COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

MECHANICAL ENGINEERING ANNUAL REPORT

Mechanical Engineering 2018-2019

MESSAGE FROM THE CHAIR

What do you get when you give some of the brightest and most motivated student minds access to world-class faculty and facilities and present them with extremely difficult problems to solve?

Mechanical engineers who have a positive impact on the world around them.

As chair of the University of Michigan Department of Mechanical Engineering (U-M ME), I have the privilege of seeing this on a daily basis. Our work — our teaching, our research, our service to the profession — has a real, tangible, positive influence. Each day in ME, our students, staff, and faculty work together to develop solutions that improve our world and the quality of life of its inhabitants.

Engagement, innovation, impact. These threads are woven throughout the efforts and accomplishments we're proud to share in the following pages.

From AI, automotive engineering, and biosystems to robotics, sustainable energy, materials, and transportation of the future, our faculty conduct high-impact research that crosses traditional disciplinary boundaries. Collaborations span the College, the University, and the world, spurring innovation. That spirit of innovation begins "at home," with several departmental initiatives designed to fuel creative teaching and research strategies.

Our Research Innovation Program in ME (RIP_ME) and Teaching Innovation Program in ME (TIP_ME) are two examples, helping our faculty explore visionary approaches. This year faculty submitted many compelling proposals, and three were selected. Teaching innovation projects include development of next-generation student design experiences that inherently take into account social, ethical, environmental, and economic factors and creation of an integrated online component of core undergraduate courses to improve engagement and learning. The winning RIP project focuses on revolutionary experimental and computational tools to address grand challenges in energy conversion, transport, and storage.

Enabling our research are state-of-the-art facilities. Following the completion of several major building and renovation projects, including the $46 million Mechanical Engineering Research Complex, the U-M Board of Regents approved the schematic design for the $75 million Ford Robotics Building. The new (and very cool) facility will include labs customized for many types of robotics technologies and applications. Several ME faculty conduct robotics research and will have space in the new building for their work.

In addition to receiving a number of prestigious awards, our faculty are having a broader impact through service, playing leading roles in many areas of the University and beyond. (Read more in ME Leads on page 6.) Further extending our impact, we welcome five new faculty members this year: assistant professors Solomon Adera, Ashley Bucsek, Jon Estrada, and Nima Fazeli, and lecturer Heather Cooper

We also welcome our new Diversity, Equity & Inclusion (DEI) Coordinator Davon Wheeler, who will support DEI activities for faculty, staff, and students so that these concepts become even more ingrained in who we are and what we do. (Read more about Davon and his role in the Q&A on page 35.) We're excited, too, about our new WoMEntoring student group, launched to support community-building among female students and open to all students. (You can learn more about the impetus for WoMEntoring in the Q&A with co-founder Laine Katherine Chan on page 33.)

You'll find many other examples throughout this report of how our work is making a difference and preparing our students for careers defined by contribution and service. I hope they inspire you the way they do me — everyday.

Q&A

When you picture U-M ME four years from now, what do you see?

I see our department as THE place people want to be. We will have redoubled our reputation in computational methods as fundamental tools, transportation, smart materials and devices, bioengineering, smart artificial intelligence, robotics and mechatronics, and advanced manufacturing — all areas called out by the mechanical engineering section of the National Academy of Engineering (NAE) as rapidly evolving. Large-scale collaboration is the hallmark of our research. We're recognized as the place for innovation in mechanical engineering education and community engagement. Our research active faculty members are nurturing more PhD students and post-docs towards academic careers at top institutions. Engaged learning is happening in the classrooms of the future and beyond, utilizing technologies and methods we've barely begun to employ today. The staff members are professional partners adding value to our research, teaching, and service enterprise. Our research portfolio is broadened with support from philanthropic and industrial sources. I envision an ME department that is excited, energized, and enthusiastic.

What are your main goals during your tenure as chair?

I really have two passions. One is elevating the research enterprise and the other is broadening participation in mechanical engineering. I think the RIP_ME and TIP_ME initiative I started speaks to how I am trying to infuse the former. Broadening participation in ME means finding ways to communicate the possibilities with an ME degree to those segments of the potential undergraduate pool who don't know that they can achieve what they want to achieve with an ME degree. We've left too many creative minds out of the applicant pool by not communicating broadly how mechanical engineers solve the world's big problems, have a huge impact, and help people by making this world safer, cleaner, and better.

What do you believe is the greatest challenge for the field of mechanical engineering in the coming years, and how is U-M ME proactively preparing students and faculty to overcome it?

Mechanical engineering is a discipline that is rapidly evolving in every one of its sub-disciplines. U-M ME is preparing for this evolution by evolving as well. To do that, I believe we need to focus on a strategy that elevates our research to heightened levels of visible novelty and impactfulness. In our teaching we need to create meaningful interactions with our undergraduate students that inspire them for careers in research and prepare them to be adaptable, resilient members of the future ME workforce. We need to explore opportunities to overhaul the lecture format, integrate "campus of the future" concepts such as augmented/virtual/mixed reality, flipped classrooms, videotaped lectures, in-class cloud access to massive databases, etc., and otherwise optimize faculty involvement for efficacy and efficiency.

TRENDS & STATISTICS

Faculty Profile

- JOURNAL CHIEF EDITORS 4
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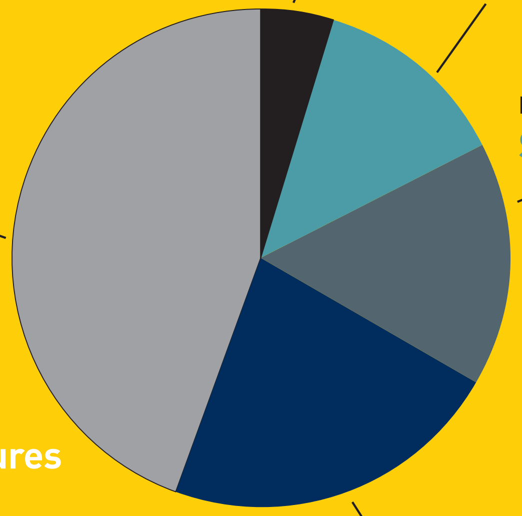
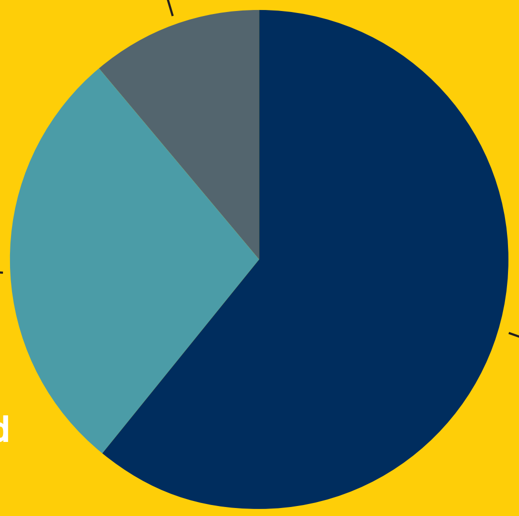
- SOCIETY FELLOWS 82



Annual Research Expenditures 2018-19

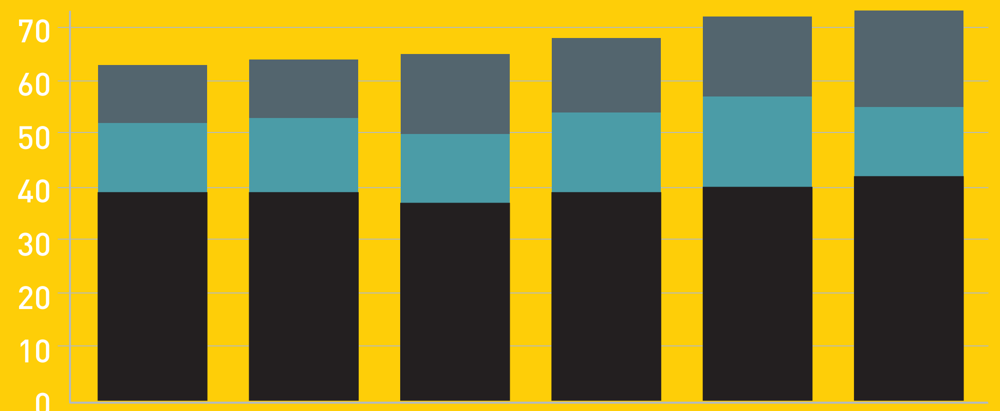
TOTAL RESEARCH EXPENDITURES
$35,229,849



Degrees Conferred 2017-18

Faculty Trends

Tenured and Tenure-Track



	FA14	FA15	FA16	FA17	FA18	FA19
Assistant	11	11	15	14	15	18
Associate	13	14	13	15	17	13
Professor	39	39	37	39	40	42
Total	63	64	65	68	72	73

ME Leads

ME FACULTY

Featuring nine ME faculty who are motivating and inspiring others through their leadership — on campus, nationally, globally. We're proud of the prominent roles they play at the University of Michigan and beyond, and we asked them to briefly describe their work, their favorite parts about it, and its impact. Here's what they had to say:

KON-WELL WANG

Stephen P. Timoshenko Collegiate Professor of Mechanical Engineering
Division Director, National Science Foundation (NSF) Engineering Education and Centers

The National Science Foundation (NSF) Division of Engineering Education and Centers that I lead invests in the creation of 21st-century engineers and the discovery of transformative technologies via convergent research to achieve societal impact. Its focuses include enabling centers and networks, such as the large-scale Engineering Research Centers (ERCs), that address grand challenges via basic research and launch new industries, broadening participation in engineering, improving education, and developing the engineering workforce of tomorrow.

I'm thrilled to have the opportunity to provide strategic leadership and serve the scientific enterprise at the national level in this role. My ME background, as a researcher, an educator, and an administrator (former department chair), helped prepare me for this position very well. ME has rapidly evolved into a very diverse discipline in recent decades, covering many different aspects of engineering and science. My experience helped me appreciate the importance of convergent cross-disciplinary research to make a true impact on the technical community as well as on our society. It also gave me the vision and skill to lead people with vastly different backgrounds to create a culture of inclusion that is critical for the new generation of center-type research, education, broadening participation, and workforce development.

BOGDAN EPUREANU

Arthur F. Thurnau Professor, Mechanical Engineering
Director, Automotive Research Center (ARC)

The ARC is a hub where new ideas are generated and translated into key technologies in several areas of autonomy of ground systems. These include vehicle dynamics, control, and autonomous behavior; human-autonomy teaming; high-performance structures and materials; intelligent power systems; and fleet operations and vehicle system of systems integration. For example, ARC leads the way in the creation of the next-generation combat vehicles.

I am passionate about building ecosystems of research and innovation based on sustainable foundations for talented people to succeed. That involves securing resources, defining values, creating strategies, and implementing processes. I find most rewarding the success that ARC students, faculty, government sponsors, and industry partners achieve in the ARC's daring projects.

My background is nonlinear dynamics, an area of research that helps us understand, model, and predict unique phenomena in complex systems, both engineered and natural. The ARC deals with complex systems that involve autonomous assets and their interaction with humans. Such convergence of disciplines and integrative thinking are prevalent in nonlinear dynamics and key strengths that ensure ARC's longevity.

> "ME has rapidly evolved into a very diverse discipline in recent decades, covering many different aspects of engineering and science."

VOLKER SICK

Arthur F. Thurnau Professor, Mechanical Engineering
DTE Energy Professor of Advanced Energy Research
Director, Global CO^2 Initiative

The Blue Sky-funded project I lead provided funding to launch a new technical research program within the U-M Global CO^2 Initiative, where we develop and deploy technologies that turn carbon dioxide into commercially successful products, such as concrete, fuels, and plant-based composite materials (see related article on page 17). The research program supports the creation of a new economy that we project to be at the $1 trillion level, built on reusing carbon dioxide and thereby helping to fight the effects of climate change. I'm thrilled to be able to identify and foster synergies among faculty across the University and beyond to pursue new directions.

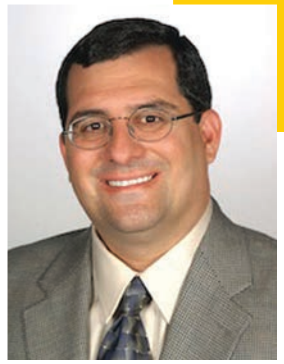
KRISHNA GARIKIPATI

Professor, Mechanical Engineering
Director, Michigan Institute for Computational Discovery & Engineering (MICDE)

MICDE now has a broad and deeply engaged community of computational scientists and engineers across the University. This has led to significantly greater and higher quality activity in research, education, and outreach for computational science and engineering. Additionally, we are recognized beyond the University as a leading institute of computational science and engineering.

The breadth of connections in engineering and science that Mechanical Engineering fosters has allowed me to engage with faculty members of all possible intellectual backgrounds at the University in my role as MICDE director. Among my favorite aspects of this role is the charting of future directions of research in computational science and engineering.

STEVE CECCIO



Professor, Mechanical Engineering
Vincent T. and Gloria M. Gorguze Professor of Engineering
Michigan Engineering Associate Dean for Research

As Associate Dean for Research (ADR), I support the research activities across the College of Engineering. There are over 1,400 sponsored research projects going on at any given time in the CoE, from very small to very large, totaling about $270 million in annual expenditures. In this role, I enjoy having a bird's-eye view of the many research topics our faculty and students are exploring — they teach me something new every day. Our team in the ADR's office is committed to helping our faculty engage in impactful research efforts. Much of what we do is embodied in the College's strategic plan, ME2020, where I manage the research pillar, including our Blue Sky Initiative. Our office also interfaces with units across the University and with external partners in government and industry. Whether it is working with the federal government on sponsored programs, developing resources from industry and private benefactors, or maintaining a culture of research compliance, our goal is always to provide research opportunities to and support for our faculty and students.

DIANN BREI

Professor, Mechanical Engineering
Chair and Professor, Division of Integrative Systems + Design (ISD)

As chair of ISD, I oversee the full division, including faculty, our six graduate programs, staff, and students. I really treasure our uniqueness — bringing together and effectively integrating across disciplines to holistically create real systems that add value to industry and, more broadly, to society. Energy systems, automotive systems, manufacturing systems, and other systems — how you design and build such complex systems in this rapidly changing world encompasses so many aspects beyond the technical, including social, global, political, business, and environmental contexts.

We're educating tomorrow's leaders to think transformatively since many industries are drastically changing. Our students aren't just contributing, they're leading. One of the best parts of my role is hearing industry leaders who work with our students say, "We don't know exactly what you've done, but we want more of it." We instill an integrative mindset in our students that's invaluable to the workforce of tomorrow. The world needs people who can think — who can lead — in an integrative way.

> "Mechanical Engineering is unstoppable, diverse, and inspiring."

ANNA STEFANOPOULOU

Professor, Mechanical Engineering
William Clay Ford Professor of Manufacturing
Center Director, University of Michigan Energy Institute

The U-M Energy Institute leverages many of our strengths — from leadership in powertrains to pioneering work on batteries for developing comprehensive energy storage solutions for electrified transportation. We envisioned and started the planning for an innovative research testbed and Living Laboratory for testing and supporting technology for a fully networked, high power charger integrated with the grid, campus buildings, repurposed batteries, and solar that will be used over 20 hours per day throughout the year for electric buses and shuttles. The installations will support cold weather operation, long-distance routes, scale-up of the decarbonization of the U-M vehicle fleets. And it could support resiliency hubs at U-M and in Ann Arbor for emergency response. We also focus on community engagement for EV policies and are educating the generation that will lead EV technology, policy and business development.

Mechanical Engineering is unstoppable, diverse, and inspiring. Working alongside extremely talented and motivated students and colleagues keeps me at the cutting edge. I love communicating the potential impact of the research of our faculty affiliates and reaching out to students who want to reduce the environmental footprint of our current unsustainable energy landscape.

ANGELA VIOLI

Professor, Mechanical Engineering
Principal Investigator, Accelerating the response to biothreats: Machine learning as screening for antimicrobials, Blue Sky Initiative

Antibiotic resistance has risen by as much as two-thirds in the last two decades and is now responsible for an estimated 700,000 deaths annually worldwide. By 2050, it is estimated that it will cause 10 million deaths per year — unless we ramp up efforts to tackle it.

It's been incredible to create a diverse team of outstanding researchers from across the University to work on a common vision: to use machine learning, molecular simulations, and biological experiments to develop next-generation antimicrobial nanomaterials that lower the odds of bacterial resistance.

In addition to scientific publications, we're reaching out to companies, government agencies, and NGOs to make sure our efforts get our team and Michigan on the map and these organizations are aware of our novelty, breadth, and uniqueness. We've also developed new instructional modules for high school science students and taught a course for eighth-grade students. We plan to expand this work to include elementary, secondary, and college students. There's so much momentum, and we're excited about the many opportunities ahead.

DAWN TILBURY

Professor, Mechanical Engineering
Assistant Director, Engineering Directorate, National Science Foundation (NSF)

The mission of the National Science Foundation (NSF) is to promote the progress of science; to advance the national health, prosperity, and welfare, and to secure the national defense. Most of the funds we are allocated by congress are sent out the door, to fund basic research — from astronomy to zoology, and everything in between. We also strongly support broadening participation, both creating opportunities for women and underrepresented minorities to participate in education and research activities and expanding our resources to underserved states and communities. Fundamental, basic research originally funded by NSF has led to 3D printing, touchscreens, and search engines. I look forward to seeing the advances that will arise out of the research we're funding today.

In my role as Assistant Director for Engineering, I get to work with incredible people. I had met many people in the Engineering directorate before — writing proposals, serving on panels, attending workshops, etc. Now, I interact at least as much with people outside Engineering as within. It's a wonderful opportunity to learn and discuss the major challenges in other fields — and learn how Engineering researchers can help contribute to solving those challenges.

At U-M ME, I learned to appreciate this type of multidisciplinary approach to research. I also found a very collaborative environment there, with faculty interested in working together, and helping each other, identifying challenging problems to work on that have a significant impact on the field, in industry, and on society.

NEW FACULTY

What drew you to U-M ME and how do you hope to help make it even better?

HEATHER COOPER

Title: LEO Lecturer

Education: Graduate of Purdue University with a BS in Mechanical Engineering and a Master's in Engineering, Masters in mathematics education from New York University

Cooper is the newest LEO Lecturer for ME and is coordinating the ME 450 capstone design course. She comes to U-M ME with over 20 years combined practice in industry and education, most recently as an education programs manager with the SME Education Foundation. She previously worked as a noise and vibration performance engineer for General Motors, an assistant professor of mechanical engineering technology at Purdue University, and a secondary math teacher in New York City.

"I am excited to be teaching the ME 450 capstone design course at U-M because it's a perfect blend of teaching, mentoring, and real engineering problems. My industry practice experience allows me to enhance the curriculum with many relevant examples of design process, collaboration, ethics, and career development. My goal is to help inspire the next generation of U-M mechanical engineers to use their unique talents to change the world."

SOLOMON ADERA

Title: Assistant Professor

Education: PhD in Mechanical Engineering from MIT, Post-doc from Harvard University

Research: Fundamental studies of heat and mass transfer, fluid-structure interactions, and water-energy nexus.

"In addition to academic excellence and longstanding reputation, the University of Michigan is diverse and inclusive. I was impressed by the collegiality of faculty and staff that I had the pleasure of meeting during my visit. I am delighted to join ME at U-M."

ASHLEY BUCSEK

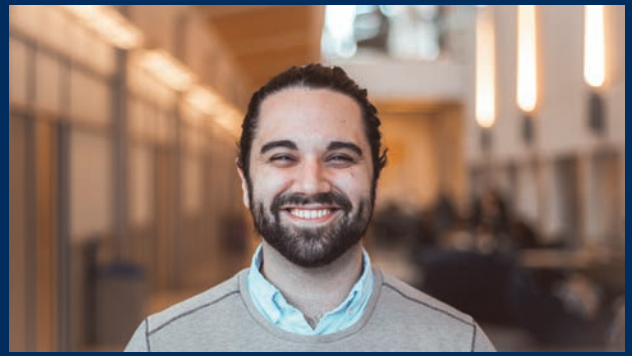
Title: Assistant Professor

Education: PhD and Master's in Mechanical Engineering from Colorado School of Mines, BS in Mechancial Engineering from the University of Wyoming, Post-doc from University of Minnesota

Research: Mechanical behavior of materials, micromechanical modeling, in situ/in operando 3D X-ray microscopy, energy conversion, among other topics.

"I was drawn to the U-M ME department to teach because I believe that ME students receive the most thorough and balanced engineering education, leading to competent and versatile engineers. The U-M ME department has established itself as one of the top ME departments in the world, producing some of the very best and brightest."

What drew you to U-M ME and how do you hope to help make it even better?



JON ESTRADA

Title: Assistant Professor

Education: PhD and Master's in Solid Mechanics from Brown University, Bachelors from MIT in Material Science and Engineering, Post-doc from the University of Michigan

Research: Experimental mechanics of soft and biomaterials, material characterization including high-speed rheometry, magnetic resonance, and inverse techniques, inertial cavitation dynamics, photoacoustic and laser microscopy, cell mechanics, image processing techniques, digital image, and volume correlation.

"As a faculty member, the ultimate privilege is to work with and set foundations for inquisitive, motivated, and collaborative students — the precise qualities that make the Michigan undergraduate and graduate populations uniquely excellent. As an engineer whose research spans the interdisciplinary space between materials science, solid and fluid mechanics, and biomedical engineering, it's exciting to bring my unique take on and do justice to some of the fundamental core classes that inspired me in my own academic journey.

I look forward to what collaborations will grow between my soft experimental mechanics laboratory and the skill-sets of this tremendously diverse ME faculty, and the prospect of teaming up across the University of Michigan to pursue and create truly world-class research."

NIMA FAZELI

Title: Assistant Professor

Education: PhD from MIT, Master's from University of Maryland at College Park, Post-doc from MIT

Research: Robotic manipulation, inference and state-estimation, physics-based learning and semantic AI, controls for hybrid systems, and contact modeling for robot interactions.

"U-M ME is a special place. The department brings together over 70 faculty from a broad range of expertise together in one place. This diversity, both in research and background, fosters a unique environment for growth, development, and discovery. I am proud and excited to be a member of this vibrant community.

I believe that robotic manipulation and AI hold the key to realizing the promise of robotics — a solution to society's biggest challenges. Healthcare, automation, disaster response, and so many other fields stand to gain tremendously from progress in these disciplines. Through my expertise in these areas, I plan on training the next generation of researchers and scientists who will tackle some of the most difficult challenges at the frontier of robotics."

NSF AWARDS

Featuring the National Science Foundation (NSF) Graduate Research Funding Program (GRFP) roles they play at the University of Michigan and beyond, we asked the awardees to briefly describe their work, their favorite parts about it, and its impact. Here's what they had to say:

Christina Rice

U-M ME is a good place to pursue this NSF-funded research because of the interdisciplinary nature of the program. For example, I regularly work with chemical engineers and the U-M hospital during my research. U-M ME also provides a good balance between fundamental work and emerging fast-to-market technologies. Finally, the faculty and staff blow me away with their support of my work and well-being.

I am working on simulating polymer behavior, specifically polymers that are heavy and take a long time to move. This means researching new algorithms that are computationally efficient and studying the physics of the polymers as they interact with surfaces and neighboring molecules. This research allows us to rapidly screen innovative new polymers for application and to gain fundamental insight into small-scale polymer behavior that is difficult to capture experimentally. This research has applications in several fields, from health to energy, but one application area we are particularly interested in pursuing is the role of polymers in blood clotting.


CHRISTINA RICE


REVANTH DAMERLA

Revanth Damerla

I chose to come to U-M ME because it gives me the opportunity to work on cutting-edge research at an institution with world-class facilities and resources. U-M ME is unique in that it also provides multiple pathways to translate my research into real-world solutions and have societal impact.

I am currently working on the design of an upper limb prosthesis concept for transradial amputees. This prosthesis will hopefully provide improved functionality over existing solutions and more closely mimic the capabilities of a real arm. This would increase convenience for amputees as well as allow them to have improved independence.

Nosakhare (Nosa) Edoimioya

U-M ME is a great place to utilize my NSF Award because I'm working with an advisor who has a wealth of knowledge in this field and I have access to the resources I need to learn about, design for, and implement my ideas for research.

I'm working to increase the productivity of additive manufacturing machines (3D printers) through the development of advanced control algorithms and improved mechanical design.

My research will address one of the key drawbacks of 3D printing in industry: low productivity. It has the potential to take 3D printers from a niche item to a tool that is essential to industrial manufacturing in the 21st century.

NOSAKHARE (NOSA) EDOIMIOYA

150TH CELEBRATION

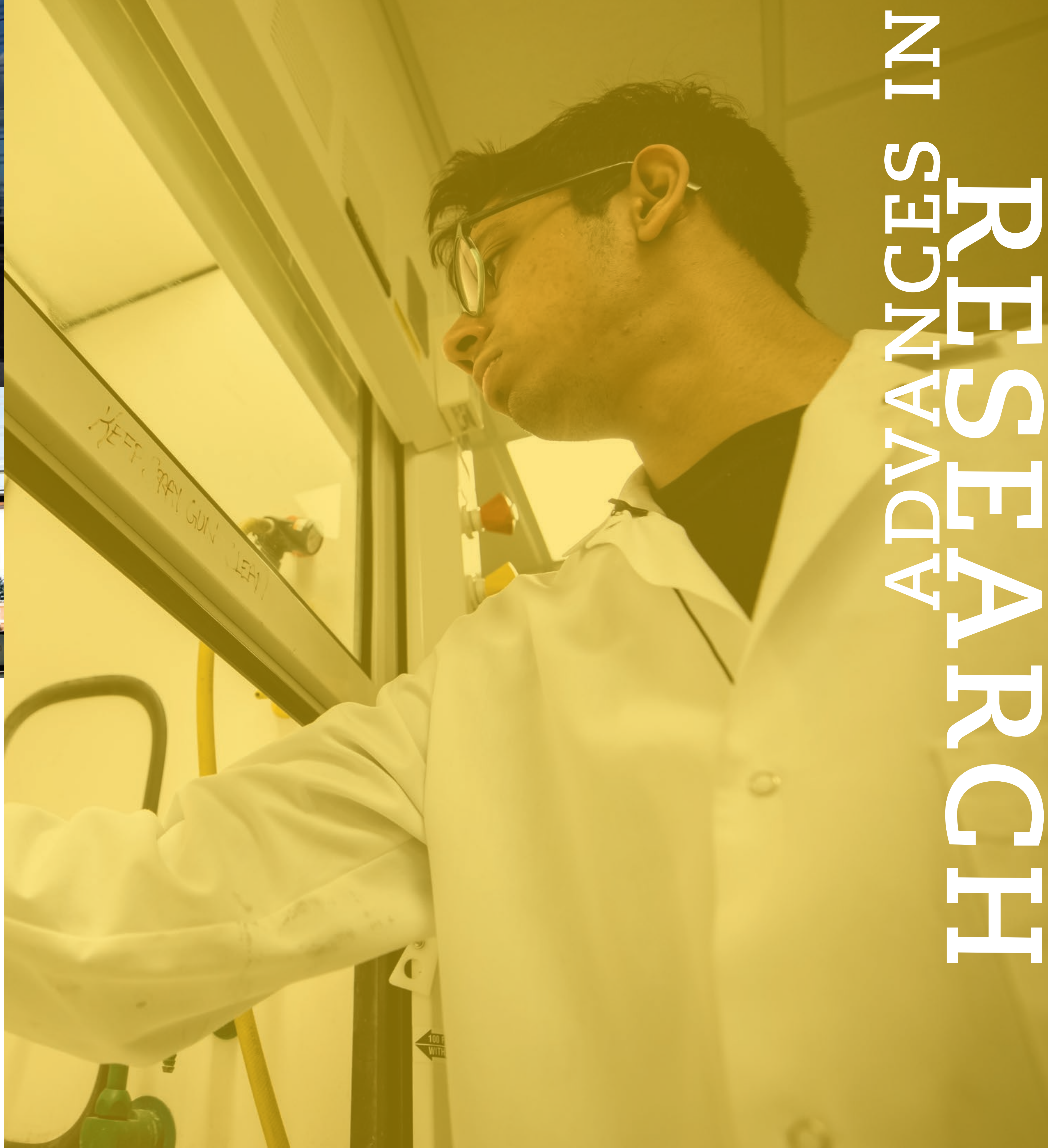
The University of Michigan Mechanical Engineering Department celebrated a major milestone in 2018, its 150th anniversary! ME helped pioneer the field 150 years ago, and continues to be a worldwide leader in research and education, both basic and translational, from transportation engineering to energy, from bio/health to manufacturing and beyond. Throughout 2018 the Department celebrated its sesquicentennial with a variety of events, including a distinguished speaker lecture series, culminating on September 21, 2018 with a full day of on-campus activities including panel discussions focusing on the Department's rich history and exciting future. The celebration also included a dinner at the historic Henry Ford Museum in Dearborn.

FORD MOTOR COMPANY Robotics BUILDING

Opening in early 2020, the Ford Robotics building will become the home of Michigan Robotics. The 140,000-square-foot, four-story complex will house classrooms, offices, a startup-style open collaboration area, and tailored lab space for a variety of robotic technologies. The building will include a three-story fly zone for autonomous aerial vehicles, an outdoor obstacle course for walking robots, high-bay garage space for self-driving cars, and dedicated space for rehabilitation and mobility robots such as prosthetics and exoskeletons.

And in a unique agreement, Ford will lease the fourth floor to perform robotics research and engineering in collaboration with U-M and other industry leaders.

This new building is designed to promote collaborative work across disciplines, involving students and faculty at all levels, from a variety of fields. U-M ME is the most represented department in Robotics with six core and eight affiliate faculty. U-M ME Joint Professor Jessy Grizzle is the Director of the Robotics Institute.



ADVANCES IN RESEARCH

Alan Taub
ME Professor

“ WHEN WE’RE SUCCESSFUL, WE’LL HAVE A CO^2 NEGATIVE MATERIAL. NOT ONLY DOES USING PLANT FIBERS PREVENT CO^2 EMISSIONS DURING FIBER PRODUCTION, OUR METHODS ALSO RECLAIM CO^2 AS THE PLANTS GROW.”

STRONGER, STIFFER, GREENER: CARBON-NEGATIVE NATURAL-FIBER COMPOSITES

Pictured left to right is MSE PhD student Amy Langhorst, U-M ME Professors Volker Sick and Alan Taub, Debbie Mielewski (Ford Senior Technical Leader), and ME Research Associate Professor Mihaela Banu.

Lightening the weight of the machines that move people by land, sea, and air is beneficial for many reasons, including improved fuel efficiency and the ability to carry higher payloads or added safety systems. A 10% reduction in the weight of a passenger car, for instance, leads to about a 6% improvement in fuel economy.

One key strategy to reduce weight is to design structures using lighter materials with improved properties, such as those with greater specific strength and stiffness. Given their light weight, neat polymers are attractive materials for weight reduction, but they’re neither strong enough nor stiff enough for structural applications. As a result, manufacturers across industries add reinforcing fibers such as glass (and more recently, carbon fiber) to add strength and stiffness to the material.

But producing the fibers — whether glass or carbon — for use in today’s advanced structural composites requires energy, and generating this energy releases greenhouse gases into the atmosphere.

“It takes a lot of energy to make these reinforcing materials,” said ME Professor Alan Taub. “Unfortunately, this makes many types of fiber-reinforced lightweight composites carbon positive and compels us to ask how we can do better. How can we produce advanced materials that are carbon neutral or, better yet, carbon negative?”

Taub, in collaboration with Ford Motor Company and ME Research Associate Professor Mihaela Banu, are looking beyond carbon neutrality and toward nature for a greener alternative: natural fibers from plants, since they absorb — rather than release — CO^2 as they grow.

Ford Motor Company has been developing natural fiber composites for over 10 years and has implemented many “green” materials in semi-structural Ford parts, including a wheat straw-filled storage bin, rice hull-filled wiring harness, and a cellulose-based armrest substrate. However, due to strength and stiffness limitations, natural fibers have yet to fully replace glass fiber reinforcement in structural automotive applications. In 2016, Ford’s team initiated a project to improve the properties of natural fibers using nanomaterials, and the project evolved into a doctoral thesis investigated by Amy Langhorst, a research scientist at Ford and PhD student in Taub’s group.

Triple challenge

Taub’s group is working with bamboo, hemp, and flax, adding an environmentally friendly nanomaterial to particular cells in the plants during growth or after harvesting to improve strength and stiffness. The cells form fibers, and these would then be extracted and used to reinforce the polymer composites.

Part of the challenge, noted Taub, is that plant transport mechanisms are extremely complex, which makes getting even nanoscale material to the targeted cells difficult. And therein lies another challenge: the need to work simultaneously at multiple scales. Extracting the strengthened fibers presents yet another hurdle since current methods can cause the fibers to undergo damage. The team is developing new ways to extract them from the plant to avoid this.

Abundant applications

With three decades of auto industry experience, Taub is first looking at automotive applications for the natural-fiber reinforcements under development. “But we’re certainly not restricted to one application — everything from appliances and sporting goods to commercial aircraft and ocean-going vessels could make use of natural-fiber-reinforced composites if we’re successful,” he said. And although the process for producing the strong natural fibers will be different than for glass or carbon fibers, the processing and equipment used for forming the resulting polymer composite into structures remains for the most part the same from an industrial perspective.

“What we’re looking at is a material substitution that fits into existing processing capabilities,” Taub said. This means the natural fibers have potential for large-scale implantation, which is key to positively impacting the environment.

“To have a real impact,” he said, “we have to replace tons of material. Fortunately, enough of this plant material is already being grown, so what we’re focused on now is improving the properties, improving the extraction methods, and making these advances with minimal cost increases.”

The project draws upon expertise across the University and includes collaborator Regina Baucom, associate professor of Ecology and Evolutionary Biology. Students from the Fall 2019 semester of MSE489, the Materials Science and Engineering senior capstone design course, will conduct an environmental lifecycle and cost analysis.

The project grew out of work by graduate student Amy Langhorst, who earned her bachelor’s degree in U-M Materials Science and Engineering in 2013 and took the senior design course with Taub. She now works at Ford Motor Company and is pursuing a doctoral degree with Taub as her advisor.

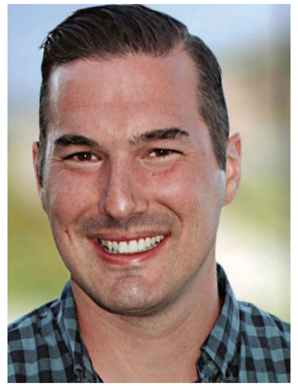
The project is part of U-M’s Global CO^2 Initiative, which supports development of sustainable and commercially viable carbon-negative technologies. Funding for early-stage, exploratory work is provided through the U-M College of Engineering Blue Sky Initiative, designed to help faculty develop high-risk, high-reward concepts. Additional funding is being provided by Ford Motor Company.

The project has high reward potential indeed. “When we’re successful, we’ll have a CO^2 negative material,” Taub said. “Not only does using plant fibers prevent CO^2 emissions during fiber production, our methods also reclaim CO^2 as the plants grow. We should be able to achieve lighter-weight structures, enabling better fuel economy using materials that are CO^2 negative. Our challenge is to improve the mechanical properties of the fibers while maintaining low cost.”

OPEN-SOURCE BIONIC LEG: FIRST-OF-ITS-KIND PLATFORM AIMS TO RAPIDLY ADVANCE PROSTHETICS

"THIS REPRESENTS THE FUTURE OF RESEARCH—RAPID PROTOTYPING OF OPEN-SOURCE ROBOTIC HARDWARE AND EMBEDDED SYSTEMS WITH SHARED CODE."

ME Assistant Professor Elliott Rouse makes last-minute adjustments to the Open Source Bionic Leg during testing.



Elliott Rouse
ME Assistant Professor

A new open-source, artificially intelligent prosthetic leg designed by University of Michigan and Shirley Ryan AbilityLab researchers is now available to the scientific community. The leg's free-to-copy design and programming are intended to improve the quality of life of patients and accelerate scientific advances by offering a unified platform to fragmented research efforts across the field of bionics.

"Our Open Source Bionic Leg will enable investigators to efficiently solve challenges associated with controlling bionic legs across a range of activities in the lab and out in the community," said lead designer Elliott Rouse, core faculty at U-M's Robotics Institute and assistant professor of mechanical engineering. "In addition, we hope our bionic leg will unite researchers with a common hardware platform, and enable new investigators from related fields to develop innovative control strategies."

Rouse and collaborator Levi Hargrove, director of the Center for Bionic Medicine at the Shirley Ryan AbilityLab, a research hospital in Chicago, unveiled the leg and its platform at the Amazon re:MARS conference in Las Vegas. Details on where to order the parts, how to put them together, and how to program the leg are now available at opensourceleg.com.

Hargrove, also an associate professor of physical medicine and rehabilitation and biomedical engineering at Northwestern University, is already using the leg in clinical studies.

"While the designs and code are free, the leg is still a high-end, state-of-the-art machine," said Hargrove. "It's a unique plug-and-play system that allows scientists to avoid research and development costs in the millions of dollars and immediately begin testing on prosthetics for the knee and ankle. It effectively lowers the barriers to entry for researchers."

Efficient, first-of-a-kind design

While designing the leg, Rouse focused on keeping it simple, low cost, and portable, yet high-performance. The result incorporates relatively inexpensive parts from just a few suppliers; a modular design that can act as a knee, ankle, or both; and an onboard power supply and control electronics that allow it to be tested anywhere.

In addition, the team adapted and incorporated new motor technology that has been developed for the drone industry. The flat pancake-style motors trade reduced speed for more torque. These lower-geared motors allow for more efficient, finer control and more human-like movements.

Researchers who work directly with people with disabilities often have to build their own robotic leg system, said Rouse. Instead of starting from scratch, researchers can take this common platform and, after some assembly, begin working on better solutions to help people with mobility impairments. The common platform also enables direct comparisons of new algorithms used to control the bionic leg, which researchers can then iterate and build upon.

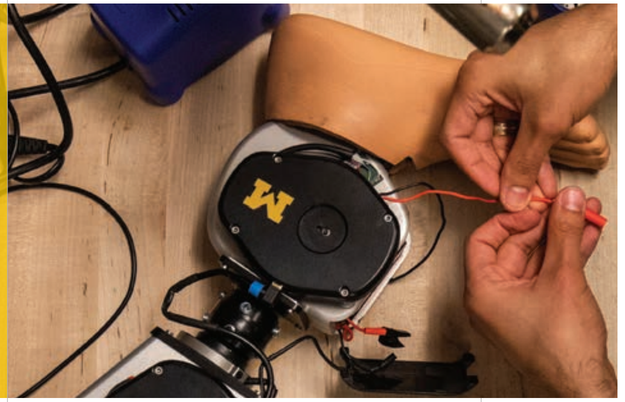
While there exist many open-source projects that develop prosthetics for the upper body, such as hands, this is the first such platform for the lower extremities. Research in lower limb bionics has traditionally lagged that of the upper limb prosthetics, primarily due to the high risk to maintain balance and support a patient's entire body.

The full bionic leg as specified costs $28,500, which includes parts machined by Star Rapid, actuators from Dephy, Inc., and a Raspberry Pi mini-computer that powers the artificial intelligence.

The advanced AI-based control, led by Hargrove, can automatically adapt the actions of the bionic leg to seamlessly switch activities, such as going from walking, to going up stairs, to down a ramp. To accomplish this, the team uses a combination of muscle contraction signals and sensor data from within the bionic leg to predict whatever behavior is required for the next step.

Community-driven research and development

As an open-source project, anyone can contribute to improving the leg's design and function. While the leg is meant as a research tool and not as a build-at-home solution, patients involved in the project can help focus and improve the design through their feedback in trials. Companies can prototype the leg with their own parts to enhance the design. And researchers can utilize the project website to discuss modifications and suggestions in design and control.



"This represents the future of research," Rouse said, "rapid prototyping of open source robotic hardware and embedded systems with shared code."

Elliott Rouse, is a core faculty member at U-M's Robotics Institute and assistant professor of mechanical engineering.

The team previously presented progress on the leg at the 2018 IEEE International Conference on Biomedical Robotics and Biomechatronics. This paper included first-author Alejandro Azocar, a PhD student in mechanical engineering at U-M, and Luke Mooney, co-founder of Dephy, Inc.

They are now partnering with groups nationally and internationally in developing and testing the leg, including Carnegie Mellon University, the University of Texas at Dallas, Georgia Tech, VA Puget Sound and University of Washington, and the University of Sydney.

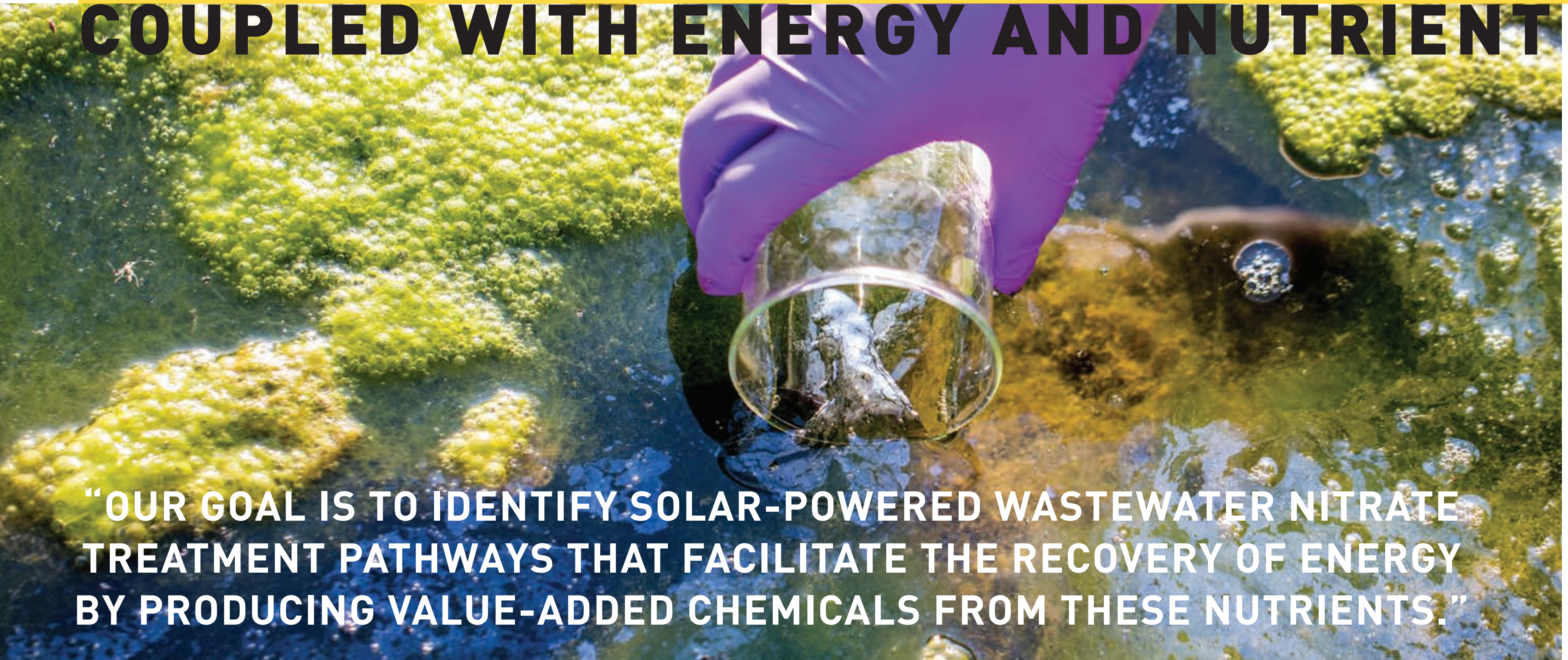
The project is supported by the National Science Foundation's National Robotics Initiative and the MSL Renewed Hope Foundation.

SOLAR-POWERED WASTEWATER TREATMENT COUPLED WITH ENERGY AND NUTRIENT RECOVERY

Rohini Bala Chandran
ME Assistant Professor

If a harmful algal bloom has ever closed your favorite lakeside beach or caused your municipality to issue a drinking water warning, a possible cause is excess nitrogen, phosphorous, and organic nutrients. These nutrients are present in the surface water runoff from farms, factories and our own well-fertilized backyards, and the excess nutrient build-up has been identified as a major cause of eutrophication, or the explosive growth of algae in water bodies. This can pose environmental threats to aquatic species and result in health risks in humanbeings (see fig. 1). The increased production and utilization of nitrogen fertilizers combined with fossil fuel combustion and contamination of groundwater and other surface-water bodies with reactive nitrogen species, including nitrates (NO3-), nitrites (NO2-), and ammonia (NH3), has become an increasingly concerning issue.

One area of particular concern to ME Assistant Professor Rohini Bala Chandran is the excess nitrogen-based nutrient buildup in wastewater. "Municipal wastewater treatment is energy-intensive requiring between 15 and 45 megajoules per kilogram of nitrogen-species present. Moreover, the overall energy consumption by public drinking water and wastewater utilities can often represent up to 40% of a municipality's electricity use," she said. "Water and wastewater treatment accounts for a surprising amount of the power consumption in the United States."



"OUR GOAL IS TO IDENTIFY SOLAR-POWERED WASTEWATER NITRATE TREATMENT PATHWAYS THAT FACILITATE THE RECOVERY OF ENERGY BY PRODUCING VALUE-ADDED CHEMICALS FROM THESE NUTRIENTS."

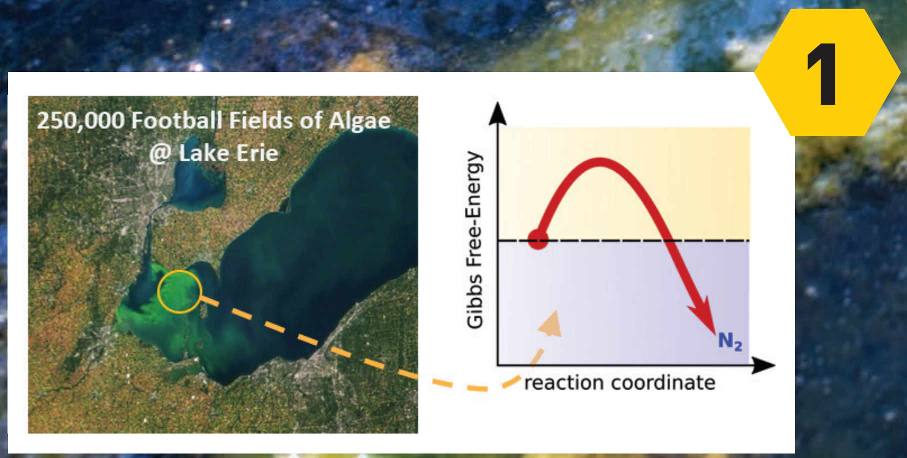


Fig. 1: Bright-colored algal fields, of sizes equivalent to 250,000 football fields, appear in Lake Erie every summer. Excess nitrogen, phosphorous, and organic contaminants in surface water and agricultural runoffs cause environmental threats of eutrophication and human health risks. The figure on the right indicates that the reduction of nitrogen-species including nitrates, nitrites, and ammonia are thermodynamically downhill reactions (negative free-energy change). We propose designing a process that catalyzes a spontaneous reaction to tap into the chemical energy stored in these nitrogen-contaminants.

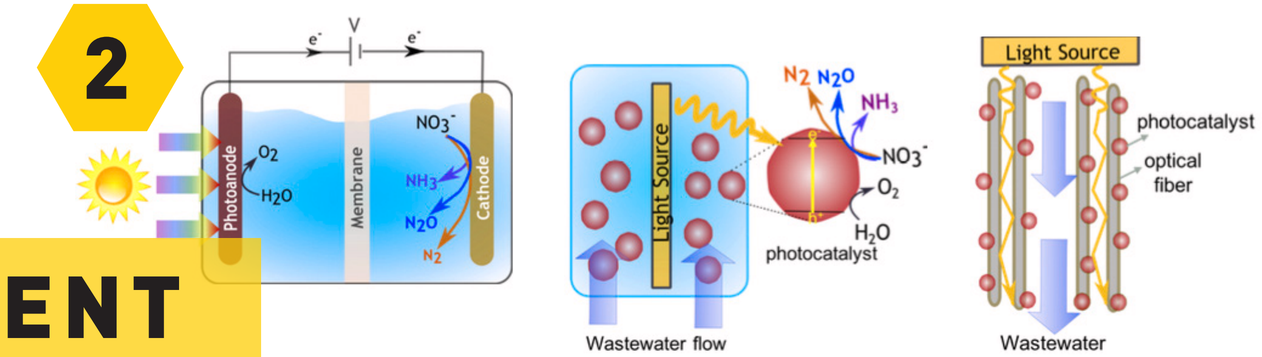


Fig. 2 Device-design concepts for the proposed solar device for wastewater nitrate treatment paired with water oxidation: (a) Planar photoelectrode architecture with a membrane to facilitate ionic transport and new reactor concepts with photocatalyst particles facilitating improved species transport and volumetric reactivity; (b) fluidized photocatalytic media with an upward moving wastewater stream that entrains the photocatalytic particles; and (c) immobilized photocatalysts on optical fibers to directly control delivery of light.

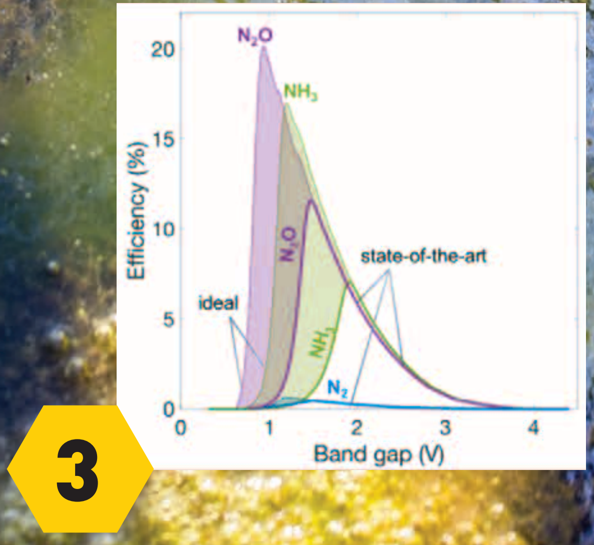


Fig. 3: Solar energy conversion efficiencies obtained as the ratio of the rate of chemical power released to the input solar power for the various nitrate reduction pathways as a function of light absorber bandgap for different electrocatalytic parameters. The thick lines assume properties of the state-of-the-art electrocatalysts and the lighter lines evaluate efficiencies assuming ideal reduction electrocatalysis, i.e. zero kinetic resistance to effect the nitrate reduction reaction.

Bala Chandran, who directs the U-M Transport and Reaction Engineering for sustainable Energy (TREE) Laboratory, also notes a bit of irony. "Some of the nutrients and chemical species present in wastewater could actually provide energy, yet we're spending money and energy to get rid of them. Wastewater is a misplaced resource in that respect."

State-of-the-art techniques to remediate nitrogen-based contaminants from wastewater are biological (microbial) and electrochemical ion-exchange processes. Both processes are typically energy intensive. Biological approaches may not be applicable for all waste streams, especially industrial effluents that harbor conditions unsuitable for microbial growth, and electrochemical ion-exchange approaches commonly applied at the industrial scale for drinking water applications often result in the generation of secondary concentrated waste streams.

Bala Chandran's research group, including ME doctoral student Luisa Barrera and ME senior Erika Brower, is developing more sustainable and scalable options. More specifically, her team is developing processes and devices that use renewable energy sources to pair energy and nutrient recovery from wastewater contaminants.

"Our goal is to identify solar-powered wastewater nitrate treatment pathways that facilitate the recovery of energy by producing value-added chemicals from these nutrients" said Bala Chandran. The work is funded by her startup funds and Mcubed, a University initiative to encourage innovative, interdisciplinary research. The project marries fundamental materials-scale catalysis, physics-based modeling, and experimental investigations.

Energy recovery

Fundamental efforts include gaining physical insights into understanding different nitrogen reduction pathways that yield value-added products, such as: ammonia (NH3) for use directly as a fuel or ammonium (NH4+) in dissolved form that can be used in fertilizer production and nitrous oxide (N2O) for use as an oxidizer in the burning and combusting of fuels, including in turbocharged automobile and jet engines.

An experimental component entails reactor prototyping, design, and demonstration of a solar-powered photocatalytic reactor to recover the energy and nutrients from the wastewater nitrates.

"Since we don't yet fully understand which nitrate reduction pathway is the most effective in maximizing energy recovery from the treatment process and which materials and device-scale designs help attain the most optimal process efficiencies, we're developing predictive physics-based models to determine the energy and nutrient recovery potential of the different reduction pathways and to guide materials selection and overall device design," she said.

The reactor design concepts Bala Chandran is developing will achieve a greater reactive surface area per unit volume and enhanced light and mass transport and therefore result in a more efficient utilization of materials and incident sunlight. Her group plans to accomplish this by exploring fluidized-bed photocatalytic particle reactors and fixed-bed photocatalysts immobilized on optical fibers (see fig. 2).

"As we improve species transport by maximizing reactive surface area, we improve the overall efficiency of our system," she said. The concepts under development also enable scalability — a challenge for photocatalytic reactor designs that have commonly used planar electrode architectures.

Preliminary results have identified efficiency limits for the different nitrate reduction pathways (see fig. 3) as a function of an important material properties — the photocatalyst bandgap and the electrocatalytic properties.

"Our results show we can attain solar energy conversion efficiencies of up to 11% and 7% respectively for producing nitrous oxide and ammonia with the state-of-the-art catalysts," said Bala Chandran.

The results also indicate there is scope for improved efficiencies aided by new materials discovery and design, because the group observed a twofold increase in the efficiency values for all the products formed (fig. 3) when ideal electrocatalysis for the nitrate reduction reaction was assumed.

Solving grand challenges

Bala Chandran's work is paving the way toward new, more sustainable and scalable ways to approach wastewater treatment. This is critical to help balance the global nitrogen cycle, a problem the National Academy of Engineering has designated a grand challenge for engineering in the 21st century.

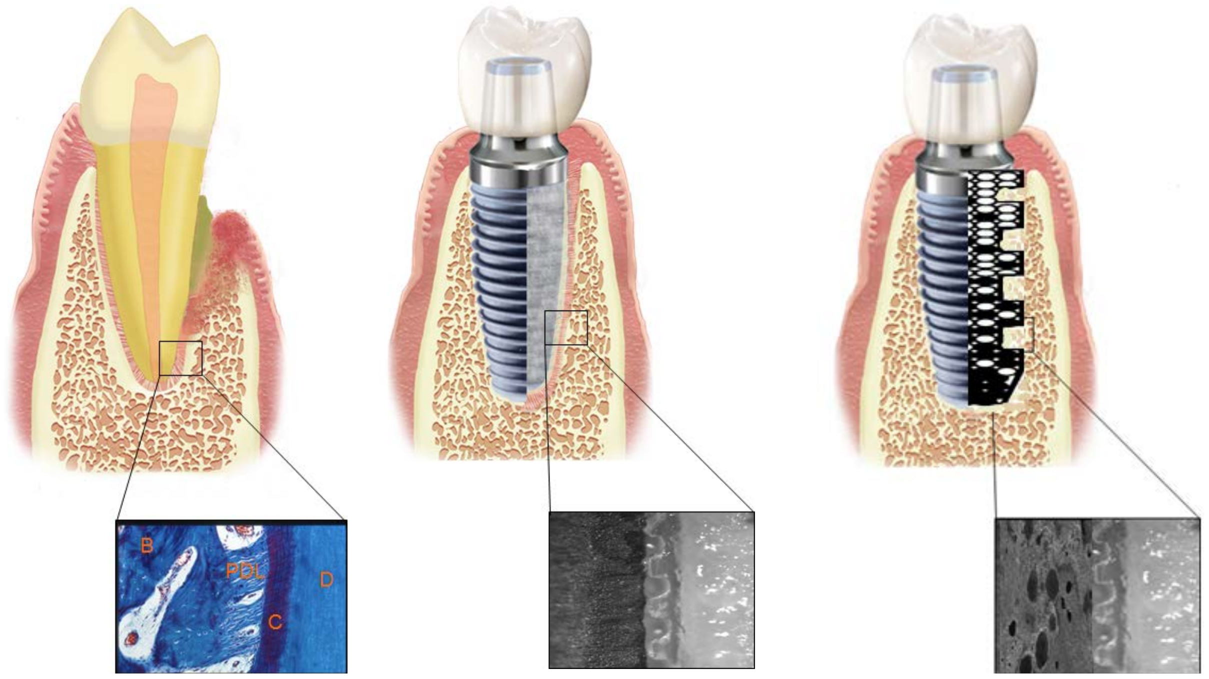
As with all grand challenges, the work transcends disciplines. It requires not only mechanical engineering expertise but also knowledge of materials science, chemical engineering, and chemistry.

Next steps include developing an experimentally validated modeling framework for understanding the combined influences of various physical phenomena and prototyping and evaluating reactor components against those of state-of-the-art reactors to measure performance and predict efficiencies.

"From there, we'll work on the design and fabrication of the reactor itself," said Bala Chandran, "with a focus on first prototyping the improvements we think will make a real difference."

Making a difference is crucial, she added. "We need to find new processes that don't just destroy but also recover."

TOWARD SMART DENTAL IMPLANTS



Left to right: natural tooth, titanium implant, titanium foam implant

B - bone; PDL - periodontal ligament; C – cementum; D – dentin

Mihaela Banu
ME Research Associate Professor

Activity trackers, smart watches, glucose monitors, and other wearable biosensor technology are a growing part of our lives. Now, ME Research Associate Professor Mihaela Banu is putting her research where our mouths are, with a collaborative initiative to develop a new smart, cyber-physical dental implant system.

The University's Mcubed program, designed to spur innovative, multidisciplinary solutions to current problems, has brought together a cohesive and productive team of mechanical engineers and dentists. Their collaboration contributes to the 2030 roadmap of the National Institute of Dental and Craniofacial Research and a project campaign to accelerate development of oral biodevices by advancing technologies.

The system Banu and colleagues are developing overcomes several challenges of current artificial implants and is likely to enhance patient outcomes, overall health and quality of life.

"Intelligent dental implants have the real potential to improve patients' lives," said Laurie McCauley, dean of the U-M School of Dentistry and a collaborator with Banu's team, along with Gustavo Mendoca, DDS, MS, PhD, clinical associate professor, and Sun-Yung Bak, DDS, clinical assistant professor.

"Many people, particularly those with health problems that affect their bones or who have had cancer treatment — and healthy people, too — are suffering with issues related to tooth loss," Banu added, "and we probably can help them."

Worldwide, nearly 160 million people suffer from edentulism, or toothlessness. In the United States, about 15 million people have crown and bridge replacements for natural teeth, and over three million have implants. The use of implants will only rise as the population ages and the incidence of health conditions and treatments that lead to bone loss, such as diabetes, osteoporosis, periodontitis, and cancer therapy, also increases.

Implants in healthy patients with good bone integrity boast high early-success rates but over time, the risk of failure grows, in many cases caused by an inflammatory reaction known as peri-implantitis. This can lead to serious infection and the need for implant removal. In less healthy patients, unfortunately, the risks are greater and the time until possible failure is shorter.

Improving compatibility through porosity

For success over the long term, implants must be stiff enough to withstand the stresses caused by chewing, which leads to perpendicular loading as well as lateral and rotational displacements. Together, these create nonuniform stresses on the bone that, over time, can lead to trouble.

In finite element simulations, Banu's group has shown that even very small displacements or rotations of the implant will generate nonuniform stress points, which lead to inflammation. And this process, when it occurs repeatedly, often results in infection. A mismatch between the stiffness of the implant and stiffness of the bone also contributes to nonuniform stresses.

Today's implants, primarily made from titanium and its alloys, are solid, with the surface treated through chemical etching or laser ablation to create pores. The roughened surfaces facilitate bone cell adhesion and growth around the wall of the implant, a process known as osteointegration. Using a new approach, Banu and her doctoral student Jaekwang Shin have introduced porosity inside the implant and demonstrated that doing so gives bone cells greater, and deeper, surface area for adhesion.

U-M ME student Robert Buechler and U-M ME Professor Bogdan I. Popa discuss designing the embedded sensor in the implant.

"INTELLIGENT DENTAL IMPLANTS HAVE THE REAL POTENTIAL TO IMPROVE PATIENTS' LIVES."

"The specific porosity we introduced has two important effects," Banu said. "It offers greater stability and it decreases the stiffness of the implant. In this way, we can match the stiffness of the implant to the bone more closely and mitigate much of the nonuniform stresses."

Novel manufacturing approaches

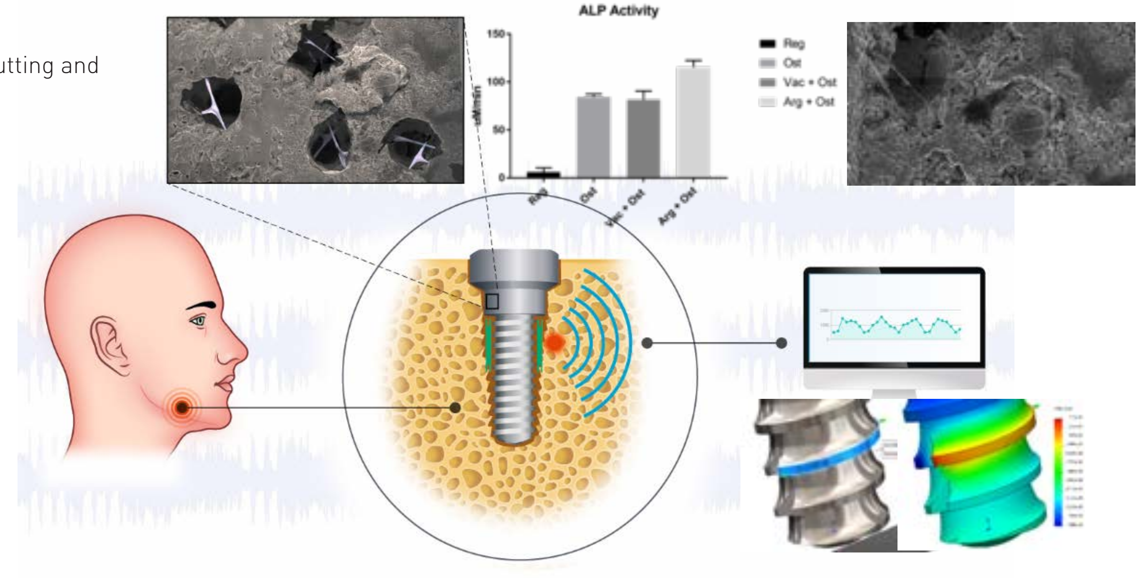
While conventional implants are produced by cutting and milling a metal rod, Banu's group has demonstrated another concept. She and her team are using selective laser sintering of titanium (and the alloy Ti6Al4V) powder and resin to create a porous titanium foam. Future work will also use another additive 3D manufacturing process, direct metal printing.

During the manufacturing process, a sensor will be embedded in the implant to monitor displacement and stresses. This solution was developed together with Bogdan I. Popa, assistant professor in ME. The intriguing design and its manufacturability attracted Robert Buechler, a senior ME student, to be deeply involved in realizing the system's first virtual version.

The sensor will be interrogated wirelessly and passively and therefore won't require a power source. Signals from the sensor will be recorded by software — an app installed on the user's smartphone, watch, tablet, or other mobile device. The data can then be used to predict the evolution of implant mobility and to detect possible failures early. This will enable patients to seek treatment before symptoms develop.

To date, Banu's team has manufactured a prototype system and, *in vitro*, demonstrated an improved osteointegration rate compared to a solid titanium structure. Postdoctoral fellow Jessica Alfonso Ferreira, DDS, was integral to obtaining these results.

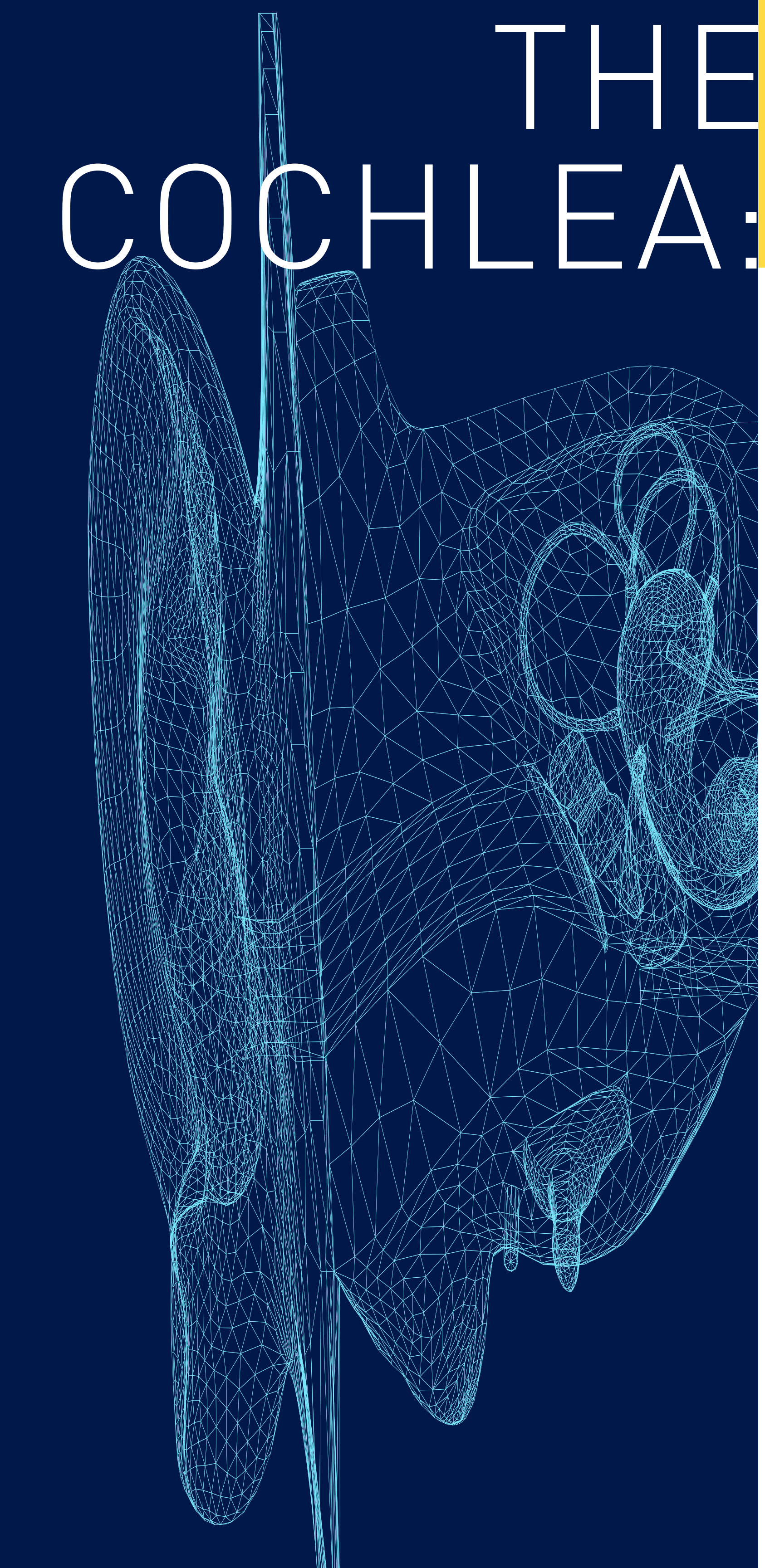
The team has been working together since 2015. "It's been a close and productive collaboration," Banu said. "Few other places in the world have this caliber, depth, and breadth of engineering and biomechanical expertise."



Intelligent dental implant cyber-system

CRACKING THE COCHLEA:

U-M TEAM CREATES MATHEMATICAL MODEL OF EAR'S SPEECH CENTER



Until now, the part of the ear that processes speech was poorly reflected in computer models, but University of Michigan researchers have figured out the math that describes how it works. It could help improve hearing tests and devices that restore some hearing to the deaf.

Inside the ear, a snail-shaped organ called the cochlea takes in pressure information from the eardrum and turns it into nerve impulses that are sent to the brain. A full understanding of how this tube-like structure does its work, from end to end, has been elusive.

"No one has been able to piece together a complete model that describes the entire cochlea, especially at the apex, or the end furthest from the eardrum," said Karl Grosh, a professor of mechanical engineering. "Existing models were unable to match the low frequencies processed at the apex.

"And that's been a problem since it's where speech is processed."

That apex has been problematic for researchers because it is tapered and features a different cell structure from the base. Due to its location further inside the ear, it has been harder to access for testing without doing damage.

Recent advances in optical coherence tomography (OCT), the use of light waves to create 3D images and measure how sound moves through different parts of the ear, have allowed for a closer look at the cochlea's apex region.

Using OCT data from other researchers, Grosh worked with Aritra Sasmal, a PhD student in mechanical engineering, to break down the cochlea's mechanics, fluid-structure interaction, and cell makeup.

Their work sheds new light on the role of a particular part of the cochlea, the basilar membrane. It runs the length of the cochlea, separating two liquid-filled tubes, the scala media and scala tympani. Previous research has suggested that the membrane is the critical element to the ear's ability to amplify and transmit sound waves.

But Grosh and Sasmal's work shows the basilar membrane is only part of the equation. They showed that subtle changes in the cell structure along the cochlear spiral and the shapes of the liquid-filled tubes are key elements at speech frequencies. Their work is published online in the *Proceedings of the National Academy of Sciences*.

"Most numerical models work well at the base but fail miserably at the apex," Sasmal said. "Our modeling work is the first to show why the apex behaves differently, and it paves the way for modeling the transduction of speech and music at the level of the cochlea."

Karl Grosh
ME Professor

The researchers believe their model is promising for improving the way newborns are tested for hearing impairment. One non-invasive procedure, typically done in the first days of life, sends two tones into the ear and records a third tone that is produced in response.

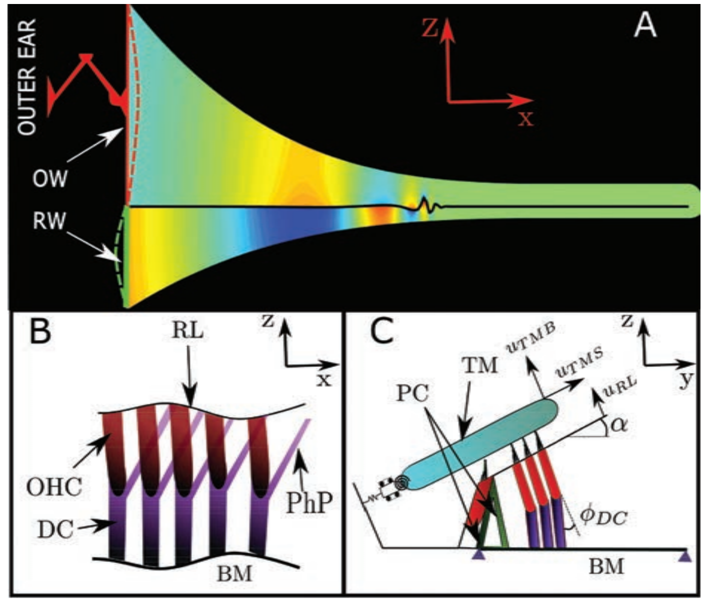
A better understanding of the cochlea's function, particularly at the apex/low frequency region, can help better analyze the third tone, improving our understanding of the baby's hearing.

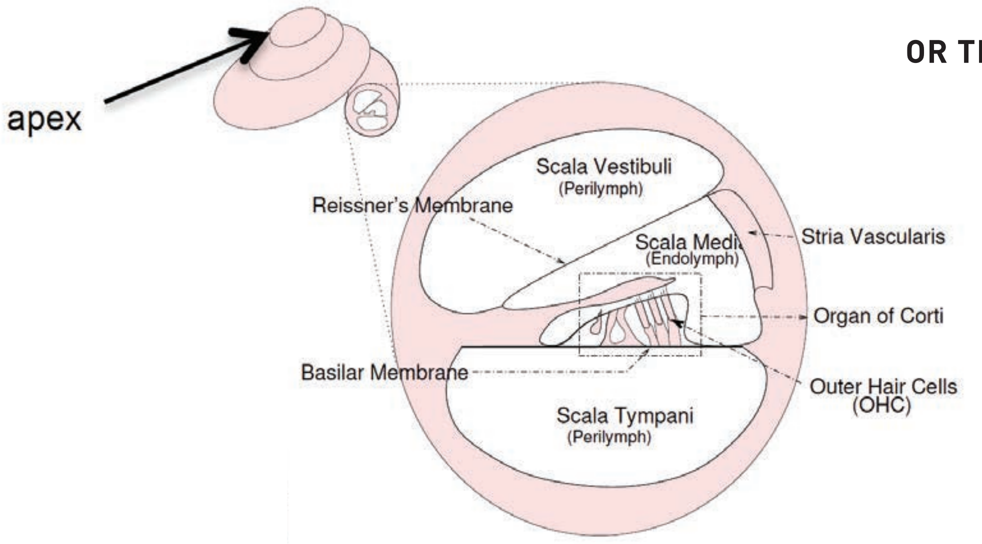
Improved modeling for speech and music transduction could boost the performance of cochlear implants, devices that can restore speech perception for deaf people. This device takes in sound, mimics the electrical signal it would create in a healthy ear, and passes it on to the brain.

That mimicked signal is often a poor approximation of what a normal ear would create. Furthering our understanding of how the cochlea works could lead to better speech processing algorithms — giving cochlear implants and hearing aids the ability to reproduce sounds more accurately.

The paper on this work is titled "Unified cochlear model for low- and high-frequency mammalian hearing" and appeared in the *Proceedings of the National Academy of Sciences* in 2019. His research was supported by the National Institutes of Health.

Grosh is also a professor of biomedical engineering and an affiliated faculty of the Kresge Hearing Research Institute.





"NO ONE HAS BEEN ABLE TO PIECE TOGETHER A COMPLETE MODEL THAT DESCRIBES THE ENTIRE COCHLEA, ESPECIALLY AT THE APEX, OR THE END FURTHEST FROM THE EARDRUM."

Top diagram: Figure (A) - A false color plot of our predictions of the pressure in response to sounds from the outer ear (note the spiral shaped cochlea is unwrapped). (B) and (C) show schematics of our computer model of the cochlear structures.

Bottom diagram: The cochlear spiral is shown alone with an exploded view of the cross section in the far bottom picture. For reference, the outer hair cell diameter is 10 microns, one-seventh the diameter of a human hair.

ICE-PROOFING

BIG STRUCTURES WITH A "BEAUTIFUL DEMONSTRATION OF MECHANICS"

Michael Thouless
ME Professor

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, 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, or 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 he 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."

"THE ADVANTAGE OF DESIGNING COATINGS BASED ON THEIR FUNDAMENTAL MATHEMATICAL PROPERTIES IS THAT YOU DON'T END UP WITH JUST ONE COATING, YOU GET MORE OF A RECIPE, AND YOU CAN THEN ADJUST THAT RECIPE TO CREATE A VARIETY OF SLIGHTLY DIFFERENT COATINGS FOR DIFFERENT APPLICATIONS."

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 1 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, the Nanomanufacturing program (grant #1351412), and the U-M College of Engineering MTRAC Transportation program.

Abhishek Dhyani (top left), a macromolecular science & engineering PhD student, demonstrates use of low interfacial toughness (LIT) coatings in the North Campus Research Complex at the University of Michigan in Ann Arbor, MI on April 15, 2019. The coatings help shed ice effortlessly from large surfaces and could be used for such surfaces such as cargo ships, airplanes, power lines, wind turbines, oil rigs, and commercial buildings.

TOWARD MOLECULAR COMPUTERS:

FIRST MEASUREMENT OF SINGLE-MOLECULE HEAT TRANSFER

If Moore's law's endgame is really computer components made from single molecules, we're going to need to know how to cool them.

Heat transfer through a single molecule has been measured for the first time by an international team of researchers led by the University of Michigan. This could be a step toward molecular computing—building circuits up from molecules rather than carving them out of silicon as a way to max out Moore's Law and make the most powerful conventional computers possible.

Moore's Law began as an observation that the number of transistors in an integrated circuit doubles every two years, doubling the density of processing power. Molecular computing is widely believed to be Moore's Law's end game, but many obstacles stand in the way, one of which is heat transfer.

"Heat is a problem in molecular computing because the electronic components are essentially strings of atoms bridging two electrodes. As the molecule gets hot, the atoms vibrate very rapidly, and the string can break," said Edgar Meyhofer, a professor of mechanical engineering at the University of Michigan.

Until now, the transfer of heat along these molecules couldn't be measured, let alone controlled. But Meyhofer and Pramod Reddy, also a professor of mechanical engineering at U-M, have led the first experiment observing the rate at which heat flows through a molecular chain. Their team included researchers from Japan, Germany, and South Korea.

"While electronic aspects of molecular computing have been studied for the past 15 or 20 years, heat flows have been impossible to study experimentally," said Reddy. "The faster heat can dissipate from molecular junctions, the more reliable future molecular computing devices could be."

Meyhofer and Reddy have been building the capability to do this experiment for nearly a decade.They've developed a heat-measuring device, or calorimeter, that is almost totally isolated from the rest of the room, enabling it to have excellent thermal sensitivity. They heated the calorimeter to about 20 to 40 Celsius degrees above the room temperature.

The calorimeter was equipped with a gold electrode with a nanometer-sized tip, roughly a thousandth the thickness of a human hair. The U-M group and a team from Kookmin University, visiting Ann Arbor from Seoul, South Korea, prepared a room-temperature gold electrode with a coating of molecules (chains of carbon atoms).

They brought the two electrodes together until they just touched, which enabled some chains of carbon atoms to attach to the calorimeter's electrode. With the electrodes in contact, heat flowed freely from the calorimeter, as did an electrical current. The researchers then slowly drew the electrodes apart, so that only the chains of carbon atoms connected them.

Over the course of the separation, these chains continued to rip or drop away, one after the other. The team used the amount of electrical current flowing across the electrodes to deduce how many molecules remained. Collaborators at the University of Konstanz in

Pramod Sangi Reddy
ME Professor

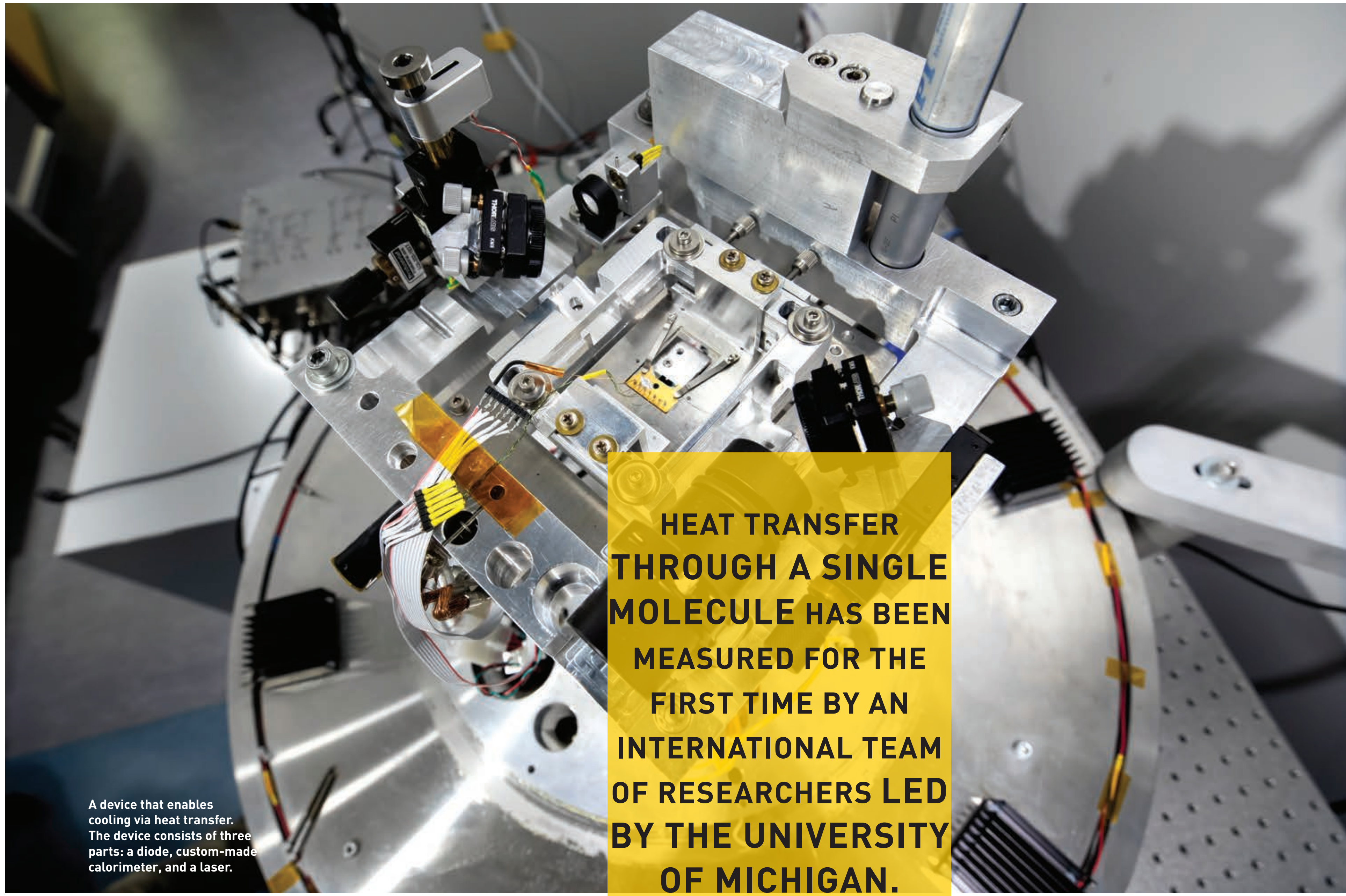
Edgar Meyhofer
ME Professor

Germany and the Okinawa Institute of Science and Technology Graduate University in Japan had calculated the current expected when just one molecule remained — as well as the expected heat transfer across that molecule

When a single molecule remained between the electrodes, the team held the electrodes at that separation until it broke away on its own. This caused a sudden, minuscule rise in the temperature of the calorimeter, and from that temperature increase, the team figured out how much heat had been flowing through the single-molecule carbon chain.

They conducted heat flow experiments with carbon chains between two and 10 atoms long, but the length of the chain did not seem to affect the rate at which heat moved through it. The heat transfer rate was about 20 picowatts (20 trillionths of a watt) per degree Celsius of difference between the calorimeter and the electrode held at room temperature.

"In the macroscopic world, for a material like copper or wood, the thermal conductance falls as the length of the material increases. The electrical conductance of metals also follows a similar rule," said Longji Cui, first author and U-M PhD graduate (PhD ME '18), currently a postdoctoral researcher in physics at Rice University.



A device that enables cooling via heat transfer. The device consists of three parts: a diode, custom-made calorimeter, and a laser.

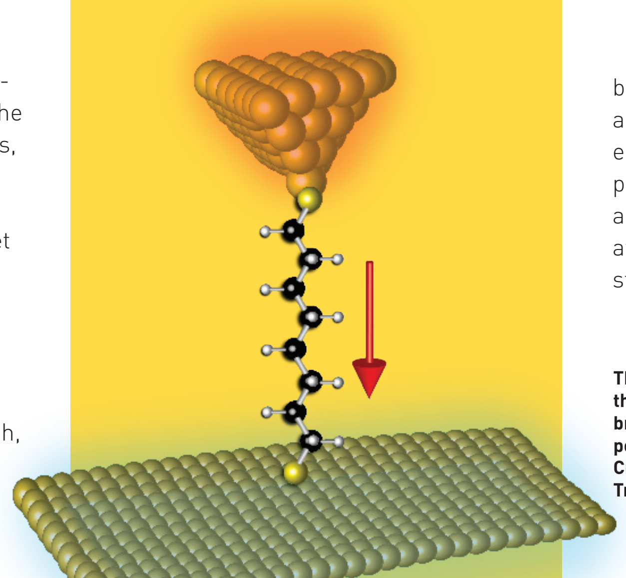
HEAT TRANSFER THROUGH A SINGLE MOLECULE HAS BEEN MEASURED FOR THE FIRST TIME BY AN INTERNATIONAL TEAM OF RESEARCHERS LED BY THE UNIVERSITY OF MICHIGAN.

"However, things are very different at the nanoscale," Cui added. "One extreme case is molecular junctions, in which quantum effects dominate their transport properties. We found that the electrical conductance falls exponentially as the length increases, whereas the thermal conductance is more or less the same."

Theoretical predictions suggest that heat's ease of movement at the nanoscale holds up even as the molecular chains get much longer, 100 nanometers in length or more—roughly 100 times the length of the 10-atom chain tested in this study. The team is now exploring how to investigate whether that is true.

This work is described in a paper in the journal *Nature*, titled, "Thermal conductance of single-molecule junctions."

This study was funded by the U.S. Office of Naval Research, Department of Energy, and National Science Foundation; the Korean National Research Foundation; and the German Research Foundation. The devices were made in the Lurie Nanofabrication Facility at U-M.



Meyhofer is also a professor of biomedical engineering. Reddy is also a professor of materials science and engineering. Cui will be an assistant professor of mechanical engineering and materials science and engineering at the University of Colorado, Boulder starting in January 2020.

The illustration on the left shows the heat flow through a single molecule—a chain of carbon atoms bridging the room-temperature electrode and the pointed, atomic-scale tip of the heated electrode. Credit: Longji Cui, Nanomechanics and Nanoscale Transport Labs, Michigan Engineering

THIS IS US:

ME POSITIONED TO LEAD SUSTAINABILITY EFFORTS

Margaret Wooldridge
ME Professor

Mechanical engineers are perfectly positioned to lead efforts toward more sustainable energy, but they can't do it alone. Margaret Wooldridge, Arthur F. Thurnau Professor of Mechanical Engineering, imparts this message to students in many ways, including through the Advanced Energy Solutions (ME 433) course she developed more than 12 years ago and in her leadership of the Dow Sustainability Fellows Program, which she has directed for the past two years.

"On the first day of class every semester, I tell students the foundation of the ME discipline is on moving energy around. When we look at sustainable energy solutions, this is us," Wooldridge said.

It isn't exactly a hard sell. "A course on sustainable energy topics could only be successful because students are craving the information. They want to be part of a bigger solution and conversation about how we can move toward more sustainable energy generation and use," said Wooldridge, who has been working on and teaching the physics of climate change in thermodynamics courses long before it moved into mainstream focus.

When Wooldridge first offered the Advanced Energy Solutions course in Fall 2007, about 25 students enrolled. Now two sections of Advanced Energy Solutions are offered every semester to full classrooms. Six instructors teach over 200 students annually and, although the course is an elective, nearly every graduating ME student has taken it.

Grassroots behavior change

Working in teams, students complete two main projects: a video about a high-impact but low- or no-cost behavior change to reduce energy demand and a more technical written report. Common video projects over the years have included moving from disposable plastic water bottles to reusable containers and carpooling or biking to work. Other student teams have shown the impact of reducing beef consumption, turning off the water when brushing teeth, and replacing incandescent and compact fluorescent bulbs with LEDs.

"Many of the videos are extraordinarily clever in how the teams present the problem and the behavior change, and many also make policy suggestions," Wooldridge said.

The projects teach an important lesson — that while policy and technology are important, efforts to reduce energy demand also have to come from individuals at the grassroots level. She said, "If you carpool one day a week to work, you're reducing your carbon emissions by close to 20 percent —assuming you commute five days a week. National standards can't get close to that in the short term, and not without a lot of technology and cost."

Mechanical engineering is a natural lens through which to view, and teach, the need for behavior change, she added, and to develop solutions.

Solutions require interdisciplinarity

Those solutions invariably cross traditional disciplinary boundaries. As director of the Dow Sustainability Fellows Program at the University of Michigan, a university-wide, co-curricular program that supports professional, master's, and doctoral students to become sustainability leaders, Wooldridge's oversight enables in-the-trenches teamwork across multiple fields. Together, team members create sustainable solutions at the community level and with global reach.

For example, a recent Dow Distinguished Award team, advised by ME Professor Kazu Saitou, focused on developing a solar-powered bicycle trailer to assist low-income entrepreneurs in sub-Saharan Africa. When not being used for transportation, the cart could serve as a power source for lighting and mobile phone charging.

To ensure interdisciplinarity, project teams must include representatives from at least three U-M schools or colleges. Saitou's team included students and faculty from the College of Engineering, Michigan Ross and the School for Environment and Sustainability. College alumni, entrepreneurs, and faculty at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana, also participated.

"There are so many decisions involved in adapting and optimizing sustainable technologies," said Saitou. "You need math and engineering and a systems view to know how to pose each decision-making problem. You also need to look at the environmental impact, the economic and ethnologic aspects. These change over time, which impacts innovation and transformative technologies. All of these aspects are crucial to projects like these."

In both her courses and the Dow Sustainability Fellows Program, Wooldridge is most pleased and impressed by both the solutions teams develop and by "how they internalize opportunities and challenges. They come out with a real sense of personal ownership and leadership." Many take jobs in the energy sector and other sustainability-related areas. In a recent impact assessment, fellows reported the program was their only opportunity to have this type of interdisciplinary experience.

Such experiences are "very influential," Wooldridge said. About 85% of past fellows reported now working in a sustainability-related career. "And that's my goal," she said, "to help them internalize this approach as an engineering professional as well as a global citizen."

"STUDENTS WANT TO BE PART OF A BIGGER SOLUTION AND CONVERSATION ABOUT HOW WE CAN MOVE TOWARD MORE SUSTAINABLE ENERGY GENERATION AND USE."

Group (pictured to the right) working on the 2016-2017 Dow Distinguished Awards project, The Crow House. The Crow House is an urban settlement house model, using sustainability education, and programming for the community and personal development located in Detroit, Michigan. Co-created with the community, Crow House efforts focus on service learning to teach green retrofit and permaculture skills. The result is a perennial teaching site and community center.

EXCELLENCE IN EDUCATION

Q A

Womentoring

Laine Katherine Chan
Graduate of the Mechanical Engineering SUGS program, MSE '19 BSE '18

Why do you think it is important to have a group like WoMEntoring for the women in ME?

Belonging to a community is so important for education. Having a group of people who automatically share and understand your experiences validates the feelings of female engineers. My first semester of college, I joined an a cappella group. I wasn't exactly like the other women in the group and it led to feelings of isolation. My second semester, I joined Society of Women Engineers and became very active attending events most nights of the week. I became close to the newly elected executive board, 4 out of 5 of whom were rising seniors in mechanical engineering. This changed my entire college experience. I finally belonged and had women to look up to. I was fortunate to quickly find a group of mentors in my major, but not everyone is so lucky and the feelings of loneliness and isolation can continue.

What goals does WoMEntoring have for the ME community?

WoMEntoring hopes to foster an environment of inclusion and openness, while providing a space where women can acknowledge the hardships experienced daily. Being able to recognize and vocalize injustice is the first step toward change. My experience in DEI is very social justice-oriented and as a result I am quick to point out the flaws present throughout the entire engineering community that have developed from systemic oppression. Through the creation of WoMEntoring, the Mechanical Engineering department has signaled that they support women in STEM and will work to retain them in the field of mechanical engineering.

How did you become involved in WoMEntoring?

I first became involved with WoMEntoring by participating in a Women in Mechanical Engineering Focus Group in October 2018. For Winter 2019, I knew I would be taking one less class than my usual load and decided I wanted to do more to contribute to the efforts related to the focus group. In December, I approached Rachel (Casanova, Manager of Academic Programs) about creating a job so that I could help with WoMEntoring by planning events and being the department's point person to the students on the committee. This became the Diversity, Equity and Inclusion (DEI) Intern position that I now hold.

Before working as the DEI Intern, I worked as the first solely dedicated Diversity Peer Educator (DPE) in the Martha Cook Building for University Housing for two years. In this position, I educated my residents on diversity, equity, inclusion, and social justice and advised the building's multicultural council, which I advocated in my first year as the DPE to create. In addition, I worked to create other social changes to make the building a more inclusive community. What I was able to accomplish as a DPE allowed me to be the only undergraduate engineer to win one of the Martin Luther

King, Jr. Spirit Awards in 2018. Later in 2018, I was also one of the recipients of the Mechanical Engineering Department's Charles Vest Award. Charles Vest was an educator, a provost, and an ME professor at Michigan. Later in his career he became the president of MIT, where he worked to make conditions equal for female employees. In many ways, I feel very connected to Charles Vest. In the final semester of my bachelors, I was one of the student facilitators for an introduction to social justice class that incoming resident advisors are required to take in order to work for University Housing. This opportunity gave me my first taste of life as an educator. That same semester, I was offered a position to be a Graduate Student Instructor for ENGR 101, the intro to computer science class. My biggest goal as a GSI was to create a community for my students and teach them that classes are for more than learning: they are also a vehicle to create friendships that will carry you through college and beyond. While I was able to infuse social justice into my classroom, this was not the DEI work I was accustomed to. When I went to Rachel wanting to do more for the Department, it was partially because my life doesn't feel complete when I'm not involved in some type of social justice work. I'm so grateful and thankful the ME Department gave me the opportunity to explore my passions!

What are your goals as a female studying mechanical engineering?

My overall goal as a female mechanical engineer is to promote and support other women in mechanical engineering. I plan to mentor younger women at my company to champion their success while striving to make things better for women in STEM overall. I myself have experienced a decent amount of marginalization in industry. At my second internship, I returned to the same group at the same company with the same manager. This manager made me get his laptop charger for him because he didn't want to walk up the stairs despite having a brand-new male intern in the group and it being my second summer. At another internship, I had my testing stopped and my manager needed to come and stand in the lab with me while I worked because other employees felt I looked young. But he had walked by without saying anything earlier when a male intern, who happened to be younger than myself, was in the lab with me.

Currently, my career goal is to be the first Chief Diversity Officer at the company I am going to work for full time. Many people believe that I won't be able to achieve this, but I know that any work worth doing isn't easy and I'm ready for the challenge! Having dedicated DEI positions shows an organization's willingness to adapt with the times and allows them to strive to be a leader in their field in terms of change.

Does being a woman in engineering give you advantages to problem-solving?

I think being a woman in engineering, and especially being a woman of color in engineering, makes me more empathetic. I know the stares when I enter a machine shop or pick up a tool. I understand what it means to be marginalized. This allows me to connect to people more easily, which gives me an advantage in industry. People are more willing to help me and take the time to get to know me. This means that any problem I can't solve on my own, I have dozens of friends at a company who can help me. But strictly speaking on whether being a woman gives me advantages to problem-solving on my own, I think it does. I'm used to adapting to a world that wasn't created for me. When people think of someone with a master's in mechanical engineering, they most likely don't imagine me. So I'm accustomed to modifying my intended approach to achieve the desired result.

What is next for you and how did ME get you there?

My next adventure is working full time for Schlumberger, the oilfield service company. In late August, I will be training in Abu Dhabi for two months. Then I will move to Ecuador for 16 months, where I will be the lead engineer on oil rigs in the Amazon rainforest. Following my 18 months abroad, I will move to Houston, Texas to work in the office where I hope to become a recruiter. In addition, I hope to spearhead the sustainability and diversity initiatives at the company.

For my master's and late in my bachelor's, I focused on sustainability. This technical training will allow me to charge forward with the confidence that I have the knowledge to make concrete, positive environmental changes in an industry that is oftentimes seen as a villain in society. In addition, I now have the confidence and experience with creating a position for myself to do work that I saw a need for. I will forever be grateful to the Mechanical Engineering Academic Service Office's generosity by creating this position for me! They let me work around my teaching and class schedules and let me continue into the summer.

Advice for others?

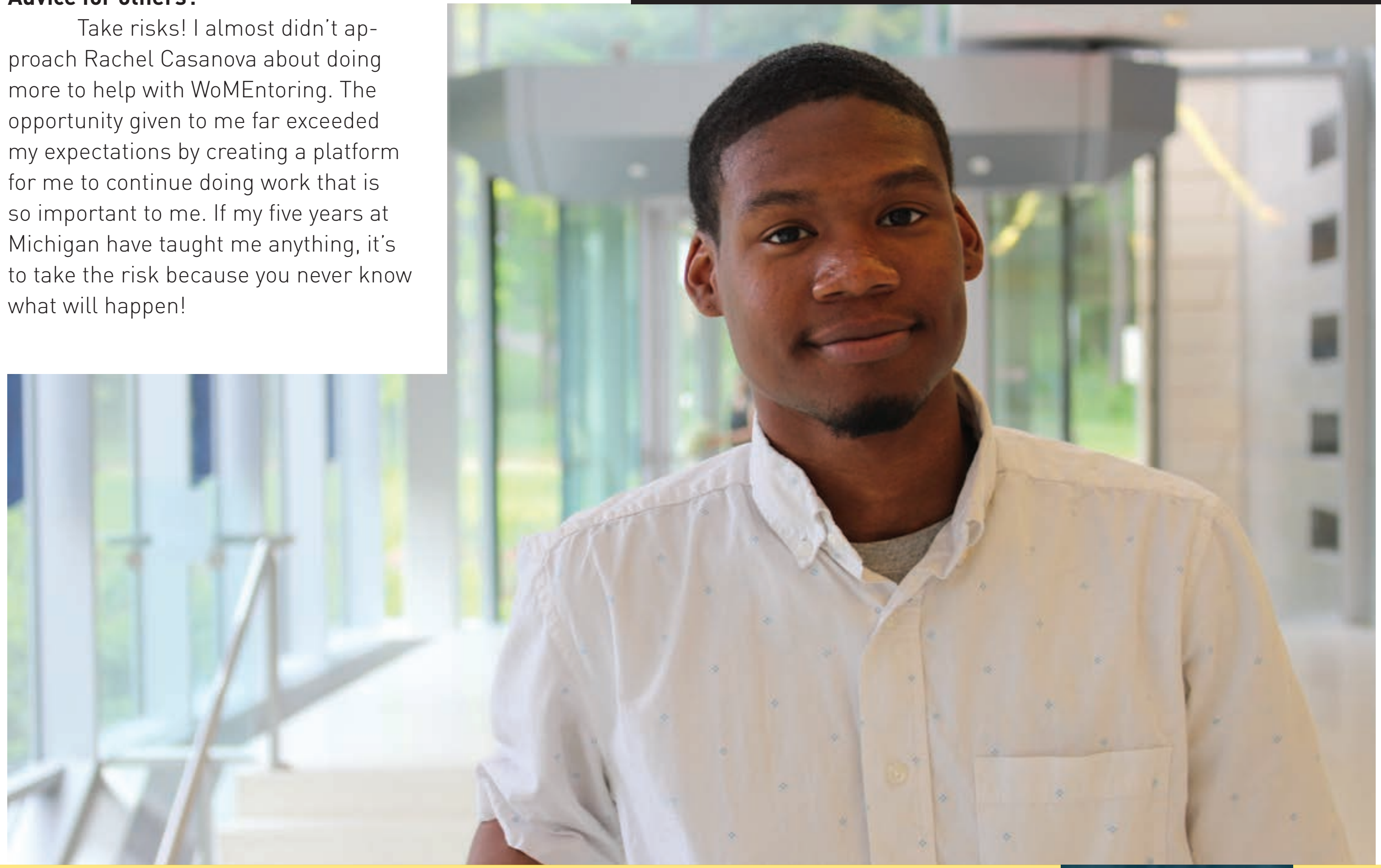
Take risks! I almost didn't approach Rachel Casanova about doing more to help with WoMEntoring. The opportunity given to me far exceeded my expectations by creating a platform for me to continue doing work that is so important to me. If my five years at Michigan have taught me anything, it's to take the risk because you never know what will happen!

U-M ME WoMEntoring group following an event at the Michigan League.

STEM+DEI

Q A

Davon Wheeler
Diversity, Equity and Inclusion Program Coordinator, U-M ME



Why is DEI so important in STEM?

I believe that DEI is important in STEM because STEM plays such a huge part in deciding what the future will look like and how it is we will get there. Including the concepts of diversity, equity and inclusion into STEM pedagogy and allowing these concepts to reshape norms, makes that decision more holistic. It ensures that a wider range of people will be at the table, listened to, and respected for what they have to contribute.

Tell us a little about your experiences with DEI.

I have been involved with a variety of DEI projects including the planning and evaluating of programs for U-M LSA, the creation of a storytelling series, "Value the Voice," for the University's Department of Afroamerican and African Studies, and a role on the Michigan Men's Steering Committee, to help build holistic identities of men within the fraternity culture. I have sat on various panels on the U-M campus, ranging from black men's health to adjusting to academic and social life for first-generation students.

What are you most looking forward to in your new role?

I am mostly looking forward to getting to know all the brilliant and dedicated students, faculty, and staff of the ME Department. I want the work that I do as the DEI Program Coordinator to not just be a replica of what I've done in my past roles, but be responsive to the real needs of the department. I look forward to hearing what is currently working and where some of the skills and perspective that I have gained along the way could be helpful. I feel that can only be done by getting to know the people.

Kenn Oldman
Professor, Associate Chair for Undergraduate Education

"These activities are intended to help incoming students form a cohort of people they know, and act as a lead-in to discussion of key topics from their earlier math and physics courses that they may want to review."

Transfer Student Program

We have seen that transfer students are a growing percentage of our mechanical engineering student body, with a particular emphasis placed on encouraging first-generation and low socioeconomic status applicants by the University and College of Engineering. CoE runs a number of activities to help incoming transfer students adjust to U-M, but we still see a disproportionate number struggle in their first term or two. I decided to try out an additional ME-specific orientation, beginning in Summer 2018. I talk the students through our curriculum and common challenges and opportunities, and then we break up into small teams for hands-on activities. These activities are intended to help incoming students form a cohort of people they know, and act as a lead-in to discussion of key topics from their earlier math and physics courses that they may want to review. We end with a brief introduction to MATLAB, as many students coming in as transfers have programming credit in other languages, and will need to use MATLAB in their early ME courses. We don't have a great deal of assessment results as of yet, but anecdotally, we have seen students involved in the orientation forming something of a group in later college-wide orientation events and courses, and some appreciation of the MATLAB content from students heading into classes like ME 240.

Karl Grosh
ME Professor

"The challenge to all of us should be how we clear those hurdles to make an impact on engineering, science, and society, not to worry if we belong."

Q A

Can you tell us a little bit about U-M ME's DEI strategy and vision?

As an overarching principle of our department, we seek to foster creativity, learning, innovation, and productivity by building a welcoming and inclusive environment for all students, faculty, and staff. Our department is large, with over 1,300 students (undergraduate and graduate), 80 faculty (tenure track and research), and nearly 60 staff members. The people in our Department are diverse with respect to almost any perspective one could imagine (geographic origin, race, ethnicity, religion, sexual orientation). This diversity is a great strength of our department, as it provides an educational opportunity to learn from others and garner ideas from different perspectives, which can lead to more informed, effective, and creative designs. However, such diversity often presents challenges, especially for people in underrepresented groups who may feel isolated and even unwelcome. We do not want anyone to feel unwelcome; hence we want to put in place activities to educate our entire department and to help initiate, cultivate, and sustain groups of underrepresented people so they know that they are embraced by our Department. Let's face it, the technical hurdles we face as engineers, be they research in the lab or learning in the classroom, are daunting. The challenge to all of us should be how we clear those hurdles to make an impact on engineering, science, and society, not to worry if we belong.

Hence, as a department we look to support activities for innovative and inclusive scholarship and teaching. Some of these efforts will be one-off workshops, others will be annual and continuous. I am sure we'll try some things that work well and others that don't; so we will look for feedback on what we try. We think that grassroots activities will usually work best, like ideas coming from students for activities that affect students directly. Some of our activities will directly assist all students, like the recent Strategizing for Resiliency workshop put on by Counseling and Psychological Services (CAPS) addressing mental health. Other activities centered on facilitating the formation of small groups aimed at creating community for underrepresented folks and a chance for those groups to communicate with the administration and faculty their needs or matters arising. While we have a lot of ideas on how to move forward, we are always open to great suggestions!

Can you share a few DEI highlights from the past year?

First and foremost, our Department hired a DEI Program Coordinator, Davon Wheeler, in July of 2019. He is already making a huge impact at all levels (student, faculty, and staff). We are excited to have him on board as he brings expertise in this area. Further, there are many ongoing activities at the Department, College, and University levels designed for students, faculty, and staff (that's already nine possible combinations!), so activity origination, coordination, and curation are important for us to be effective.

I'll just communicate a few activities from last year. We continued our successful WoMEntoring program, which started as a peer mentoring group for female PhD students and now has been extended as a parallel group for our undergraduate women. In addition, we continue our Black PhD student peer groups at the graduate level (MElanin) and undergraduate level (BMECHx). At the PhD level, these groups complement our Department-wide PhD peer mentoring efforts, where new PhD students are paired with established ones. We also received a Rackham Allies grant which supports new student-initiated DEI activities (workshops — peer groups — new proposals are welcome!). This past April, ME Grad Council students helped lead a Day of Silence in support of and raising visibility for our LGBTQA+ students, including a Spectrum-led Ally Training workshop during the day. Over the course of the year, faculty and staff took part in a number of workshops including the Move the Needle (education on sexual harassment in the workplace) and bystander intervention (the Change it Up! Workshop that gives attendees intervention skills to help build an inclusive and respectful environment) — and this latter workshop is one that all new students attend. In addition to workshops and student groups, we continue to seek to improve our inclusive teaching strategies, especially in our team classes (the X50 and X95 design and lab classes). Here, we are looking to coordinate the team teaching in both sequences as well as enact best practices from our Winter 2018 teaching circle on this topic. These are a snapshot of what is going on — sorry if I missed any! As you can tell, we are working vigorously to implement sustainable and effective activities to help improve our environment and to educate us all on the diversity that helps to make our Department great.

THE U-M ME ACADEMIC SERVICES OFFICE (ASO) has been selected as a team recipient of the 11th Annual Distinguished Diversity Leaders Award (DDLA)!

In close partnership with the U-M Vice Provost for Equity & Inclusion and Chief Diversity Office and Associate Vice President for Human Resources, the Distinguished Diversity Leaders Award was established to spotlight and honor those staff members who work tirelessly toward achieving a welcoming and supportive campus environment with their dedication and contributions to diversity, equity, and inclusion. They will be honored at the DDLA Ceremony on December 4th at the Michigan League.

Congratulations Rachel Casanova, Rachael Clarke, Adam Mael, Tim Moore, Kristel Oelke, Kathryn Orwig, Julie Tashjian, and Davon Wheeler.

GISE campers learn about vibration, acoustic, and wave propagation during U-M ME Assistant Professor Serife Tol's session.

U-M ME HELPS SPUR INTEREST IN STEM THROUGH WISE GISE CAMP

In June of 2019, U-M ME participated in WISE (Women in Science and Engineering) GISE (Girls in Science and Engineering), a summer day camp for current 7th- and 8th-graders where real scientists engage students in dynamic, hands-on experiments to foster curiosity and build confidence in STEM (Science, Technology, Engineering, and Math).

GISE is sponsored by the University of Michigan Women in Science and Engineering (WISE) Program in cooperation with the College of Literature, Science, and the Arts, The College of Engineering, and the U-M Medical School.

During the program campers learned from world-renowned women scientists and engineers and role model students who share their interest in science, math, and engineering. Focus projects are planned and taught by University of Michigan faculty, staff, and students. The camp's counselors are undergraduate student leaders in science and engineering robustly trained in safety and facilitation. ME faculty Ellen Arruda and Serife Tol participated.

Tol launched the Inspire-ME as part of the camp because she is passionate about developing a mechanical engineering module for the WISE GISE camp. Joined by her undergraduate student Michael Rose, she hosted approximately 40 7th- and 8th-grade female students on the U-M campus, teaching them vibration, acoustic, and wave propagation concepts through demonstrations and hands-on activities.

Arruda's group worked with campers to perform experiments on various materials to estimate their stiffness. The girls measured how the distance between two lines drawn on the material changed as weights were added to the bottom clamp to stretch it. The girls learned about force, strain, and stiffness. They also worked on teaching the girls about friction by performing experiments to estimate the coefficient of friction between two polymer sheets by securing the bottom material to a ramp and measuring the minimum angle required to induce sliding of the top material.

To find out more about WISE GISE, please visit https://lsa.umich.edu/wise/k-12-students-families/summer-camps/girls-in-science-and-engineering.html.

U-M ME'S ME450 CAPSTONE DESIGN PROJECT

U-M ME's ME450 capstone design project course is meant to challenge our future mechanical engineers. Required by all ME undergraduate students, the semester-long projects allow them the opportunity to apply (almost) everything they have learned from the first several years of school on an open-ended design problem. And these "real world" projects almost always include projects that aim to make a difference in the lives' of others.

The photos featured here showcase a recent ME450 project worked on by U-M ME students.

The team, which was comprised of U-M ME students Foivi Amparioti, Alex Anderson, Sarah Fuhrman, Meghan Luoma, Joseph Martinez, and Margaret Poppe, focused on making mobility device improvements to Braden Gandee's power wheelchair. The improvements were aimed to allow Gandee, who was born with Cerebral Palsy, to join in playing soccer with his friends. Two of the issues he was wrangling with were that his chair would run over the ball when he was playing, and that he couldn't kick the ball while sitting.

The team was able to build out some solutions, try them out, and then make any necessary adjustments to Gandee's chair while he tested it firsthand with a soccer ball at the University of Michigan's Oosterbaan Field House.

ME450 projects are proposed from the different areas of study within mechanical engineering and reflect the expertise of instructing faculty. Each semester, several of the projects come from industry partners, as students really enjoy working on these "real-world" projects and sponsors like having access to bright, talented, enthusiastic students. Faculty-sponsored, Global Health, and student-initiated projects are also offered each semester.

Interested in sponsoring an ME450 project? Visit http://me450.engin.umich.edu/project-sponsorship-information.html for more information.

PHOTOS BY JOSEPH XU

#GoingBeyondME STUDENT BLOGS

U-M ME students do some pretty amazing things. Here are a few examples of the work they do both within ME and beyond, #GoingBeyondME.

Matt Pirone, ME Master's Student

I am starting my second year as a dual master's student in mechanical engineering and design science, intending to graduate in the Winter 2020 semester. I earned my bachelor's degree in Biomedical Engineering at the University of Michigan in 2018 with a biochemical concentration, but in my final two years of undergrad I became particularly interested in the application of design in an engineering context through two important academic internship experiences. I was a participant for the Global Health Design Initiative (GHDI) and traveled to Ghana for two months to conduct clinical observations to inform my team's design of a device for post-partum hemorrhage. I was also hired as a program assistant at the U-M Center for Socially Engaged Design (C-SED), where I helped develop training protocols and consulted on student-led design projects. For me, working with C-SED united academia, which focuses on theory, and the real world, which focuses on application. By the time I finished my undergraduate studies, I became interested in applying my growing knowledge of socially engaged design principles specific to the field of sustainable development. . .

To read Matt's full blog piece, visit
https://me.engin.umich.edu/news-events/news/going-beyond-stories-me-students-matt-pirone

Abby Chapin, ME Senior

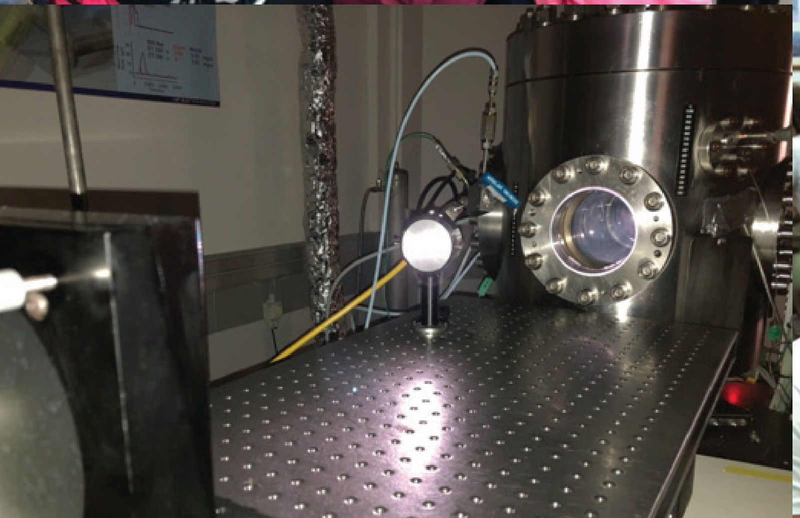
¡Hola mis amigos! My name is Abby Chapin and I am going to be a 5th-year senior in ME here at U-M. This summer, four other U-M engineering honors students and I participated in a two-week volunteer abroad trip to Guatemala. All of us (Erich Shan, CS; Utsav Lathia, CS; Marissa Martinelli, BME; Marina Engstrom, ME) were working together on coffee plantations learning about the process and taking a look into the daily lives of the farmers. We were partnered with De La Gente, (DLG), an organization that assists 5 co-op's of farmers from all over Guatemala to give them the support and sustainability education they need to keep their businesses running and lucrative. We worked with the farmers of the San Miguel Escobar co-op. DLG wants to show that the farmers' work is just as valuable as anyone else's, and wants the farmers to be able to do more than just survive. DLG knows they can't change the system that has been in Guatemala for 500 years, but at least the farmers they support know that there are people willing to do something about it. Being a farmer is not synonymous with being poor! No one in the world would be able to live without farmers! Since there is still a large dependency on coffee, people still want to be coffee farmers, but with more fair opportunities. No one wants to necessarily move away from coffee farming, but they just want the option to pursue other avenues. Over the years, coffee dependence has moved from a national to a local dependence, but these farmers do not want to stop farming. Their children are still learning about and participate in the process, but they also go to school. They aren't leaving the farms or abandoning this family practice, they just want their hard work to be valued for what it is which would allow them to provide for their families. . .

To read Abby's full blog piece, visit:
https://me.engin.umich.edu/news-events/news/going-beyond-me-abby-chapin

Mario Medina, ME PhD Student

My name is Mario Medina and I am a PhD candidate in the Mechanical Engineering Department. I currently work on understanding the physical mechanisms that govern spray behavior of fuel injectors as it pertains to atomization, under non-reactive and reactive conditions. I also look at a phenomenon known as injector tip wetting, which is responsible for high particulate emissions during certain engine operating conditions. I am in my 5th year of graduate school and I'm planning to present my dissertation by early-mid March 2020. During my time at the University of Michigan (U-M) I have been involved in many programs, organizations, workshops, and research projects. I want to share my experiences that have left a lasting impression during my time at U-M as a graduate mechanical engineering student. First, I will focus on my research experiences at three separate institutions: U-M, Robert Bosch LLC (Bosch), and the Universitat Politecnica de Valencia (UPV). Second, I will go over my involvement with the Society of Hispanic Professional Engineers – Graduate Committee (SHPE-GC). . .

To read Mario's full blog piece, visit:
https://me.engin.umich.edu/news-events/news/going-beyond-me-mario-medina



DISTINGUISHED ALUMNI

Alumni Merit Award Recipient

Marshall Jones (BSE ME '65)

Mechanical Engineering alumnus Marshall Jones has been selected to receive the 2019 U-M ME Alumni Merit Award. Jones, a mechanical engineer at General Electric (GE), pioneered the use of lasers for industrial materials processing. He invented novel methods to weld dissimilar metals, and developed fiber optic systems making lasers more convenient for industrial applications. He is a member of the National Academy of Engineering and was inducted into the National Inventors Hall of Fame in 2017. He holds over 50 U.S. patents and 57 foreign patents.

IN HIS OWN WORDS

"Within ME, I truly loved design, as well as the mechanics and materials of all lab work. U-M ME's design training led to my first job in high energy physics at Brookhaven National Labs and that same training provided a great foundation for my grad studies at UMass, opening the door to my 44-year career at GE Global Research in laser technology. It was this foundation that led to my election to the National Academy of Engineering and the National Inventors Hall of Fame. I do feel so very honored to have been selected to receive the 2019 ME Department Alumni Merit Award! I truly love the ME Department at the University of Michigan! Go Blue!"

AWARDS

DTE Endowed Professorship

In May of 2019 U-M ME Professor Volker Sick was installed as the DTE Energy Professor of Advanced Energy Research.

The DTE Energy Professorship of Advanced Energy Research was established in September 2007 with a $2 million endowment commitment, funded with a $1.5 million grant from the DTE Energy Foundation and a $500K matching grant from then-U-M president Mary Sue Coleman.

Sick is the third faculty member to hold this title.

At U-M since finishing his PhD at Heidelberg University in Germany, Sick was promoted to full professor in 2005 and served as the Associate Vice President for Research from 2012-2018. He currently leads the Global CO^2 Initiative, a research effort focusing on "carbon-negative, dollar- positive" commercially sustainable approaches that have the potential to reduce global CO^2 emissions.

Alec Gallimore, Dean of the College of Engineering, commented on the importance of the DTE relationship: "We value DTE's longstanding support of the University. They have provided nearly $8 million in funding to the success of U-M students through competitions and support in the College of Engineering, Michigan Ross, University Musical Society, and Michigan Medicine to name a few. DTE's comprehensive engineering recruiting reinforces the excellent relationship between our two organizations. Thank you, DTE, for your ongoing commitment to the University of Michigan."

Heather Rivard, DTE Senior Vice President of Distribution Operations, said, "The DTE Energy Foundation is one of the largest foundations in the state of Michigan and provides funding to many programs, but has a particular focus on energy and the environment. We support many things on U-M's campus, but none more important than this endowment, which will live on for years to come. We have a lot in common with U-M in terms of our focus on making an impact on the environment, and we are proud to be working in collaboration with President Schlissel on carbon neutrality goals at the University."

The essential funding provided by endowed professorships serves to attract, reward, and retain outstanding faculty, bringing prestige and recognition to the recipient and acknowledging their contributions to the University and their field.

The DTE Energy Professor of Advanced Energy Research is one of five corporate endowed chairs at U-M.

2019 Michael Korybalski Distinguished Lecture

Rich Strader, Vice President of Mobility Platforms at Ford Motor Company, delivered the 12th annual Korybalski Lecture on November 8, 2019. Strader's talk, titled "Smart Mobility," covered the global trends in mobility that are pushing companies, such as Ford, to change the way they look at the design gap that has developed with respect to mobility and transportation. He talked about how this will shape the way people and goods move in the future world, and described some of the technologies and businesses that will be required to support these people and goods movement.

In his role at Ford, Strader is responsible for supporting and delivering software engineering services that enable mobility solutions, connected vehicle, electric vehicle, connected consumer, and analytics across the enterprise. His team is engaged in the research, experimentation, delivery, and ongoing operations in these areas.

Strader's lecture was a part of the annual lectureship endowed by Michael Korybalski, chair of ME's External Advisory Board and former chief executive officer of Mechanical Dynamics. The lectureship was created as a means to bring high-profile, inspiring speakers to the U-M community to help promote the impact engineers have on large societal problems, including energy and environment, health and quality of life, national security, and disaster prevention.

FACULTY Awards & Recognition

EXTERNAL FACULTY AWARDS

Ellen Arruda
Society of Engineering (SES) James R. Rice Medal, 2018
ASME Nadai Medal, 2019

Jesse Austin-Breneman
ASME Ben C. Sparks Medal Award, 2019

Andre Boehman
American Chemical Society Fellow, 2019

Diann Brei
SSM Lifetime Achievement Award, 2018
ASME Adaptive Structures & Materials Award, 2018

Jesse Capecelatro
NSF CAREER Award, 2019
Office of Naval Research (ONR) Young Investigator, 2019
ASME Pi Tau Sigma Gold Medal Award, 2019

Daniel Cooper
ASME Ben C. Sparks Medal Award, 2019

Shanna Daly
NSF CAREER Award, 2019

Neil Dasgupta
NSF CAREER Award, 2018
DARPA Young Faculty Award, 2018
ECS Toyota Young Investigator Fellowship, 2019

Jianping Fu
American Institute for Medical and Biological Engineering College of Fellows, 2019

Krishna Garikipati
U.S. Association for Computational Mechanics Fellow, 2019

Karl Grosh
ASME Per Bruel Gold Medal for Noise Control and Acoustics, 2019

Jack Hu
Foreign Member of the Chinese Academy of Engineering, 2018

Yoram Koren
Best Paper Award of the International Journal of Production Research, 2018

Jyoti Mazumder
TMS Bruce Chalmers Award, 2018

Edgar Meyhofer
ONR MURI Award, 2019

Panos Papalambros
ASME Ben C. Sparks Medal Award, 2019

Huei Peng
ASME Rufus Oldenburger Award, 2019
Yasundo Takahashi Education Award, 2018
ASME Yasundo Takahashi Education Award, 2019

Elliott Rouse
NSF CAREER Award, 2019

Kazu Saitou
IEEE Fellow, 2018

Pramod Sangi Reddy
ONR MURI Award, 2019

Volker Sick
Fellow of The Combustion Institute, 2018
DTE Energy Professor of Advanced Energy Research Endowed Professorship, 2019

Kathleen Sienko
ASME Engineering Education Donald N. Zwiep Innovation in Education Award, 2018

Albert Shih
SME Frederick Taylor Research Medal, 2018
Fellow of the International Academy of Production Engineering, 2019

Anna Stefanopoulou
ASE Fellow, 2018
ASME DSCD Charles Stark Draper Innovative Practice Award, 2018
AACC Control Engineering Practice Award, 2019

Steve Skerlos
William T. Ennor Manufacturing Technology Award, 2019

Jing Sun
National Academy of Inventors Fellow, 2018

Aaron Towne
Young Investigator Program Award from the U.S. Air Force Office of Scientific Research, 2019

Michael Umbriac
ASME Ben C. Sparks Medal Award, 2019

Ram Vasudevan
NSF CAREER Award, 2018
Office of Naval Research (ONR) Young Investigator Award, 2018

Angela Violi
SAE Fellow, 2018
Fellow of The Combustion Institute, 2019
Society of Automotive Engineers' J. Cordell Breed Award for Women Leaders, 2019

Kon-Well Wang
Pi Tau Sigma-ASME Charles Russ Richards Memorial Award, 2018

Margaret Wooldridge
Fellow of The Combustion Institute, 2019

INTERNAL FACULTY AWARDS

Miki Banu
University of Michigan Office of Research Faculty Award, 2019
University of Michigan Research Faculty Achievement Award, 2019

Diann Brei
Rackham Master's Mentoring Award, 2018

Bogdan Epureanu
Arthur F. Thurnau Professorship, 2019

Tulga Ersal
Kenneth M. Reese Outstanding Research Scientist Award, 2018

Amy Hortop
Jon R. and Beverly S. Holt Award for Excellence in Teaching, 2018

Massoud Kaviany
Monroe-Brown Foundation Research Excellence Award, 2018

Katsuo Kurabayashi
Wise-Najafi Prize for Engineering Excellence in the Miniature World Award, 2018

Xiaogan Liang
Monroe-Brown Foundation Education Excellence Award, 2019

Jun Ni
E. & M. Ulsoy Citation Leader Award, 2019

Volker Sick
President's Award for Distinguished Service in International Education, 2018

Anna Stefanopoulou
Rackham Distinguished Graduate Mentor Award, 2018

Galip Ulsoy
Edward Law Emeritus Outstanding Service Award, 2019

Kon-Well Wang
University of Michigan Distinguished Faculty Achievement Award, 2019
Stephen S. Atwood Award, 2019

FACULTY & STUDENT AWARDS

STUDENT Awards

GRADUATE STUDENT AWARDS

Kumar Aanhaneya
Tom S. Rice Tau Beta Pi Award, 2019

Alejandro Azocar
Rackham PreDoctoral Fellowship, 2019

Colleen Crouch
Marian Sarah Parker Prize, 2018

Revanth Damerla
National Science Foundation Graduate Research Funding Program, 2019

Shannon Danforth
National Science Foundation Graduate Research Funding Program, 2018

Nosakhare (Nosa) Edoimioya
National Science Foundation Graduate Research Funding Program, 2018

Andrew Gayle
National Science Foundation Graduate Research Funding Program, 2018

Amin Ghadami
Ivor K. McLvor Award, 2019

Michael Potter
National Science Foundation Graduate Research Funding Program, 2018

Lauren Mancia
Rackham PreDoctoral Fellowship, 2019

Mary McMeekin
Richard F. and Eleanor A. Towner Prize For Outstanding Graduate Student Instructors, 2019

Nicolas Mesyngier
Microfluidics in Biomedical Sciences Training Program, 2018

Joshua Nkonge
National Science Foundation Graduate Research Funding Program, 2018

Christina Rice
National Science Foundation Graduate Research Funding Program, 2019

Victor Rodriguez
National Science Foundation Graduate Research Funding Program, 2018

Mohsen Taheri Andani
Richard F. and Eleanor A. Towner Prize For Distinguished Academic Achievement, 2019

Dakotah Thompson
ProQuest Distinguished Dissertation Award, 2019

Michael Wadas
Department of Energy National Nuclear Security Administration Stewardship Science Graduate Fellowship (DOE NNSA SSGF) award, 2018

UNDERGRAD STUDENT AWARDS

Marcos Cavallin
RISE Best Paper Fall, 2018

Joe Chen
Mechanical Engineering Department Spirit Award, 2018

Sarah Kalasky
R&B Machine Tool Company Scholarship, 2019

Justin Kraft
Robert M. Caddell Memorial Scholarship, 2018

Maya Makhlouf
R&B Machine Tool Company Scholarship, 2019

Emily Mallon
Robert M. Caddell Memorial Scholarship, 2018

Leo McManus
Henry Ford II Prize, 2019

Jessica Mosier
J. A. Bursley Mechanical Engineering Award, 2019

Lakshmanan Periakaruppan
Lloyd H. Donnell Scholarship Fund, 2019

Evan Rinder
Robert M. Caddell Memorial Team Award for Research, 2018

Patrick Roach
Charles F. Barth, Jr Prize, 2018

Jacqueline Schmiedeler
College of Engineering Distinguished Leadership Award, 2019

David Van Dyke
Robert M. Caddell Memorial Team Award for Research, 2018

Charles Velis
Roger M. Jones Fellowship, 2019

Michael Wolf
R&B Machine Tool Company Scholarship, 2019

Allison Zweng
Mechanical Engineering Department Spirit Award, 2019

EXTERNAL ADVISORY BOARD MEMBERS

COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

University of Michigan
College of Engineering
Department of Mechanical Engineering
2370 GG Brown Laboratory
2350 Hayward Street
Ann Arbor, MI 48109-2125
me.engin.umich.edu
Phone: 734-764-2694
Fax: 734-647-3170

Executive Editor
ELLEN ARRUDA

Managing Editor
ANGELA WEGRECKI

Writing
ANGELA WEGRECKI
DAN NEWMAN, MICHIGAN ROBOTICS
OUTWORD COMMUNICATIONS, LLC
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MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

University of Michigan College of Engineering
Department of Mechanical Engineering
2370 GG Brown Laboratory
2350 Hayward Street
Ann Arbor, MI 48109-2125