Dear Alumni and Friends,

I hope you have been enjoying your summer, we have a lot of exciting news to share from the last several months!

In January Professor Mark Bansazak Holl became Head of Chemical Engineering at Monash University in Melbourne, Australia after serving for two and a half years as our Macro Director. We deeply appreciate Mark’s enthusiasm for and outstanding contributions to our program, and wish him great success at Monash! After Mark left I filled in as interim director and recently accepted to serve as the new Macro Director. This is an honor and I look forward to working with you to continue to build an outstanding Macromolecular Science & Engineering Program.

We were thrilled to learn in February that the ACS POLY/PMSE student chapter was selected as winners of the 2018 College of Engineering Elaine Harden Award. This is given to the student organization that “best exemplifies dedicated leadership and service to the community”. Their wonderful work and excitement for both on and off campus outreach activities was also recognized by ACS POLY/PMSE. They received the Best Student Chapter Award for 2018. This is the third time the chapter has been selected, previously winning in 2017 and 2014.

Our Macro faculty members have stepped in for important leadership positions. Professor Ellen Arruda was selected as the Chair of Mechanical Engineering and will begin her appointment in September. Professor Michael Solomon has been appointed Dean of the Rackham Graduate School and Vice Provost for Academic Affairs-Graduate Studies. His appointment will begin in July, though Professor Solomon has also been serving as interim dean since last year.

Professor Scott VanEpps from the Department of Emergency Medicine has joined Macro, enriching our already profound research portfolio. Lastly, Professor Tim Scott has been promoted to Associate Professor with tenure. Congratulations to all!
Director's Message (CONTINUED FROM PAGE 1)

PPG has again generously provided valuable fellowship support to the Macro program. Six Ph.D. students received PPG Summer Fellowships and a few new incoming students will receive PPG Fellowships this fall.

This fall we will have 13 outstanding new students joining the Macro program (9 Ph.D. and 4 Master’s). Our thanks to Professors Somin Lee and Henry Sodano for their work on the admissions committee to conduct a holistic review of a large number of applications. We also appreciate the work of current Macro students for their efforts during the campus visit days.

The upcoming 42nd Annual Macro Symposium will be held on October 24th and 25th this fall. The theme this year is “Physical & Chemical Interactions of Polymeric Systems.” We are excited to once again be planning a day of student-focused professional development short courses. This fall will also be 50 years since the Macromolecular Research Center (Macro’s original name) was founded. We hope you will be able to join us for the symposium and celebrate this exciting time!

Best wishes for the rest of your summer and the coming school year.

IN MEMORIAM

Professor Mark Banaszak Holl Accepts Position As Professor & Head of Chemical Engineering at Monash University

In January 2018 Professor Mark Banaszak Holl began a new position as Professor and Head of Chemical Engineering at Monash University in Melbourne, Australia. Professor Banaszak Holl had been Macro Director since the fall of 2015 and was an active Macro faculty member for over twenty years. The Chemical Engineering program at Monash is the top ranked in Australia and the university is a member of the Group of Eight, a collective of Australia’s top research institutions.

As Macro Director Professor Banaszak Holl secured funding to support Ph.D. research rotations and expansion of the program, and helped develop new ways for students to supplement their research education. This includes providing opportunities for students to use entrepreneurship-focused coursework as part of their degree, take part in a wide range of professional development activities, and connect with industry partners. We wish Professor Banaszak Holl all the best for this exciting new opportunity!

Professor Ellen Arruda Named Chair of Mechanical Engineering

Professor Ellen Arruda has been selected as the next chair of the Department of Mechanical Engineering and will begin the appointment on September 1st. Professor Arruda has been at Michigan since 1992 and joined the Macro faculty in 1999.

“I am honored and excited to lead this fantastic mechanical engineering department at this time,” Arruda said. “Mechanical engineering at Michigan is one of the best places in the world to be if you desire to engage in creative solutions that improve the quality of life and make the world safer, better, and cleaner.”

Recognized as a trailblazer in her field, Arruda’s groundbreaking research and teaching have secured her position as a world leader in the areas of theoretical and experimental mechanics of molecular materials and in tissue engineering of soft tissues and tissue interfaces. Her work has made tremendous impact on improving human health and life, such as advancing technologies for the repair of the anterior cruciate ligament and the development of a shock-absorbing helmet to prevent brain injury.

42nd Annual Macro Symposium

October 24th & 25th, 2018

The 42nd Annual Macro Symposium, “Physical & Chemical Interactions of Polymeric Systems”, will be held later this year on October 24th and 25th.

The event will again feature on the first day a series of professional development short courses followed by a networking dinner. This year the short courses will focus around the roles and responsibilities of a scientist and engineer outside the lab.

The schedule for the second day includes invited research talks from Professors Sharon Glotzer (Michigan), Phil Messersmith (UC Berkeley), Chinedum Osuji (Yale), and M. Scott Shell (UC Santa Barbara). As always the day will also include poster sessions and selected student speakers.

More information will be available at: macro.engin.umich.edu/symposium
PPG Donation Supports Fellowships, Symposium, and More

Macro is thrilled to share that a generous $50,000 donation from PPG has provided support for a number of student fellowships, the Macro Symposium, and important professional development opportunities for Macro students. PPG has been active on campus with Macro and other CoE students, visiting regularly and offering a variety of workshops and chances for students to learn more about industry research opportunities.

In the spring six current Ph.D. students were selected as the second class of Summer PPG Fellows. Derek Frank, Nisha Hollingsworth, Tianyu Liu, Laura Saunders, Harry van der Laan, and Da Seul Yang each received $5,000 in support from PPG to fund their research efforts during the summer of 2018. Additional awards will be made in the fall to members of the incoming Ph.D. class.

PPG has again also provided important support to the Macro Symposium. This includes sponsorship of the polymer engineering poster awards, travel grants for undergraduate attendees, and more. Lastly, part of the award was designated for both on and off-campus professional development opportunities for Macro students. This award will be used to bring special workshops and speakers to campus for Macro students in addition to funding unique professional development opportunities that students may not otherwise be able to attend.

Macro Alumni Visits

Macro was happy this term to welcome back to campus two graduates, Professor Sarah Calve (’06, Arruda) and Dr. Priyanka Desai (’15, Larson). Dr. Desai, who is currently a project leader at Shell, presented to a large group of students from Macro and other CoE programs about opportunities at Shell and more broadly her experiences of working in industry after graduation. In the spring Professor Calve visited campus to present a research talk, “Extracellular Matrix Dynamics During Musculoskeletal Development” and also had the opportunity to meet with Macro students and discuss her pathway to academia after completing her Ph.D.

It is always exciting to host our alumni on campus, please keep us updated if you plan to be in Ann Arbor!

“Everything-Repellent” Coating Could Kid-Proof Phones, Homes

In an advance that could grime-proof phone screens, countertops, camera lenses and countless other everyday items, Professor Anish Tuteja has demonstrated a smooth, durable, clear coating that swiftly sheds water, oils, alcohols, and, yes, peanut butter. The new “omniphobic” coating repels just about every known liquid and is the first that’s durable and clear. Easily applied to virtually any surface, it’s detailed in a paper published in ACS Applied Materials & Interfaces.

Tuteja envisions the new coating as a way to prevent surfaces from getting grimy, both in home and industry. “I have a 2-year-old at home, so for me, this particular project was about more than just the science,” Tuteja said. “We’re excited about what this could do to make homes and daycares cleaner places, and we’re looking at a variety of possible applications in industry as well. In the past, researchers might have taken a very durable substance and a very repellent substance and mixed them together,” Tuteja said. “But this doesn’t necessarily yield a durable, repellent coating.” More important than durability or repellency is a property called “partial miscibility,” or the ability of two substances to mix together in exactly the right way.

To make a versatile coating that’s optically clear and smooth enough to repel oils and alcohols, the team needed a repellent and a binder with exactly the right amount of miscibility, as well as the ability to stick to a wide variety of substrates. They also needed a coating that would stay smooth during processing and drying. “You can repel water with a rough surface that creates tiny pockets of air between the water and the surface, but those surfaces don’t always repel oils or alcohols because of their lower surface tension,” Tuteja said.

“We needed a very smooth surface that interacts as little as possible with a variety of liquids, and we also needed ingredients that mix together very well.” The team discovered that a mix of fluorinated polyurethane and a specialized fluid-repellent molecule called F-POSS would do the job. Their recipe forms a mixture that can be sprayed, brushed, dipped or spin-coated onto a wide variety of surfaces and its extremely precise level of phase separation makes it optically clear. “The repellent and binder mix together well enough to make a clear coating, but there’s a very small amount of phase separation between them,” explains Macromolecular Science & Engineering graduate Dr. Mathew Boban, an author on the paper. “That separation allows the F-POSS to sort of float to the surface and create a nice repellent layer.”

Tuteja believes that the coating will be inexpensive by the time it see market—fluorinated polyurethane is an inexpensive, common ingredient. And while F-POSS is rare and expensive today, manufacturers are in the process of scaling it up to mass production, which should dramatically lower its cost. The research team is also doing further studies to ensure that the coating is non-toxic for use in places like daycare centers. Tuteja estimates that the coating could go to market within the next two years.

The coating could also be used in refrigeration, power generation and oil refining—all industries that depend on the condensation of liquids. The new coating could enable equipment to slough off condensed water and chemicals more quickly, increasing efficiency by up to 20 percent. That’s a game changer, as those industries are some of the world’s most high-volume and energy intensive.

PPG Fellows from Macro & Chemistry at a meeting with PPG researchers Dr. Betsy Brown-Tsing (back, far right), Dr. Darin Laird (back, second from left), and Dr. Se Ryeon Lee (front, far left).
Kevlar-based Artificial Cartilage Mimics the Magic of the Real Thing
Katherine McAlpine, Michigan Engineering

The unparalleled liquid strength of cartilage, which is about 80 percent water, withstands some of the toughest forces on our bodies. Synthetic materials couldn’t match it—until “Kevlartilage” was developed by researchers at the University of Michigan and Jiangnan University. “We know that we consist mostly of water—all life does—and yet our bodies have a lot of structural stability,” said Professor Nicholas Kotov. “Understanding cartilage is understanding how life forms can combine properties that are sometimes unthinkable together.”

While other varieties of synthetic cartilage are already undergoing clinical trials, these materials fall into two camps that choose between cartilage attributes, unable to achieve that unlikely combination of strength and water content. The other synthetic materials that mimic the physical properties of cartilage don’t contain enough water to transport the nutrients that cells need to thrive, Kotov said.

Meanwhile, hydrogels—which incorporate water into a network of long, flexible molecules—can be designed with enough water to support the growth of the chondrocytes cells that build up natural cartilage. The new Kevlar-based hydrogel recreates the magic of cartilage by combining a network of tough nanofibers from Kevlar—the “aramid” fibers best known for making bulletproof vests—with a material commonly used in hydrogel cartilage replacements, called polyvinyl alcohol, or PVA.

In natural cartilage, the network of proteins and other biomolecules gets its strength by resisting the flow of water among its chambers. The pressure from the water reconfigures the network, enabling it to deform without breaking. Water is released in the process, and the network recovers by absorbing water later. This mechanism enables high impact joints, such as knees, to stand up to punishing forces. Running repeatedly pounds the cartilage between the bones, forcing water out and making the cartilage more pliable as a result. Then, when the runner rests, the cartilage absorbs water so that it provides strong resistance to compression again.

The synthetic cartilage boasts the same mechanism, releasing water under stress and later recovering by absorbing water like a sponge. The aramid nanofibers build the framework of the material, while the PVA traps water inside the network when the material is exposed to stretching or compression. Even versions of the material that were 92 percent water were comparable in strength to cartilage, with the 70-percent version achieving the resilience of rubber.

As the aramid nanofibers and PVA don’t harm adjacent cells, Kotov anticipates that this synthetic cartilage may be a suitable implant for some situations, such as the deeper parts of the knee. He also wonders whether chondrocytes might be able to take up residence inside the synthetic network to produce a hybrid cartilage. But his potential applications are not limited to cartilage. He suspects that similar networks, with different proportions of aramid nanofibers, PVA and water, may be able to stand in for other soft tissues. “We have a lot of membranes in the body that require the same properties. I would like to evaluate the space,” Kotov said. “I will talk to doctors about where the acute need is and where this intersection of the properties will allow us to make best headway and biggest impact.”

Soft Power Cells Could Run Tomorrow’s Implantables
Gabe Cherry, Michigan Engineering

Inspired by the electric eel, a flexible, transparent electrical device could lead to body-friendly power sources for implanted health monitors, medication dispensers, and much more. The soft cells are made of hydrogel and salt, and they form the first potentially biocompatible artificial electric organ that generates more than 100 volts. It generates a steady buzz of electricity at high voltage but low current, a bit like an extremely low-volume but high-pressure jet of water. It may one day be useful for powering implantable or wearable devices without the toxicity, bulk or frequent recharging that come with batteries.

The researchers say they’ve taken an important first step that advances fundamental understanding of soft power sources. “The eel polarizes and depolarizes thousands of cells instantaneously to put out these high voltages,” said Professor Max Shtein, a co-author on the paper. “It’s a fascinating system to look at from an engineering perspective—it’s performance metrics, its fundamental building blocks and how to use them.”

One secret to the eel’s success is a phenomenon called trans-membrane transport. Specialized electrical organs contain thousands of alternating compartments, each with an excess of either potassium or sodium ions. The compartments are separated by selective membranes that, in the eel’s resting state, keep the two ions separate. When the eel needs to create a jolt of electricity, the membranes allow the ions to flow together. This creates a burst of power.

The researchers built a similar system, though instead of sodium and potassium, they used the sodium and chloride that are naturally combined in common table salt, dissolved in water-based hydrogel. They printed thousands of tiny droplets of the salty gel on a plastic sheet, alternating them with hydrogel droplets of pure water. The alternating droplets are similar to the eel’s compartments, and their differing salinity can be used to produce electricity.

To mimic the eel’s selective membrane the team used a second sheet of alternating droplets, this one made of charge-selective hydrogel. Each droplet allows either positively charged sodium or negatively charged chloride to pass, excluding the other. To generate power the two sheets are pressed together, connecting saline and freshwater droplets across the charge-selective droplets in series. As the salty and fresh solutions mix, the charge-selective droplets move the sodium and chloride ions in opposing directions, producing an electric current.

The researchers took one final trick from the eel: its thousands of compartments can shuffle ions instantaneously, producing a coordinated jolt just when it’s needed. The researchers needed to do something similar with their thousands of alternating cells, combining them all in exactly the right order, simultaneously. The team solved the problem with an origami technique called a Miura fold, alternating all four droplet types in a precise pattern on a flat sheet that had been laser-scored in a Miura pattern. When pressure was applied, the sheet quickly folded together, stacking the cells in exactly the right positions.

“The electric organs in eels are incredibly sophisticated; they’re far better at generating power than we are,” said Professor Michael Mayer of the Adolphe Merkle Institute of the University of Fribourg, the corresponding author on the paper. “But the important thing for us was to replicate the basics of what’s happening. You need two ionic solutions of different strengths and two membranes with selectivity for different ions. If you can assemble and disassemble a large number of these four compartments in a repeating sequence in a fast and coordinated fashion, you’re creating essential parts of what the eel does.”
Microscale 3D Printing for Medicine
Kate McAlpine, Michigan Engineering

Precision 3D structures can be built with implantable materials using a new method pioneered at the University of Michigan, and this capability could enable better cancer treatments as well as implants using stem cells to create living patches.

For a long time, polymers (such as plastics) have been spun into threads with diameters on the microscale by electrically charging the polymer and flowing it through a needle. This produces a thin jet that runs toward an electrical ground, but lacks control over where that thread lands. Now, by modifying the electric fields around the polymer thread, the team has achieved fine control over the jet and built the threads into a variety of lattices.

“The 3D jet writing enables the next step forward in tissue engineering applications including drug screening, tissue regeneration and personalized medicine,” said Joerg Lahann, professor of chemical engineering. “We can stack fibers one tenth the size of a human hair into complex 3D structures, creating housing for living cells using very little non-biological material. This is particularly important for stem cells, which turn into particular tissues based on cues in their environments.”

To prove this concept, the team created 3D-written scaffolds to patch holes in the skulls of mice. They loaded stem cells into the scaffolds and soaked them in a fluid that encouraged the cells to become bone cells. They then inserted the scaffolds into the holes in the skulls. While these holes were too big to heal on their own, they closed completely in the patched mice.

Lahann is also interested in the potential to use the scaffolds to create a tumor-like environment. Tumor cells captured from patients – either through biopsies or blood draws – could be implanted in the scaffolds. These artificial tumors could then be treated with different drug combinations, helping doctors identify the right therapy to kill off a tumor.

“The 3D jet writing bridges the macroscale and microscale. While the scaffold itself is large enough to handle, the features within it are on the scale of a cell. This provides an environment where cells can grow in 3D alongside other cells, creating a more accurate tissue mimic,” said Jacob Jordahl, the inventor of 3D jet writing. “Whether this tissue is anything from cancer to bone, 3D jet writing can be implemented to answer a diverse range of research questions.”

Bone is a common metastatic site, so the team implanted the bone scaffolds into mice to see if the scaffolds could fool cancer cells into starting new tumors there. They then injected breast cancer cells into the mice. Indeed, the bone scaffolds soon supported colonies of breast cancer cells.

The study, titled, “3D Jet Writing: Functional Microtissues Based on Tessellated Scaffold Architectures,” is published in Advanced Materials.

Faculty News

Nicholas Kotov - Professor Kotov was selected as one of five Gold Prize award winners in the inaugural 2018 Mobile World Scholar Challenge. He was recognized for his work on biomimetic vibration isolation technology which uses nanostructured materials to build composites that replicate the structure and function of tooth enamel. This has a wide range of potential applications for mobile technology in environments with constant vibration.

Samuel Krimm - Professor Emeritus Samuel Krimm recently authored a paper in the Journal of Physical Chemistry, “Milieu-Initiated Inversion of the Aqueous Polyproline II/β Propensity in the Alanine Tripeptide: Aggregation Origin of the Onset of Amyloid Formation”. Professor Krimm writes that “we have gained insight into the possible initiation step of amyloid plaque formation, which also leads to the need for a paradigm change in thinking about the description of the resulting neurodegenerative diseases.”

See page 3 for updates on Professor Ellen Arruda and Professor Mark Banaszak Holl.

Ph.D. Graduates

Mathew Boban (Anish Tuteja) - This spring Matt defended his dissertation, “Designing Robust Liquid and Solid Repellent Surfaces”. Matt’s exciting work on omniphobic surfaces is detailed further on page 5.

Ming Dang (Peter Ma) - Ming’s dissertation, “Biomimetic Approaches for Bone Tissue Engineering” was defended last winter. Ming won the 2017 Overberger Student Research Award and in January he began working as a Senior R&D Engineering with Boston Scientific.

Jaehun Jung (Jinsang Kim) - Jaehun completed his Ph.D this January. His dissertation examined molecular design principles to achieve bright room temperature phosphorescence from metal free purely organic phosphors.

Bradley Keller (Ted Goodson) - In the spring Brad defended his dissertation, “From Small Molecules to Polymers: Linear and Nonlinear Optical Properties of Organic Conjugated Systems for Solar Application”.
Student News

Rosy Cersonsky (Sharon Glotzer) - Rosy has led development and planning of the Research Education & Activities for Classroom Teachers (REACT) event, an on-campus outreach initiative taking place this summer. Earlier in the year she received a Rackham Predoctoral Fellowship and was awarded the 2018 North Campus Dean’s Martin Luther King Spirit Award. In January her paper, “Relevance of packing to colloidal self-assembly” was published in PNAS.

Abhishek Dhyani (Anish Tuteja) - Abhishek advanced to candidacy during the Winter 2018 term and will serve as the Macro Peer Mentorship Coordinator for the 2018-19 school year.

Candy Gong (Ronald Larson) - This summer Candy is working as an intern at Ford as part of her participation in the Tauber Institute for Global Operations.

Taesu Kim (Theodore Goodson III) - Taesu advanced to candidacy for the Winter 2018 term.

Wang Li - In addition to his Macro Master’s degree, Wang is also earning his Master’s in Applied Economics at Michigan. This summer he is interning at Air Liquide in Shanghai.

Ying Liu (Ronald Larson) - Ying advanced to candidacy for the Winter 2018 term.

Laura Saunders (Peter Ma) - Laura advanced to candidacy for the Winter 2018 term.

Tianyu Liu (Michael Solomon) - Tianyu advanced to candidacy for the Fall 2017 term.

Harry van der Laan (Timothy Scott) - Harry received a Phi Kappa Phi Project Grant that will cover some research expenses and a trip to the Spring 2019 ACS Meeting. During the 2018-19 school year he will serve as Student Vice President of the University of Michigan Phi Kappa Phi chapter.

Mengjie Yu - This summer Mengjie is working as an intern for SABIC in Indiana.

Yingying Zeng (Jinsang Kim) - Yingying received a Rackham International Student Fellowship during Spring/Summer 2018 term.

ACS POLY/PMSE Student Chapter

The Winter 2018 term was another busy and productive one for the ACS POLY/PMSE student chapter. The chapter won the 2018 Elaine Harden Student Organization Award from the College of Engineering. The award is presented to the CoE student organization “that best exemplifies dedicated leadership and service to the community”.

The chapter continued to host industry partners, invited faculty speakers, and Macro alumni while also collaborating with other departments and campus student groups. Alongside these events students continued outreach efforts and hosted many social events for Macro students. The chapter hosted visits with Dow, PPG, and Shell during the term. During PPG’s visit Macro and Chemical Engineering students were invited to make short research presentations and receive constructive feedback from the PPG team.

Recent Macro alumna Dr. Priyanka Desai (’15, Larson) visited in January on behalf of Shell Oil, where she is a research scientist and project leader. Priyanka presented on the work she is doing at Shell and offered advice for students interested in industry jobs after graduation. The chapter hosted Priyanka for a networking dinner after her presentation that also drew students from several other graduate programs. Later in the term Professor Sarah Calve (’06, Arruda), an Assistant Professor of Biomedical Engineering at Purdue University, was hosted for a seminar and campus visit.

Working to build on-campus partnerships, the chapter also hosted faculty visits with other programs and departments. Former Macro faculty member, Professor Jeffrey Moore (University of Illinois) was jointly hosted in April by ACS POLY/PMSE and CALCIUM and CSIEIUM, two Chemistry department groups. The Biointerfaces Institute and ACS POLY/PMSE hosted Professor John Rogers of Northwestern University in February for a presentation about materials for biodegradable electronics.

The chapter has continued their outstanding outreach work and this summer is expanding on-campus efforts for teacher outreach. The student team of Rosy Cersonsky, Ayse Muniz, and Alyssa Travitz has again organized an on-campus teacher workshop, Research Education and Activities for Classroom Teachers (REACT). The REACT program brought over 60 K-12 teachers to campus for a day of research presentations, lab tours, and walkthroughs of classroom activities. Each teacher was provided materials so that they can run the activities within their classroom. The event was sponsored by individual faculty, departments, and other offices around campus and expanded to involve students from across the College of Engineering and other Rackham Graduate School programs.

Looking to next year, the chapter recently selected officers for the upcoming 2018-19 school year. Ayse Muniz and Alyssa Travitz will serve as Co-Presidents. Violet Sheffey will be the Vice President for Outreach, and Ying Liu the Vice President for Student Affairs. Zhihe Gao will be treasurer, and Muru Zhou the secretary.
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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