FALL 2017

ENGINEERING PHYSICS

UNIVERSITY OF WISCONSIN-MADISON

NEW COURSE TEACHES INDUSTRY APPLICATIONS OF DRONES

CHAIR'S MESSAGE

Douglass Henderson

Greetings!

There are many exciting things happening in the department, and I'm pleased to share some of our recent accomplishments.

The department's excellence is fueled by our renowned faculty, who develop innovative learning experiences for students and lead major research efforts that benefit society. I'm happy to share that Associate Professor Oliver Schmitz has been awarded tenure in the department. Since joining the department in 2014, Schmitz has won a number of prestigious awards for his work, including a National Science Foundation CAREER award. Schmitz's groundbreaking plasma fusion research is an asset to the department and our students.

Our alumni are also making an impact both in Wisconsin and beyond. SHINE Medical Technologies, founded by Greg Piefer (BSEE '99, MSNEEP '04, PhDNEEP/MedPhys '06), continues to grow and recently broke ground on its new facility near Janesville, Wisconsin. SHINE's technology proposes to eliminate the use of highly enriched uranium in making molybdenum-99, an isotope needed in about 20 million medical imaging procedures annually in the United States. The Janesville facility is slated to employ around 150 people. And another alumnus, Adam Steltzner (PhDEM '99), recently had a prominent exhibit unveiled in UW-Madison's new Alumni Park, a green space located between Memorial Union and the Red Gym. The exhibit pays tribute to Steltzner's involvement with NASA's Mars rover *Curiosity*. (See more on pg. 7)

The department has also been busy updating various labs and teaching spaces to increase hands-on learning opportunities. Several lab improvements are planned or have been completed in the Engineering Research Building, including the NE526 course lab located in Room 718 and a complete remodel of the 3rd floor plasma physics graduate student space. The EMA senior design lab in Engineering Hall has gone through a comprehensive update as well.

To support the creation of more state-of-the-art learning spaces, consider giving to the department online at allwaysforward.org/giveto/ep. No matter the size of your gift, it will help make a difference as we continue to enhance our students' educational experience.

Thank you for your continued involvement and support of our department.

ON, WISCONSIN!

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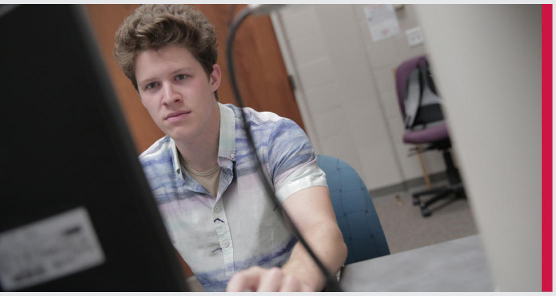


AN AGGRESSIVE APPROACH TO IDENTIFYING STRONG, LONG-LASTING REACTOR MATERIALS

Calvin Parkin's graduate research interest is messing everything up.

Specifically, messing up high entropy alloys by blasting them with radiation. The first-year graduate student recently received a Department of Energy (DOE) research fellowship from the Nuclear Energy University Program to fund his education and research in creating new alloys.

Conventional alloys, Parkin says, are made up mostly of one material such as aluminum or iron. "The idea is if you design an alloy and then you hit it with a bunch of radiation, it's just going to scramble everything up," he explains. "You get defect formation that can mess with your macroscopic properties. We're looking for alloys that can withstand high levels of radiation damage in fast reactors because the fast neutrons are much more damaging than in thermal reactors."

Conventional alloys cannot withstand exposure to radiation for very long due to their finely tuned composition. Parkin hopes to discover a new alloy by combining many different elements to find just the right combination of equiatomic—or having an equal number of atoms—components.

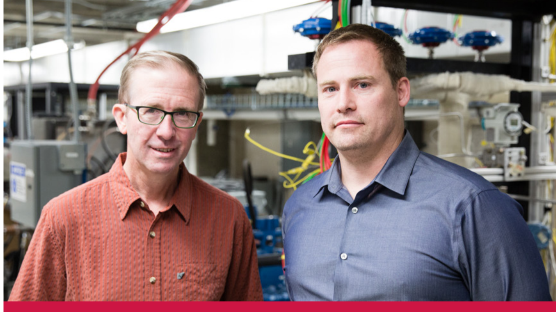
"If you're all equimolar to begin with and you're hitting it with radiation, you're messing everything up, but everything's already kind of messed up anyway," he says. "If you have your properties right, the radiation will not do as much damage to the alloys."

Parkin, who is advised by Assistant Professor Adrien Couet, will be using heavy ions instead of the neutrons in nuclear reactors because the ions will provide a much better idea of the amount of damage sustained after a 60- or 70-year lifetime in a shorter amount of time.

The three years of added tuition funding plus a stipend coming from the DOE will provide him with just the freedom he needs to find an alloy to sustain that kind of damage.

"You can get some really interesting properties from these new alloys and there's so much variation possible in the composition ranges that you could run into properties you'd never expect," he says. "We want to see if we can find something just crazy-good."

UW-MADISON SELECTED FOR $9.3 MILLION IN NUCLEAR ENERGY RESEARCH FUNDING



Todd Allen (left) and Mark Anderson. *Photo: James Runde.*

UW-Madison engineers have received an estimated $9.3 million in funding from the United States Department of Energy (DOE) for advanced nuclear energy research. The awards will drive new research on compact heat exchangers, nuclear fuel cycles, enabling technologies, and advanced reactor concepts.

Issued by the DOE's Nuclear Energy University Program, UW-Madison's portion of the projected funding is substantial, representing more than 17 percent of the funds awarded to universities through that program in 2017.

The Nuclear Energy University Program, which seeks to maintain U.S. leadership in nuclear research through support of university-led research programs, has a long and robust record of funding research in the College of Engineering.

"Over the history of this program, UW has garnered more funds than any other university," says Professor Todd Allen, a 2017 award recipient. "This funding builds on that history."

Of the eight UW-Madison awards selected for final negotiation with DOE, the largest consists of nearly $5 million for research led by Allen, Research Professor Mark Anderson, and technical director of industry relations Bruce Beihoff (Wisconsin Energy Institute). The three-year project will focus on advanced compact heat exchangers—devices that transfer heat from one matter to another—for use in nuclear systems.

Advanced compact heat exchangers provide more efficient heat transfer than traditional heat exchangers, and yet the very features that make them efficient also make them difficult to use in nuclear systems. Thinner walls and smaller channels mean they are harder to image and inspect, and their small tubes are potentially more susceptible to clogging. For heat exchanges involving nuclear material, ensuring the integrity of the exchanger is a critical safety issue.

The goal of Allen's team is to optimize the manufacturing of compact heat exchangers to provide the safety assurances needed to commercialize them for use in advanced nuclear reactors. To do that, his team will collaborate with major players in the nuclear sector, including the nonprofit Electric Power Research Institute (EPRI) and MPR Associates, a nuclear power consulting firm.

"We want to make sure that we get really practical information that helps move compact heat exchangers to commercialization," says Allen. "We will be testing prototypes made by manufacturers, and a lot of the project's guidance and philosophy will come directly from manufacturers."

The remaining seven UW-Madison projects cover broad ground, from funding research on nuclear fuel cycles, enabling technologies, and reactor concepts, to infrastructure improvements. Those projects include:

- **$800,000** for a project on extreme performance high entropy alloys (Assistant Professor Adrien Couet)
- **$800,000** to study critical heat flux for innovative accident tolerant fuel cladding surfaces (Professor Emeritus Mike Corradini)
- **$1,000,000** to develop a low-temperature powder spray process for manufacturing fuel cladding and surface modification of reactor components (Distinguished Research Professor Kumar Sridharan)
- **$400,000** to develop an advanced supercritical Brayton power cycle directly coupled to a fission reactor (Mechanical Engineering Professor Greg Nellis)
- **$800,000** to investigate radiation heat transport in molten salts and add functionality for radiative heat transport in a thermal-hydraulics system code (Assistant Professor Raluca Scarlat)
- **$300,000** in infrastructure funds for the Environmental Degradation of Nuclear Materials Laboratory (Professor Douglass Henderson)
- **$60,000** for a reactor upgrade (Reactor Director Robert Agasie)

Kumar Sridharan (left) and Raluca Scarlat. *Photo: Gregory Vershbow.*

Adrien Couet. *Photo: James Runde.*

Mike Corradini. Photo: *James Runde.*

With many of the projects depending on collaborations among UW-Madison researchers, Allen says this latest round of funding demonstrates the value of the Institute for Nuclear Energy Systems (INES), which gathers UW faculty with diverse skill sets into teams to address important nuclear research issues.

"INES is helping our researchers to collaborate on some of the most important challenges facing the field today," says Allen. "Together, we're driving things forward, and continuing UW-Madison's legacy of conducting essential research on nuclear energy."

UW-MADISON NUCLEAR FUEL COATING HELPING TO REVOLUTIONIZE NUCLEAR FUEL

In the cold spray laboratory, undergraduate student Jorie Walters positions a zirconium alloy tube in the holder for the powder cold spray deposition process, while PhD student Ben Maier looks on. *Photo: Stephanie Precourt.*

Following the 2011 Fukushima nuclear accident in Japan, the U.S. Department of Energy (DOE) initiated industry-led research-and-development programs aimed at increasing the tolerance of the fuel rods used in today's nuclear power reactors in the event of a similar beyond-design-basis severe accident.

In the initial phase of the effort, the DOE funded a broad range of projects at universities, national laboratories and companies that explored multiple concepts for producing fuel rods to better withstand the extremely high temperatures that a nuclear reactor core can reach during the unlikely event of a severe accident.

After reviewing the results from those initial projects, the DOE and its industry partners then selected only a few of the most promising concepts for accelerated development in the second phase of the program.

A UW-Madison research project led by Distinguished Research Professor Kumar Sridharan, in collaboration with Westinghouse Electric Company, is among the projects selected to advance to the second phase.

"It's very exciting to have our concept selected for this next phase amid heavy competition," Sridharan says. "We were really fortunate to have been picked by Westinghouse as a collaborator for this high-profile project, which aims to increase the temperatures that nuclear fuel can withstand and, coincidently, help solve a pressing economic challenge for the nuclear industry."

In their development, Sridharan and his research group have employed a process called powder cold spray deposition, which can be used to apply an oxidation-resistant metallic coating to zirconium alloy fuel rods.

Current industry standard fuel rods are made out of a zirconium alloy. In a reactor, these uranium fuel-filled rods are bundled together, forming the reactor core. While zirconium performs well in a nuclear reactor under normal and most accident conditions, the material can exacerbate beyond-design-basis emergencies like the one that first occurred at Fukushima. In that instance, an unprecedented 9.5 magnitude earthquake and 45-foot-high tsunami caused the reactor cooling system to fail and the core to climb to very high temperatures.

"When zirconium heats up, it oxidizes exothermically, and the reaction produces a lot of heat, causing the core temperature to rise quickly in severe accident conditions," Sridharan says. "Zirconium oxidizes very rapidly at high temperatures, so it is not fully suited for a 'beyond-design-basis' situation like what happened at Fukushima."

Oxidation, which occurs when a metal reacts with oxygen to form an oxide, can cause problems in a reactor in the case of an accident, where fuel rods can reach high temperatures. Oxidation reduces the thickness of the metal cladding of the fuel rods, decreasing their overall structural strength. In addition, oxidation of zirconium produces hydrogen gas, which was one causal factor of the explosions that occurred in Fukushima.

The UW-Madison team's protective metallic coating would slow oxidization and hydrogen generation—potentially preventing a nuclear emergency or significantly mitigating its consequences, by providing additional operating time at high temperature, as well as time for the reactor operators to react.

"Using our cold spray process, we've deposited this metallic material on the rods, and in our tests we can see that this coating achieves significant protection for the underlying zirconium from oxidation, and that's the main goal," says Sridharan. "In a nuclear accident, every minute of coping time you can buy

Professor Kumar Sridharan holds a coated zirconium alloy rod in his Cold Spray Laboratory, surrounded by students who are participating in the research collaboration with Westinghouse. From left to right: Jorie Walters (MS&E undergraduate); Greg Johnson (MS&E master's student); Kumar Sridharan; Ben Maier (MS&E PhD student); Mia Lenling (MS&E undergraduate); and Hwasung Yeom (nuclear engineering and engineering physics PhD student). *Photo: Stephanie Precourt.*

The team's protective metallic coating would slow oxidization and hydrogen generation—potentially preventing a nuclear emergency or significantly mitigating its consequences.

matters a lot, and this technology could help buy additional time for responders to bring in remedial measures."

His cold spray process entails using a spray gun to shoot powder particles of a material at supersonic velocities onto the surface of the fuel cladding tube. As the solid particles hit the surface of the tube, they deform and flatten out like a pancake, forming a coating.

Notably, this coating process is extremely fast and cost-effective while also occurring at room temperature and atmospheric pressure—making it well suited for scaling up for large-scale manufacturing.

Since this approach doesn't require any design or material changes for current light water reactors, it's a promising near-term solution for the nuclear industry, which has very long timelines for adopting new materials or designs. Sridharan and his team are continuing to work on optimizing their coating and the process.

Under the DOE program, Westinghouse is currently testing the UW-Madison zirconium alloy cladding sections at its facilities in a prototypical light water reactor environment, as well as in steam at temperatures exceeding 1,300 degrees Celsius, to represent the most severe accidents.

The team's coated claddings also are being tested under neutron irradiation in the Halden test reactor in Norway and in the Massachusetts Institute of Technology nuclear reactor. Sridharan is preparing more samples for neutron irradiation testing in the Advanced Test Reactor at Idaho National Laboratory.

"Reactor testing is very expensive and takes a long time, so the fact that we've been selected for testing in three separate reactors indicates that the DOE and industry are viewing this project very seriously and putting a lot of faith in what we're doing," Sridharan says.

NEW COURSE TEACHES STUDENTS HOW TO FLY DRONES, COLLECT DATA

Chris Johnson

In summer 2017, the College of Engineering added a new way for students to navigate the skies: a course on drones.

The first of its kind at UW-Madison, the class teaches students how to fly unmanned aircraft systems (UAS), or drones, and the practical applications of the technology, says Chris Johnson, instructor of the new course and director of the UW Flight Lab.

The course, called *Introduction to Unmanned Aircraft Systems* (EMA 601), was created by Johnson in spring 2017. He submitted the new course proposal to the College of Engineering Education Innovation Committee and was awarded a $40,710 grant in March 2017 to pursue it.

James Blanchard, the College of Engineering's executive associate dean and an EP professor, says given the rapidly growing use of drones, it's useful for students to learn about their capabilities. Eight students took the summer class. Johnson is teaching the class again in fall 2017, and he says it will continue to be offered in semesters going forward.

Drones are controlled by a remote that is held by the operator. Right now, it is illegal to fly drones farther than line of sight. *Photo: Bryce Richter.*

Overall, Johnson says there has been a lot of interest in the class and drones in general. "Most people are completely enthralled by the technology," Johnson says. "It's really refreshing to see because there is a lot of value that can come from it."

In the first half of the course, students learn how to operate drones safely and ethically by gaining an understanding of the technology itself as well as the laws and regulations surrounding drones. The midterm exam is a certification exam sanctioned by the Federal Aviation Administration, which when passed allows students to operate drones for commercial purposes.

The second half of the course teaches students about the business and engineering applications of the technology and uses of the data. Part of that learning process is completing a project to explore various industry applications. Students have to collect data using the drones and process that data to create an end product for a company. Johnson says he already has a list of 12 companies that are willing to work with students, which could lead to an internship.

Drones have applications for real estate, insurance, construction, utilities, agriculture, marketing, journalism and more, Johnson says. One example is inspecting electrical wires for hot spots and corrosion. Right now, utility companies have to hire helicopter crews when drones can collect better data faster for pennies on the dollar.

"This industry is very immature, but it's poised to boom," Johnson says. "The companies that are taking advantage of the technologies are the innovators—they're the first movers—because they realize the huge economic upside to employing these drones."

While the technology, laws and regulations are not yet in a place for the drone industry to really take off, Johnson says it's only a matter of time. "Drones are already constantly at work collecting data," he says. "They're not to the point where they're delivering packages, but they will be."

ROSS RADEL: EARLY CAREER ACHIEVEMENT AWARD RECIPIENT

We honored Ross for his corporate leadership that has led Phoenix Nuclear Labs to become an internationally recognized manufacturer of neutron sources for medical diagnostics and detecting clandestine materials.

Ross Radel
President, Phoenix Nuclear Labs
BSNE '03, MSNEEP '04, PhDNEEP '07

Do you have a favorite engineering professor from your time at UW-Madison?

The professor who stands out most for me is Jerry Kulcinski, a nuclear engineering professor. When I was a freshman, Jerry was nice enough to show me around his lab and talk applications of fusion technology. This got me really excited about not just engineering, but nuclear engineering and fusion. I ended up working with him as an undergraduate, so he was mentoring me outside the classroom. And ultimately, when I decided to go to grad school, I joined his group and he became my PhD advisor. For the eight years that I was at UW, he was a huge influence on my life. He helped me walk the straight and narrow path and get a great head start on my chosen career, but he also taught me what matters in the real world and not just what matters in school.

What is your fondest memory of your time on campus?

I was a senior at the UW when I met my wife, Tracy (who is also a nuclear engineer), and we were married when I was in grad school. That time period was a pivotal part in my life that's pretty intimately tied in with my UW experience. We were married in downtown Madison, just off campus, and lived in student housing in Eagle Heights the first year after we were married. For those first few years of married life, we were both grad students doing research in different areas, and it was a fantastic experience.

How did your experience in the College of Engineering shape your career path?

The College of Engineering provides a diversity of education. The way that the engineering curriculum is set up—whether undergraduates realize it's good for them or not at the time—forces students to take multidisciplinary courses. It gave me the breadth of background to pivot easily out in the real world, which is important because things change very quickly. For example, it's been instrumental for me to be able to know enough about mechanical or electrical design principles to communicate with those design teams. I couldn't design a circuit board, but I can speak the language and have enough understanding to help form designs. Having a diverse background has really, really helped in my career.

Of what professional accomplishment are you most proud?

Working in technology development, my proudest moments are when we bring systems online and they meet the customer's requirements. When your team is developing technologies that didn't previously exist, taking them from a piece of paper to meeting customer requirements, it gives you a fantastic sense of accomplishment.

What advice would you give current students in your discipline today?

Experience as many internships as you can. I worked at one internship in my eight years and it was a fantastic learning experience. There's a ton of value in that diversity of experience when you start looking for your first job. You can also find undergraduate research opportunities. Whether your research involves sitting behind a computer or cutting your knuckles turning wrenches, it's a fantastic opportunity. Both research and internships can help you figure out what you want to do with your life a lot sooner than you could just by hitting the books for four years.

ADAM STELTZNER: DISTINGUISHED ACHIEVEMENT AWARD RECIPIENT

> We honored Adam for his pioneering accomplishments that have yielded new ways to explore and expand the knowledge of our universe.

Adam Steltzner
Engineering Fellow,
CalTech/NASA Jet Propulsion Laboratory
Chief Engineer, Mars 2020 Project
PhDEM ’99 (BSME ’90, UC-Davis; MS applied mechanics ’91, Caltech)

Why did you choose to attend UW-Madison for your PhD?

My first wife and I were looking for a place to go to return to grad school. We looked in several locations and we happened to come to Madison on the first stunningly beautiful spring day. It’s a beautiful place with great people and a great school. Everybody was incredibly kind, pleasant and friendly. We were sitting on the Memorial Union Terrace having a beer, stunned by what we saw. Somebody came up to us and said, “Are you going to the party?” and we said, “Party?” and they said, “Yeah, the Mifflin Street Block Party. It’s down that way, turn left here, turn right here.” So, we went and it sealed the deal.

How did you initially get into engineering?

After high school, I played rock and roll around the San Francisco Bay Area. As I was heading out from playing a show one night, I noticed that the constellation of Orion was in a different place in the sky than it had been when I arrived to play the show, and I got curious about that. I went down to a local community college to take an astronomy course, which happened to be a prerequisite for a physics course, so I took physics and here I am.

Did you have a favorite engineering class while you were here?

Continuum mechanics because it’s the foundation for several different fields: fluid mechanics, solid mechanics, fracture mechanics. So many fields start from the basic essential study of continuum.

What’s your fondest memory of your time on campus?

The Memorial Union Terrace is one of the best places on earth. It’s really a remarkable physical and cultural space. Hanging out at the Terrace, playing hearts on a Friday afternoon in the spring or early fall are some of my favorite memories. I’ve been around the world a bit, and there are not a lot of places where you can have a beer and a brat, watch people sail, look out a beautiful lake with the backdrop of a beautiful old building, and just be surrounded by beauty.

How did your experience in the College of Engineering benefit you in your career?

I really got to teach, not just grade papers. I taught every lecture. I organized every lecture. I did not choose the textbook, but the exams were my own and the lectures were my own. The act of teaching was really good for me because, if you can teach it, you really understand it. I think the things I understand best are the things that I was forced to teach.

Of what professional accomplishment are you most proud?

Landing the *Curiosity* rover on Mars on August 5, 2012. I led the team that invented, developed, tested and operated the landing system that got *Curiosity* to Mars. We had invested 10 years of our lives in creating this rover and landing it on the moon. To have it come off without a hitch is, frankly, mind-numbing. I was kind of walking around in the clouds—in disbelief that, all of a sudden it was over, and it had worked.

NEW FACULTY PROFILE

RAMATHASAN THEVAMARAN: STRUCTURING MATERIALS TO GIVE THEM SPECIFIC FUNCTIONALITY


Ramathasan Thevamaran

What do submarines and football helmets have in common? Someday they could be built with the highly specialized materials Ramathasan Thevamaran is researching. Thevamaran, who joined the department in fall 2017 as an assistant professor, is interested in manipulating the structure and mechanical properties of materials to provide a very specific functionality. Materials like these could, for example, make military submarines undetectable with a wave-absorbing outer surface, or protect athletes from brain injuries with an energy-absorbing foam that makes helmets both lighter and tougher.

Although the potential applications for structured materials are virtually endless, Thevamaran isn't really thinking about those right now. "I enjoy doing fundamental research that has the potential to influence different application areas in the future," he says. "Advancing fundamental knowledge is one of my primary purposes right now."

And there's a lot of fundamental knowledge under the very big umbrella of structured materials to advance. In particular, he's experimenting with hierarchical and gradient property changes, as well as nonhermitian and parity-time symmetric acoustics.

Hierarchical property changes can be made at varying length scales—as small as the nanoscale and as big as several millimeters. Take vertically aligned carbon nanotube foams, for example. At the millimeter scale, you can see a foam with the naked eye. Through a microscope, you can see bundles of aligned nanotubes. Zooming in further, you're able to see individual nanotubes and the multiple walls that construct them. Each level, or length scale, provides an opportunity to edit structural features. In this example, the number of walls could be altered, patterns could be redesigned, and even the geometry of a single nanotube could be modified.

The ability to edit every single feature during synthesis allows for more control over the design of materials. "Whatever mechanical properties you're interested in, you can affect bulk scale properties—strength, stiffness, damping—with changes introduced at different length scales," Thevamaran says.

Learn more about Thevamaran's research: www.engr.wisc.edu/focus-new-faculty-ramathasan-thevamaran-structuring-materials-function-need/

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