UNIVERSITY OF WISCONSIN–MADISON
COLLEGE OF ENGINEERING

SPRING 2022 NEWSLETTER

ENGINEERING PHYISCS

HANDS-ON LEARNING

Brings nuclear engineering to life

Greetings!

Fundamental to engineering is the urge to translate scientific discoveries into technologies that address societal needs. We all aim for those new technologies to be unambiguously good, providing benefits to society that far outweigh the costs. In most cases, it's true and we can take pride in what we have created. In rare cases, there are consequences—generally unintended—that reveal themselves and cause us to abandon the new technologies. That still leaves a few cases in which the conclusion is ambiguous and possibly subject to different interpretations.

More importantly, there is a growing awareness that the distribution of benefits and costs is often not universally experienced—some segments of our population benefit from technologies while those same technologies cause harm to others. Understanding these disparities, and working to address them, has a growing role in the engineering design and innovation process, and is critical to establishing or maintaining the social license to deploy a technology. This was front of mind as our faculty worked in recent months to design a brand new course for first-year students in nuclear engineering. With NE 231: *Introduction to Nuclear Engineering*, we aim to help students develop a more nuanced understanding of the relationship of nuclear science and technology to society—past, present and future—to make them better nuclear engineers.

This topic was on display at a recent White House summit on fusion energy. Assistant Professor Stephanie Diem participated on a panel on the topic of energy justice and public engagement. Sitting next to UW-Madison Law School alumna Shalanda Baker, who has been nominated by the Biden administration to be the director of the Office of Economic Impact and Diversity in the Department of Energy, they discussed the opportunity for fusion energy to incorporate equity in its early stages as an energy technology, rather than as an afterthought as has been the case for many other energy sources.

On the same day, alumna Kathryn Huff (PhDNEEP '13) was addressing questions about consent-based siting of geologic repositories for used nuclear fuel from U.S. senators during her confirmation hearing to become the assistant secretary for nuclear energy in the Department of Energy. With clear connections to her UW-Madison research on modeling such repositories, Huff has already broadened the scope of research in the DOE Office of Nuclear Energy to include more social science collaboration to inform these important questions related to extending the social license for nuclear energy.

So while our first-year students get a valuable opportunity to build community with their classmates, learn about the breadth of technologies that are built upon nuclear science, and have a first experience working with the UW nuclear reactor, they will also be embarking on a journey to develop a rich and nuanced sense of how those technologies connect with societal needs and challenges.

On, Wisconsin!

Paul Wilson
Grainger Professor of Nuclear Engineering
(608) 263-0807
paul.wilson@wisc.edu

New lightweight super material can battle bullets, deflect space debris

UW-Madison engineers have created a nanofiber material that outperforms its widely used counterparts—including steel plates and Kevlar fabric—in protecting against high-speed projectile impacts.

Basically, it's better than bulletproof.

"Our nanofiber mats exhibit protective properties that far surpass other material systems at much lighter weight," says Assistant Professor Ramathasan Thevamaran, who led the research.

He and his collaborators detailed the advance in a paper published Dec. 6, 2021, in the journal *ACS Nano*.

To create the material, he and postdoctoral research associate Jizhe Cai mixed multi-walled carbon nanotubes—carbon cylinders just one atom thick in each layer—with Kevlar nanofibers. The resulting nanofiber mats are superior at dissipating energy from supersonic microprojectile impacts.

The advance lays the groundwork for carbon nanotube use in lightweight, high-performance armor materials—for example, in bulletproof vests to better protect the wearer, or in shields around spacecraft to mitigate damage from flying high-speed microdebris.

"Nano-fibrous materials are very attractive for protective applications because nanoscale fibers have outstanding strength, toughness and stiffness compared to macroscale fibers," Thevamaran says. "Carbon nanotube mats have shown the best energy absorption so far, and we wanted to see if we could further improve their performance."

They found the right chemistry: The team synthesized Kevlar nanofibers and incorporated a tiny amount of them into their functionalized carbon nanotube mats, which created inter-fiber hydrogen bonds. Experimentally, they saw that those hydrogen bonds modified the interactions between the nanofibers—and those bonds, along with just the right mixture of Kevlar nanofibers and carbon nanotubes, caused a dramatic leap in the overall material's performance.

UW-Madison researchers' advance lays the groundwork for carbon nanotube use in lightweight, high-performance armor materials. Pictured from left: Undergraduate research assistant Nicholas Jaegersberg, Ramathasan Thevamaran and Jizhe Cai.

"The hydrogen bond is a dynamic bond, which means it can continuously break and re-form again, allowing it to dissipate a high amount of energy through this dynamic process," Thevamaran says. "In addition, hydrogen bonds provide more stiffness to that interaction, which strengthens and stiffens the nanofiber mat. When we modified the interfacial interactions in our mats by adding Kevlar nanofibers, we were able to achieve nearly 100% improvement in energy dissipation performance at certain supersonic impact velocities."

Bring on the bullets: The researchers tested their new material using a laser-induced microprojectile impact testing system in Thevamaran's lab. One of only a handful like it in the United States, the system uses lasers to shoot micro-bullets into the material samples.

"Our system is designed such that we can actually pick a single bullet under a microscope and shoot it against the target in a very controlled way, with a very controlled velocity that can be varied from 100 meters per second all the way to over 1 kilometer per second," Thevamaran says. "This allowed us to conduct experiments at a time scale where we could observe the material's response—as the hydrogen bond interactions happen."

In addition to its impact resistance, another advantage of the new nanofiber material is that—like Kevlar—it is stable at both very high and very low temperatures, making it useful for applications in wide range of extreme environments.

The researchers are patenting their innovation through the Wisconsin Alumni Research Foundation.

Building community and shaping context

Unique new course offers real-world intro to nuclear engineering

A new undergraduate course is setting first-year nuclear engineering students up for success in their major by providing a hands-on introduction to technological aspects of nuclear engineering. Additionally, the unique course will help students understand the economic and sociological factors that affect the prospects for nuclear energy around the world.

Associate Professor Adrien Couet developed the course, NE 231: *Introduction to Nuclear Engineering*, from scratch, with the support of colleagues Professor Paul Wilson and Assistant Professor Stephanie Diem. It launched in spring 2022 and gives students a broad overview of nuclear engineering, exposes them to many aspects of the field and provides them a strong grounding in their major from the start.

"We want this course to help build a cohort within the nuclear engineering program and foster a sense of community among the students at the beginning of their college education," Couet says. "The course aims to give students the tools to be future leaders in advancing engineering solutions to fight climate change."

A major aspect of the course is a semester-long project in which students work in teams on a design challenge involving the use of the UW nuclear reactor, which the students tour early in the semester.

In spring 2022, the students designed, manufactured and tested a light-sensitive detector to insert into the reactor water pool to measure the intensity of the blue light it emits when operating. The students then determined how that data correlates with the actual reactor power level.

This project requires a significant amount of hands-on work, and students meet weekly in the college's makerspace, where they also participate in workshops that teach them how to use equipment including 3D printers, laser cutting machines, and electronics as well as computer-aided design software.

"The hands-on learning aspects of the course are very important because nuclear physics can seem a little theoretical sometimes. These hands-on activities help students better understand and engage with the technical concepts they are learning in class," Couet says. "In addition, through this project, the students are gaining soft skills and learning how to effectively work in teams, which is an important foundation for their success as engineering students and in their careers."

As part of the course, he also organizes roundtables with prominent alumni and others to give students insight into a variety of career paths.

Because Couet designed the course to cover a broad range of nuclear-related topics, including areas that fall under the social sciences, it includes many guest lecturers from across UW-Madison as well as from other institutions. For example, students learn about current energy markets, as well as the outlook for future energy markets, to better understand the economic context for nuclear energy. They also learn about nuclear fusion and how nuclear power could enable space exploration, as well as about medical radioisotopes production and their use to treat cancer. Other topics include ethics in nuclear engineering, including an overview of the history of the field to learn from the past and avoid repeating the same errors.

Importantly, Couet says the course doesn't shy away from controversies related to nuclear energy, such as uranium mining in the United States and its impact on Native Americans; students also explore

issues related to community acceptance of nuclear energy.

"I think it's very important for a nuclear engineering education to address the reality that there are challenges related to community acceptance of nuclear energy, and students need to understand that," Couet says. "However, this issue is not often talked about in nuclear engineering curricula. To my knowledge, this introduction to nuclear engineering course is the only one of its kind that really covers these important areas."

For Couet, the goal is to prepare students to be highly skilled nuclear engineers who can effectively advocate for and advance nuclear energy to help fight climate change. He notes that while many designs for next-generation advanced reactors are being formulated, none of these reactors have put electricity on the grid yet.

"Although evidence of climate change is every day more visible, a big obstacle to building new advanced reactors remains community and political acceptance," Couet says. "So we can teach our students to be great nuclear engineers—but if we want them to be agents of change, we need to also teach them the sociological aspects of nuclear energy and build that understanding into their educational experience."

For undergrad, internship adds international perspective on nuclear innovation

As an intern at the International Atomic Energy Agency (IAEA) in Vienna, Austria, nuclear engineering undergraduate Brienna Johnson is relishing the experience of living abroad and working on efforts that could help improve nuclear energy worldwide.

The IAEA is the world's foremost intergovernmental forum for scientific and technical cooperation in the peaceful use of nuclear energy. Established in 1957 as an autonomous international organization within the United Nations system, the IAEA currently has 173 member states.

During her year-long internship, Johnson is working in IAEA's nuclear power engineering section, where she is a member of a team focused on nuclear innovation and plant life management, including looking at ways to extend the lifetime of nuclear energy plants.

"Interning at the IAEA has been a really wonderful experience," she says. "In particular, it has been great meeting and building connections with the other interns and many experts from around the world and learning about all the different things people are working on in the nuclear field. It has really expanded my view of various career paths and opportunities that are available for nuclear engineers."

At the IAEA, Johnson helps plan and organize meetings and events, also. And she has had the opportunity to attend some conferences, including a technical meeting about artificial intelligence.

"I was able to sit in on presentations and learn about how different AI technologies could potentially be implemented in nuclear power plants, which was a great experience," she says.

In her free time, Johnson has been taking advantage of the many cultural and recreational attractions Austria has to offer. She has explored Vienna's museums and culture and taken weekend trips to places like Obertauern ski resort.

At UW-Madison, Johnson is co-president of the American Nuclear Society student chapter. She is also a student operator for the UW nuclear reactor, an experience that has been a highlight of her education. She enjoys the hands-on experience of working with the reactor and says it has helped her better understand lessons from her nuclear engineering courses.

"I think working at the reactor is really cool, and I love all the hands-on activities I get to do, such as bringing the reactor up to power, radiating samples and helping with others' experiments," she says. "It's a great way to apply some of what I'm learning in my courses."

Alum contributes to NASA's James Webb Space Telescope

Engineers deploy the forward and aft pallets that hold the James Webb Space Telescope's sunshield during launch as part of Webb's last deployment tests at Northrop Grumman in Redondo Beach, California, in December 2020. Credit: NASA.

A UW-Madison engineering mechanics alumnus made important contributions to NASA's James Webb Space Telescope, the world's largest and most powerful space science observatory.

The telescope arrived at its home in distant orbit on Jan. 24, 2022. Webb is an international program led by NASA with its partners, the European Space Agency and the Canadian Space Agency. The telescope's revolutionary technology will explore every phase of cosmic history—from within our solar system to the most distant observable galaxies in the early universe, to everything in between. Webb will reveal new and unexpected discoveries and help humanity understand the origins of the universe and our place in it.

Wei-Di Cheng (BSEMA '93) is a stress analyst at Northrop Grumman in Redondo Beach, California, where he worked on several aspects of the James Webb Space Telescope. He analyzed mechanical ground systems to propose, design, fabricate, test and deliver ground systems to support spacecraft and payload integration.

His contributions included working on the telescope's forward and aft unitized pallet structures, which contained Webb's carefully folded sunshield.

The ultrathin sunshield, about the size of a tennis court at full size, is essential to protect the telescope from the light and heat of the sun, Earth and moon, allowing Webb's instruments to cool down to the extremely low temperatures necessary to carry out its science goals.

However, maintaining the sunshield's shape as it unfolds into position involves a delicate, complicated process. Cheng played a key role in testing the unitized pallet structures to help ensure that the sunshield would successfully deploy in space.

"The unitized pallet structures are roughly three stories tall and made of a very thin and light composite material; at some points, the structure is about as thin as a few pieces of paper stacked together," Cheng says. "So my work involved testing the structure during different configurations to make sure it would function as it needed to in space."

Cheng says a particularly challenging aspect of the testing was to unfold the delicate sunshield in Earth's gravity environment, which causes friction, unlike unfolding material in space without the effects of gravity.

"So we needed to adequately test the structure without imposing too much force into it and causing it to bend or break," he says. "This had never been done before, and it was very difficult to accomplish."

The Webb team began remotely deploying the sunshield Dec. 28, 2021, and successfully completed the deployment on Jan. 4, 2022, marking a critical milestone for the mission.

In addition, Cheng worked on testing a transport container for the James Webb Space Laboratory to ensure that the laboratory could be safely transported to NASA facilities across the country for various tests.

Cheng says his UW-Madison engineering education was instrumental in his career success and enabling him to contribute to the James Webb Space Telescope.

"To this day, I'm still thankful for the solid education I received at UW-Madison, which enabled me to work on a project that will make history," he says. "My degree helped me get my foot into the aerospace industry, and as I have progressed in my career, I have an even greater appreciation for how my UW-Madison education prepared me for success in the aerospace industry."

Cheng, who has worked at Northrop Grumman for more than 16 years, says he's excited to see all the work on the James Webb Space Telescope come to fruition.

"I'm going to hang my hat on this accomplishment," he says. "I'm very proud of what our team has accomplished, and I look forward to the discoveries that will come from Webb. It's exciting to make a contribution to society through my work."

2021 college early career award recipient

Benjamin W. Longmier
(BSEP/physics ’04, MSEP ’05, PhDEP ’07)
CTO and co-founder, Swarm Technologies

An entrepreneur who has founded three aerospace companies, including one acquired by Apple, Longmier is disrupting the satellite communications industry on a grand scale—and in the process, opening the internet of things to the entire earth. At a size smaller than an average engineering textbook, the ultra-sensitive satellites manufactured by his latest company, Swarm, will form a global constellation that can provide two-way satellite connectivity everywhere on the planet.

EP honored Longmier for his achievements with a College of Engineering Early Career Award. He shares insights from his EP education in this Q&A.

How did your experience in the College of Engineering influence your career path?
I’ve always been a really hands-on person. Madison had a lot of opportunities for getting involved in extracurricular clubs, working in machine shops, and as a student, working in labs. A lot of universities don’t necessarily have that many offerings on that front. When I was 16, I worked with Professor Riccardo Bonazza’s lab and learned a lot about engineering, experimental research, machining and experiment design. That was a really nice start to my professional career. When I enrolled as an undergrad, I sought out research activities in other labs and participated in organizations like the Zero G student group. We built the entire experiment from scratch, won the NASA proposal, and operated the device in microgravity on NASA’s Vomit Comet down in Houston.

Who played the greatest role in your achievements?
My PhD advisor, Professor Noah Hershkowitz, who unfortunately passed away, was by far the biggest influence for professional growth, personal growth, how to run a lab, how to run experiments, how to think about the universe, how to find meaningful results that can help the community and the profession.

Any hobbies?
I have an airplane out here in California and we fly around to neighboring airports in Napa and Sonoma, Santa Monica, and along the coast. So I have a blast. I actually learned to fly in Wisconsin, out over the Wisconsin River practice area.

2021 college distinguished achievement award recipient

Moo Hwan Kim
(PhDNE ’86)
President, Pohang University of Science and Technology

In 1987, just a year after Pohang University of Science and Technology opened its doors, Kim began as a faculty member in mechanical engineering and advanced nuclear engineering. Alongside educating the next generation of engineers and conducting research, he simultaneously contributed to global nuclear engineering safety and security as a member of national and international commissions and advisory councils. In 2019, he was named president of the university and says he is honored to serve the school that grew with him and helped to nurture his own success.

EP honored Kim as a nuclear engineer and academic leader who has made innovations that significantly improve fundamental understanding of two-phase flow and heat transfer as applied to nuclear energy systems. He shares insights from his EP education in this Q&A.

How did your experience in the College of Engineering shape your career path?
First of all, studying at UW-Madison has influenced basically everything I have done in my work related to nuclear energy and as a professor and as president of the Korea Institute of Nuclear Safety. More importantly, the way my advisor, Professor Michael Corradini, took care of each and every student and supported us has greatly influenced me in my role as professor and in managing a university.

As a student here, how did you spend your free time?
Free time was something that was rare for an international student, especially with a wife and two sons. I cherished pockets of downtime when I golfed with friends. Even now, the places I remember the most from UW-Madison are the temporary buildings next to the football field, the Engineering Research Building, and the Odana golf course. I also can’t forget hanging out at the pub with my advisor and colleagues on Friday afternoons. We drank beer and mostly talked about restaurants, food and sports. Being new to American sports, I remember studying the sports section of *USA Today* diligently before our gatherings so I had something to say.

Anyone you’d like to mention?
First and foremost, I want to thank my wife, Jeong Nam Yoo. I owe my life to her as she gave me one of her kidneys about three and a half years ago. I can still do the things I love today thanks to her devotion. All that I am today, I owe entirely to her. I am also grateful and proud of my two sons, Bum Jun and Arthur, who are all grown up and playing their part in the world, though I couldn’t spend more time with them when they were younger because I was always working late at school. Lastly, I am deeply grateful to my deceased parents and in-laws for allowing our family to exist in this world.

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

engineering.wisc.edu/ep

Department of Engineering Physics
1500 Engineering Dr., Room 151
Madison, WI 53706

Crone applies experience in NSF

Professor Wendy Crone was named a program director within the Directorate for Engineering at the National Science Foundation.

Her responsibilities span the biomechanics & mechanobiology program, the mechanics of materials and structures program, and the major research instrumentation program in the Division of Civil, Mechanical and Manufacturing Innovation.

This position takes advantage of both her research expertise in mechanics as well as her prior experience in administrative oversight of grants and awards programs.

"I believe my background positions me to support and advance the policies and initiatives of the National Science Foundation and benefit the field of mechanics," says Crone, the Karen Thompson Medhi Professor.

Crone's research spans experimental solid mechanics, biomechanics, materials characterization and medical devices. Currently she is exploring the interplay between cells and the mechanics of their surroundings through an engineered micropatterned platform developed in her lab. This platform has provided new insights into both healthy and diseased cardiac cells, as well as skeletal muscle, with structural, mechanical and electrical readouts. In addition to journal publications and patents, she is the author of two books, *Introduction to Engineering Research* (2020) and *Survive and Thrive: A Guide for Untenured Faculty* (2010). Crone is fellow and past president of the Society for Experimental Mechanics, a discovery fellow in the Wisconsin Institute for Discovery, and recently received the Award for Mentoring Undergraduates in Research, Scholarly and Creative Activities from UW-Madison.