of the follicle. The research was recently published in Stem Cell Research & Therapy Journal.

“This is a huge step toward being able to preserve the fertility of women and girls undergoing chemotherapy and radiation for cancer since those treatments are toxic to the follicles,” said Claire Tomaszewski, a U-M doctoral student in biomedical engineering and member of the research team.

At this time, a young female leukemia patient’s hope for carrying and delivering a biologically-related child is freezing a ovarian tissue prior to treatment, and hoping technology can eventually make follicle growth and maturation a viable procedure.

And historically, attempts to grow human follicles into eggs in two-dimensional petri dishes have failed.

“A follicle is a three dimensional structure, which becomes a pancake, not the spherical structure surrounded by supportive cells, when placed on a flat surface in a dish,” Shikanov said. “As a result, it loses the contact between the supportive cells and the germs cells and then it fails to grow.”

The 3D scaffolds designed at U-M allow a single follicle to grow in all directions within polymer networks known as hydrogels. By surrounding the follicle with the adult stem cells, researchers create a smart delivery system for cytokines—growth-stimulating substances—from all directions as well. This improves the chances for successful development.
Cartilage Could be Key to Safe ‘Structural Batteries’
Kate McAlpine, Michigan Engineering

ANN ARBOR—Your knees and your smartphone battery have some surprisingly similar needs, a University of Michigan professor has discovered, and that new insight has led to a “structural battery” prototype that incorporates a cartilage-like material to make the batteries highly durable and easy to shape.

The idea behind structural batteries is to store energy in structural components—the wing of a drone or the bumper of an electric vehicle, for example. They’ve been a long-term goal for researchers and industry because they could reduce weight and extend range. But structural batteries have so far been heavy, short-lived or unsafe.

In a study published in ACS Nano, the researchers describe how they made a damage-resistant rechargeable zinc battery with a cartilage-like solid electrolyte. They showed that the batteries can replace the top casings of several commercial drones. The prototype cells can run for more than 100 cycles at 90 percent capacity, and withstand hard impacts and even stabbing without losing voltage or starting a fire.

“Nature does not have zinc batteries, but it has to solve a similar problem,” Kotov said. “Cartilage turned out to be a perfect prototype for an ion-transporting material similar to those of a good solid electrolyte, which has to meet the requirements are often mutually exclusive,” said Nicholas Kotov, the Joseph B. and Florence V. Cejka Professor of Engineering, who led the research.

To sidestep these trade-offs, the researchers used zinc—a legitimate structural material—and branched nanofibers that resemble the collagen fibers of cartilage.

In bodies, cartilage combines mechanical strength and durability with the ability to let water, nutrients and other materials move through it. These qualities are nearly identical to those of a good solid electrolyte, which has to resist damage from dendrites while also letting ions flow from one electrode to the other. Dendrites are tendrils of metal that pierce the separator from one electrode to the other. Dendrites are even more dangerous because there is no liquid to leak out.

To make working cells, the team paired the zinc electrodes with manganese oxide—the combination found in standard alkaline batteries. But in the rechargeable batteries, the cartilage-like membrane replaces the standard separator and alkaline electrolyte. As secondary batteries on drones, the zinc cells can extend the flight time by 5 to 25 percent—depending on the battery size, mass of the drone and flight conditions.

Safety is critical to structural batteries, so the team deliberately designed their cells by stabbing them with a knife. In spite of multiple “wounds,” the battery continued to discharge close to its design voltage. This is possible because there is no liquid to leak out.

For now, the zinc batteries are best as secondary power sources because they can’t charge and discharge as quickly as their lithium ion brethren. But Kotov’s team intends to explore whether there is a better partner electrode that could improve the speed and longevity of zinc rechargeable batteries.

A paper on this research is published in the journal ACS Nano, titled, “Biomimetic solid-state Zn2+ electrolyte for corrugated structural batteries.” This work was supported by the Air Force Office of Scientific Research and National Science Foundation. Kotov teaches in the Department of Chemical Engineering. He is also a professor of macromolecular science and engineering.

Faculty News

Sharon Glotzer - Professor Glotzer was elected to the National Academy of Engineering (NAE), the nation’s most prestigious engineering association. Glotzer is honored for developing computer-based design principles for assembly engineering and manufacturing of advanced materials and nanotechnology. She will be formally inducted during a ceremony at the NAE’s annual meeting in Washington D.C., on October 6th.

Jinsang Kim - Professor Kim received the Jon R. and Beverly S. Holt Award for Excellence in Teaching. The Holt Award is presented annually by College of Engineering to one faculty member in Materials Science and Engineering and one in Industrial and Operations Engineering to recognize outstanding teaching. This is the second time Professor Kim has won the award (2007).

Anne McNeil - Professor McNeil was named a 2019 Guggenheim fellow by the John Simon Guggenheim Memorial Foundation. Guggenheim Fellowships have been awarded annually since 1925 to those “who have demonstrated exceptional capacity for productive scholarship or exceptional creative ability in the arts.”

Ph.D. Graduates

Leanna Foster (Kenichi Kuroda) - In April, Leanna successfully defended her dissertation, “Combating Bacterial Infections Through Polymer-Bacteria Interactions.” She recently joined the healthcare team at Dupont in Midland, Michigan where she will be working on elastomers.


Master’s Graduates

Congratulations to our 2019 Master’s Graduates: Zihe Gao, Michael Jones, Ting Lin, Brandon Skoog, Mengjie Yu, and Shuqing Zhang!

We look forward to seeing Ting, Mengjie, and Shuqing when they return this fall to pursue the Macro Ph.D. program.
Student News

Kanat Anurakparadorn - Kanat joined the Ph.D. program in the Winter 2019 term. He earned both a Bachelor’s and Master’s degree in Mechanical Engineering from King Mongkut’s University of Technology Thonburi and Xian Jiaotong University, respectively.

Rose Cersonsky (Sharon Glotzer) - Rose received the Biointerfaces Institute Student Innovator Award, and was one of the featured speakers at the BI Research Day in March.

Derek Frank (Adam Matzger) - Derek had a paper published in Molecular Pharmaceutics, “Effect of Polymer Hydrophobicity on the Stability of Amorphous Solid Dispersions and Supersaturated Solutions of a Hydrophobic Pharmaceutical,” and presented “Polymer-Mineral Composites Mimic Human Kidney Stones in Laser Lithotripsy Experiments” in collaboration with the University of Michigan Department of Urology at the American Urological Association’s annual meeting.

Arushi Gupta (Jeff Sakamoto) - Arushi advanced to candidacy for the Winter 2019 term.

Ryan Hall (Ronald Larson) - Ryan published an article in Macromolecules, “Determining the Dilution Exponent for Entangled 1,4-Polybutadienes Using Blends of Near-Monodisperse Star with Unentangled, Low Molecular Weight Linear Polymers.”

Ying Liu (Ronald Larson) - Ying received the Teh-Hsun Lee Award from Rackham Graduate School.

Ayse Muniz (Joerg Lahann) - Ayse advanced to candidacy for the Winter 2019 term.

Da Seul Yang (Jinsang Kim) - Da Seul was awarded a Rackham Predoctoral Fellowship.

Yingying Zeng (Jinsang Kim) - Yingying was selected as a Barbour Scholar for the 2019-2020 academic year.

Lisha Zhang (Henry Sodano) - Lisha took third place for the best presentation award at the Spring 2019 American Chemical Society National Meeting for her poster titled, “New Frontier in Aerospace Polymers: Advances and Challenges in Experiments and Simulations.”

Ying Liu, Yingying Zeng, and Muru Zhou - In May, Liu, Zeng, and Zhou participated in the Biointerfaces Interlaboratory Committee’s (BIONIC) Bio-Hackathon on Aging. Students learned from world-renowned experts in the field of aging, participated in brainstorming sessions, and formed teams to develop solutions for clinical needs. In the end, their team paper was accepted to engrXiv. Congratulations!

Ying Liu, Yingying Zeng, and Muru Zhou - In May, Liu, Zeng, and Zhou participated in the Biointerfaces Interlaboratory Committee’s (BIONIC) Bio-Hackathon on Aging. Students learned from world-renowned experts in the field of aging, participated in brainstorming sessions, and formed teams to develop solutions for clinical needs. In the end, their team paper was accepted to engrXiv. Congratulations!

ACS POLY/PMSE Student Chapter

The Winter 2019 term marked the end of an eventful and productive year for the ACS POLY/PMSE chapter filled with industry seminars, outreach, and social events.

The chapter hosted three industry seminars this semester from companies including PPG, Proctor & Gamble, and Wacker Corporation. Representatives from each company spoke with graduate students about company culture, job opportunities, and the application process.

The ACS POLY/PMSE outreach initiative, led by Violet Sheffey, visited 8 different schools across Ann Arbor, Ypsilanti, Taylor, and Detroit. A new lesson called “Super Absorbent Polymers in Baby Diapers” utilizes concepts such as osmosis, equilibrium, and electrolyte behavior to explain the science behind sodium polyacrylate, the absorbent material used in baby diapers.

The chapter hosted several social events including a Lunar New Year celebration, a trivia night, and a bowling event cohosted with Macro’s mentorship program.

REACT 2019 is scheduled for July 18th, and the planning committee is still seeking sponsors. If interested in supporting this fantastic teacher outreach event, please contact Ayse Muniz at ajmuniz@umich.edu.

Macro Alums - We Would Like to Hear From You!

We would like to feature our alums on the website and in future newsletters. Please send us your updated contact information and let us know more about your current activities and news. Updates can be sent to jpollak@umich.edu.
Support Macromolecular Science & Engineering

Each year we strive to offer our students the best possible education and research opportunities. Your gift to the program provides the funding for that margin of excellence that prepares our graduates to compete in today’s world and make substantial contributions to society.

We are grateful for your continued support of the Macro program and count on you to help us offer these exceptional opportunities!

Macro has several endowed scholarships and awards that are given in honor of Macro founder Charles G. Overberger, former Director Frank E. Filisko, and longtime Macro Coordinator Nonna Hamilton.

We invite you to visit macro.engin.umich.edu/giving to contribute and learn more about the ways in which your gift can support Macro. You may also give by calling 888-518-7888.

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