SUMMER 2018

MATERIALS SCIENCE AND ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

A bright future for our field

CHAIR'S MESSAGE

Paul Voyles

Dear alumni and friends,

Welcome to the spring newsletter for the UW-Madison materials science and engineering department. In the following pages you can read about recent events around the department, including a new summer fellowship in materials informatics called NextGen, a local engineer from Fisher Barton, Daryl Crawmer, who has given back to aspiring materials engineers by teaching a course in thermal spray technology, awards won by our students and faculty, and research advances in both ceramics and metals.

Our other big news is that we have graduated 35 new engineers with bachelor's degrees in materials science and engineering this May! Twelve students graduated in December, bringing the size of our 2017-2018 graduating class up to 47, the largest it's been in several decades—and maybe ever. The size of the class is a testament to the strength of the MS&E program and the UW-Madison College of Engineering, as well as the growing recognition that engineers and scientists are the ones who will solve the most pressing challenges confronting society, from clean energy and clean water, to improved transportation, to new medical devices and treatments.

We are immensely proud of our new graduates, both for their accomplishments so far and for their future promise, but this expanded student population means we need additional resources to help us maintain the margin of excellence that makes a UW-Madison MS&E education special. Please consider contributing to either the John H. Perepezko Student Support Fund or the Materials Science and Engineering Design Course Fund. You can find more information about both funds by contacting our new director of development, Valerie Chesnik, or on the web at **www.allwaysforward.org/giveto/mse**.

Please join me in welcoming the class of '18 to the group of MS&E alumni, and enjoy the rest of the newsletter!

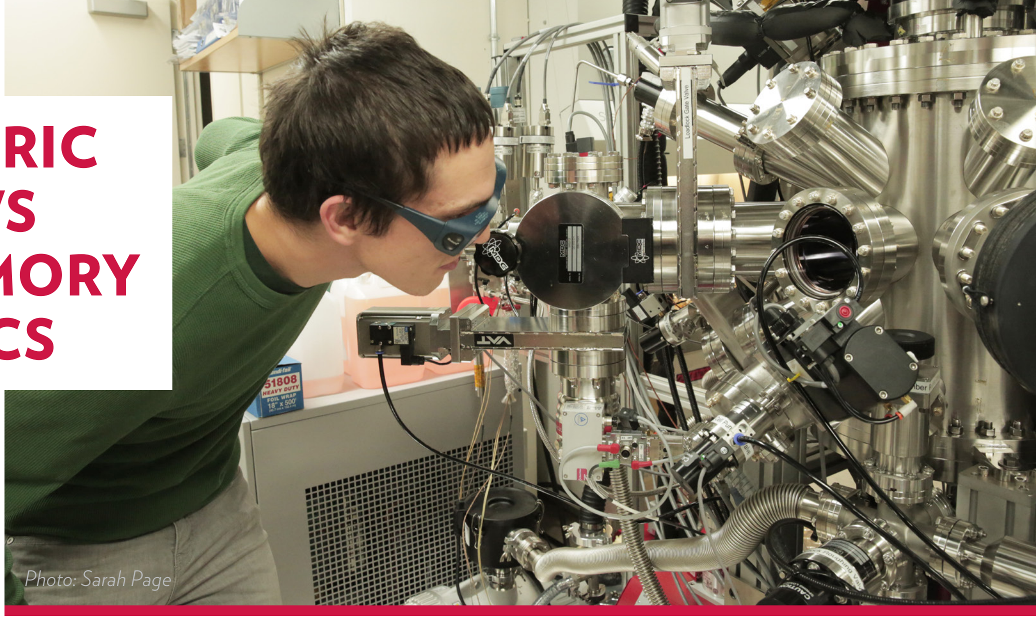
ON, WISCONSIN!

Paul Voyles, Professor and Chair
1509 University Ave., Room 262
voyles@engr.wisc.edu • (608) 262-1821

MEET VALERIE CHESNIK, NEW DIRECTOR OF DEVELOPMENT!

We're thrilled to welcome Valerie Chesnik to MS&E as the new associate director of development! A Madison native, Valerie graduated from UW-Madison in 2013 with a bachelor of arts degree in strategic communication. Before joining the department, Valerie was the marketing and development manager for the Foundation for Madison Public Schools—a position she held since September 2014. There, she spearheaded several innovative and fruitful fund-raising initiatives, including a wildly popular gala performance event called Lipsync for Schools, which raised almost $100,000 in three years. Valerie also coaches swimming for the Badger Aquatics Club and volunteers with several nonprofits in the Madison area, including the Junior League, United Way Women's Leadership, Shelly Glover Fund, Lily's Fund, AFP-Madison, and New Leaders Council. With her work in the College of Engineering, Valerie is continuing a family tradition; her father is an alum. She was drawn to MS&E in particular because she saw the department's tradition of innovation and openness to exploring new approaches. We know that Valerie's energy and creativity will be tremendous assets to the department. Contact Valerie at Valerie.Chesnik@supportuw.org or (608) 308-5226.

MAGNETOELECTRIC MATERIAL SHOWS PROMISE AS MEMORY FOR ELECTRONICS



Eom and his collaborators developed an elegant, homogenous material that not only enabled them to understand its magnetoelectric properties, but someday also could be useful to electronics manufacturers hoping to take advantage of those properties. Pictured here is physics PhD student Julian Irwin, who is part of the research team.

Smartphones and computers wouldn't be nearly as useful if they weren't full of apps, music, and videos.

Currently, devices store that information primarily in two different ways: either through electric fields (think of a flash drive) or through magnetic fields (think of a computer's hard disk).

Each has its advantages and disadvantages. However, in the future, electronics could benefit from the best of each.

"There's an interesting concept," says Chang-Beom Eom, the Theodore H. Geballe Professor and Harvey D. Spangler Distinguished Professor. "Can you cross-couple these two different ways to store information? Could we use an electric field to change the magnetic properties? Then you can have a low-power, multifunctional device. We call this a 'magnetoelectric' device."

In research published Nov. 17, 2017, in the journal *Nature Communications*, Eom and his collaborators describe not only their unique process for making a high-quality magnetoelectric material, but exactly how and why it works.

Eom and his collaborators developed an elegant, homogenous material that not only enabled them to understand its magnetoelectric properties, but someday also could be useful to electronics manufacturers hoping to take advantage of those properties.

While the homogenous material enabled Eom to answer important scientific questions about how magnetoelectric cross-coupling happens, it also could enable manufacturers to improve their electronics. "Now we can design a much more effective, efficient and low-power device," he says.

Read more: **www.engr.wisc.edu/magnetoelectric-material-shows-promise-memory-electronics/**

STRAINED MATERIALS MAKE COOLER SUPERCONDUCTORS

Superconducting materials could make the nation's power grid much more efficient, thanks to their ability to conduct electricity with zero resistance. The substances also enable MRI machines see inside patients' bodies and levitate bullet trains above the tracks because of the Meissner effect.

And UW-Madison engineers have added a new dimension to our understanding of why straining a particular group of materials, called Ruddlesden-Popper oxides, tampers with their superconducting properties.

"Strain is one of the knobs we can turn to create materials with desirable properties, so it is important to learn to manipulate its effects," says Dane Morgan, the Harvey D. Spangler Professor and a senior author on the paper. "These findings might also help explain some puzzling results in strained materials."

The findings, published Jan. 8, 2018, in the research journal *Nature Communications*, could help pave the way toward new advanced electronics.

Most materials only become superconductors when they are very cold—below a specific point called the critical temperature. For superconductors composed of thin films of the Ruddlesden-Popper material $La_{1.85}Sr_{0.15}CuO_4$, that critical temperature varies substantially depending on whether the films were grown under strain or not.

Jacobs and colleagues at Oak Ridge National Laboratory demonstrated some of the most important strain response may be a result of changes in kinetic effects for oxygen moving in and out of the material.

"Recognizing that kinetics plays a key role is very important for how you create the material," says Morgan.

The paper was also featured as a *Nature Communications* editor's highlight.

Read more: **www.engr.wisc.edu/strained-materials-make-cooler-superconductors/**

WISCONSIN ALUMNI, STUDENTS FORGE TEAM TO AID PROPOSED NASA MISSION

How did life on Earth originate? Could a bombardment of comets and asteroids laden with water, ice and essential organic molecules have enabled emergence of life on our planet early in its history? To explore this possibility—and to simply better understand comets more broadly—NASA is considering a mission that could return samples from a comet to Earth in the year 2038. If the mission is greenlighted in 2019, its approval will be in part thanks to a unique and informal collaboration between two old UW-Madison classmates and a group of enterprising and enthusiastic students at UW-Madison and UW-Platteville.

The collaboration began soon after NASA scientist Todd King (PhDMS&E '96) became involved in the comet proposal—known as Comet Astrobiology Exploration Sample Return, or CAESAR.

"CAESAR is all about getting a sample from a comet nucleus back to Earth," King says. "One of the biggest challenges in the initial proposal was that we had to come up with a design to show that, once we grab and store a sample, we can in fact bring it back to Earth, re-enter Earth's atmosphere, and land on the ground still intact and keep it cold long enough for transport to a lab. It has to survive a hot reentry and hard landing."

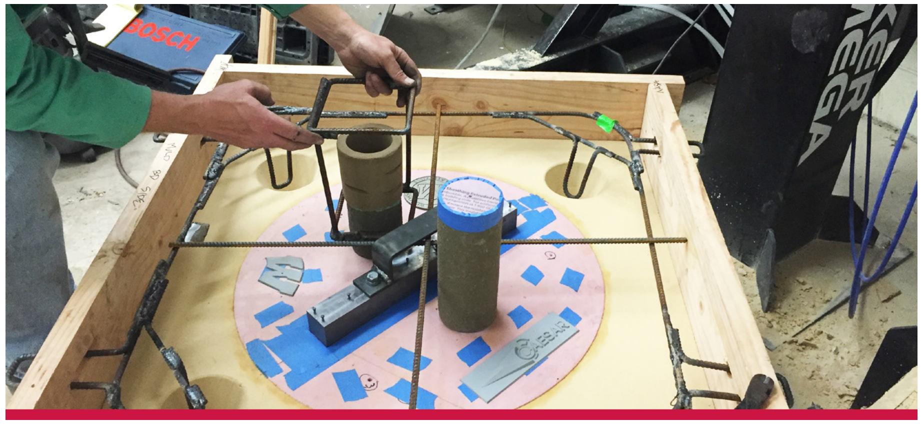


Photo: Greg Johnson

Kyle Metzloff, a UW-Madison MS&E alumnus and UW-Platteville professor of industrial studies, prepares the mold for casting the comet sample return capsule prototype for NASA's proposed CAESAR mission.

The group needed something with roughly the same shape and mass as the proposed return capsule that they could drop in a portion of the Utah desert with uncommonly soft soils where the actual return capsule would land in 2038.

King got to thinking about his time in the MS&E department at UW-Madison.

"I remembered that Madison had a small-scale working foundry when I was there in the '90s, and I reconnected with a classmate who I knew worked in the foundry and would be able to tell me if what we needed could be made there," King says.

Photo: Kyle Metzloff

Todd King (right) takes measurements of the completed comet sample return capsule prototype in the MS&E foundry.

That former classmate, Kyle Metzloff, just so happens to be on the faculty at UW-Platteville and also had recently taught UW-Madison's first metal casting course in nearly 20 years.

So began a flurry of activity orchestrated by Metzloff, who above all wanted the project to provide a challenging and exciting learning opportunity for students.

"Students helped out in every aspect of this project," Metzloff says. "Especially as we prepared for molding the sand and casting the iron, the students in Madison really stepped up and put in long hours to see this through."

Among those students was Greg Johnson, who at the time was wrapping up his undergraduate degree in materials science and engineering.

> **"CAESAR is all about getting a sample from a comet nucleus back to Earth."** — *Todd King*

"It's a fascinating experience working in the foundry because from almost any class you take in materials science and engineering, you can apply something from it here," Johnson says. "There's phase transformations, thermodynamics, deformations, heat, fluid and mass transport; the furnaces work via electronic interactions; you can get everything out of the macro and microprocessing classes. It's all in here, it's all applied, and it's inspiring to see what you're learning in action."

The collaboration paid off: On December 20, 2017, NASA announced that the CAESAR project is one of two finalists among a dozen initial proposals as the fourth installment of its New Frontiers program.

NASA expects to decide which mission will be greenlighted in summer 2019.

Read more: www.engr.wisc.edu/wisconsin-alumni-students-forge-team-aid-proposed-nasa-mission/

STUDENT MAX GOLDBERG REACHES FOR THE STARS

Max Goldberg sets his sights higher than the stratosphere.

Goldberg, who will graduate with a bachelor of science degree in materials science and engineering in 2019, isn't just shooting for the moon metaphorically—he's actively pursuing his ambitions to help humanity reap the benefits of outer space travel. Thanks to two overlapping opportunities—an internship with visionary entrepreneur Peter Diamandis and a position as the Matthew Isakowitz fellow for commercial spaceflight—during summer 2018, Goldberg has the chance to work at the forefront of exploring humankind's final frontier.

"I'm really passionate about materials and resource use in space," says Goldberg, whose fascination with space dates to his childhood.

His interests intensified in 2004, when he learned about the Ansari X Prize competition to develop a reusable rocket ship.

"I realized there's a whole economy that's about to open up in space and there's an opportunity to make a really big impact on a lot of people," says Goldberg.

After watching video of the experimental spaceplane SpaceShipOne—the 2004 X Prize winner— successfully complete its first manned private spaceflight in 2004, Goldberg closely followed the entrepreneurial endeavors of X Prize founder Diamandis. When Goldberg learned of a summer internship opportunity with one of Diamandis' many ventures, a group called Strike Force, he leaped at the chance to work alongside and learn from the serial entrepreneur.

"I'm passionate about making the most of resources," says Goldberg. "Not only in space, but also in terms of opportunities on Earth."

In keeping up to date with opportunities for new engineering graduates, Goldberg also learned of the Matthew Isakowitz Fellowship, which recruited applicants for its inaugural class in 2018.

Founded to memorialize Matthew Isakowitz—an aerospace engineer and entrepreneur who passed away in 2017 at age 29—the fellowship places exceptional students in paid internships at cutting-edge commercial spaceflight companies around the United States. The program culminates with a summit in Los Angeles, where fellows network with industry leaders, visit space start-ups and hone their entrepreneurial skills.

Goldberg was selected for the both the Matthew Isakowitz fellowship and an internship with Strike Force.

Fortunately, the Matthew Isakowitz Fellowship organizers placed Goldberg with Strike Force—his overlapping opportunities aligned perfectly.

"I'm really grateful. I get the benefits of both programs. This is a once-in-a-career opportunity," says Goldberg.

Goldberg comes from a long line of enterprising small business owners: His great-grandfather built a successful industrial vacuum company from the ground up in the years following the Great Depression. That entrepreneurial spark burned even brighter during Goldberg's time at UW-Madison thanks to his participation in student organizations like Badgerloop and Transcend.

"I'm thankful to the university for the opportunity to learn a lot and work on a project in an entrepreneurial environment," says Goldberg. "Even though Badgerloop is a student organization, we really function like a start-up, raising our own funds and building things at the same time."

On-campus mentors also helped Goldberg realize his ambitions. In particular, Kyle Hanson, lab manager for the Wisconsin Electric Machines and Power Electronics Consortium, and MS&E Professor Mike Arnold both advocated for Goldberg during the fellowship application process. Goldberg performed undergraduate research under Arnold's guidance, investigating carbon nanotube processing.

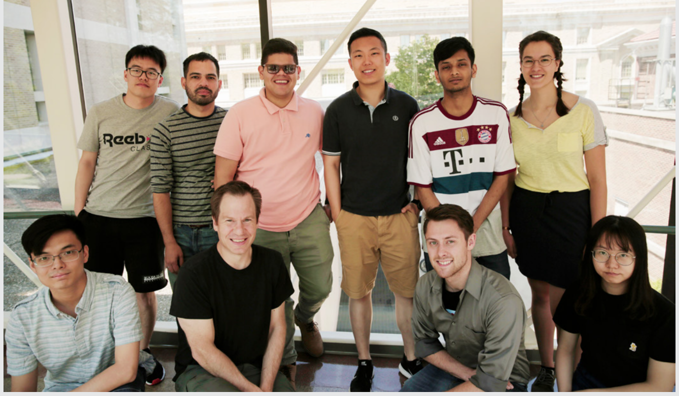
In the future, Goldberg hopes to continue merging engineering and entrepreneurship for space exploration. He's founded a company in Madison called Next Frontier, which held a well-attended MasterMind networking event in April 2018. Next Frontier is aimed at building relationships among innovators who are passionate about making the most of resources and opportunities, both beyond the confines of Earth and closer to home.

"The technology we build for space can have a huge impact on Earth," says Goldberg.

Devices that function in extreme environments or make maximum use of limited resources are important for space travel, but they can also help address terrestrial problems. One example could be extracting carbon from the atmosphere to create electrical components—an attractive proposition on Mars or in Madison.

Even as Goldberg reaches for the stars, however, his notion of business is fully grounded in reality.

"It's expensive to build technology for space, and it's risky," says Goldberg. "But if you can start developing for applications on Earth, while keeping in mind that space is the goal, then you can start legitimate companies that have real market caps on earth, and later build out for space."



NextGen fellowship recipients pose with Professor Dane Morgan. Back row: Donxia Wu, Bryan Josue Sanchez, Oigimer Torres Velasquez, Wei Has, Varun Sreenivasan, Leah Krudy. Front row: Guanzhao Li, Dane Morgan, Jake Greaves, Yuhan Li

FELLOWSHIP TRAINS CUTTING EDGE NEXT GENERATION WORKFORCE

The newly expanded Citrine NextGen summer fellowship presents an exciting opportunity for a group of nine students (six from UW-Madison, two from University of Puerto Rico at Mayaguez, and one from Hope College) to develop critical skills in the burgeoning field of materials informatics. The fellowship will not only pay undergrads to conduct materials research on campus, it will also introduce them to the world of technology startups and Silicon Valley.

With a $400,000 commitment from Schmidt Futures, Citrine Informatics is sponsoring the fellows. A relatively young Silicon Valley startup, Citrine was founded in 2014 to accelerate the development and use of new materials by harnessing the power of machine learning. Citrine and other materials informatics efforts have blossomed since the Material Genome Initiative was announced in 2011.

The fellows at UW-Madison will also be participants in the UW-Madison Informatics Skunkworks, a group dedicated to realizing the potential of informatics for science and engineering. Founded by professor Dane Morgan in 2015, the Informatics Skunkworks has engaged over 70 undergraduates in project-based research on informatics for science and engineering. The Informatics Skunkworks has recently expanded to Hope College and University of Puerto Rico, Mayaguez, both of which have contributed fellows to this year's team at UW.

Read more: **www.engr.wisc.edu/materials-informatics-fellowship-trains-cutting-edge-next-generation-workforce/**

THERMAL SPRAY CLASS PREPARES STUDENTS TO EXCEL

Future engineers in professor Daryl Crawmer's special topics in materials science and engineering class learn much more than the thermal spraying techniques described in the catalogue—the upper-division course charges students to become familiar with multiple disciplines, including electronics, robotics, and environmental control.

"The purpose has never been to teach only thermal spray," says Crawmer. "I want to give the students tools for an integrated engineering approach."

Giving an object the thermal spray treatment involves propelling millions of microscopic molten droplets toward its surface to lay down a protective coating bit by bit. While students in the class don't actually do any spraying, they do work out example problems drawn from Crawmer's career.

It's a career rich with experience: Crawmer holds multiple patents, pioneered several technologies and applications for thermal spraying, and even helped change the course of the industry during the early 1990s by helping develop safer equipment.

After completing the class, students have a foundational skillset they can contribute to their first full-time jobs. That goal—preparing new graduates to enter the job market—motivated Crawmer to work with Paul Voyles, the Beckwith-Bascom Professor and department chair of materials science and engineering to create the course after retiring from The Fisher Barton Group in June 2017.

"It's tremendously exciting for us to have someone with Daryl's expertise in thermal spray and breadth of experience in industry working with our students," says Voyles. "He brings real-world problems and solutions into the classroom, which is one of the hallmarks of an excellent engineering education."

Read more: **www.engr.wisc.edu/thermal-spray-class-prepares-students-excel/**

MIKE ARNOLD EARNS NANOCARBONS YOUNG INVESTIGATOR AWARD

Professor Michael Arnold has been named the 2018 Nanocarbons SES Research Young Investigator Award recipient. The award underscores the Arnold group's outstanding and leading work on the materials science of semiconducting carbon nanotubes and graphene nanoribbbons. Arnold received the award at the annual spring meeting of the Electrochemical Society in Seattle, Washington, in March 2018 and gave a presentation about his research.

LIQUID-TO-GLASS TRANSITION PROCESS GAINS CLARITY

Professor Paul Voyles (left) with graduate student Jason Maldonis. In the foreground is the heating chip used in the transmission electron microscope they use for their research.

For millennia, people have used molten sand and other ingredients to create a vast array of traditional glass products, including beads, vessels, lenses and windows.

These days, metallic glasses—made entirely of metal atoms—are being developed for biomedical applications such as extra-sharp surgical needles, stents, artificial joints or implants because various alloys can be ultra-hard, extra strong, very smooth and resistant to corrosion.

However, while a combination of trial and error and scientific research have helped refine glassmaking processes over time, at the atomic level, controlling the creation of metallic glasses remains an inexact endeavor informed largely by long experience and intuition.

"Our job," says Paul Voyles, "is to build fundamental understanding by adding more data."

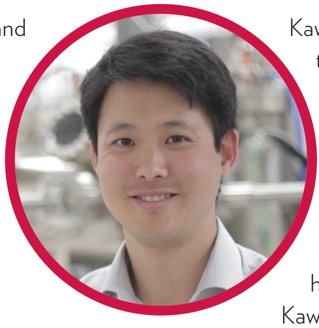
The Beckwith-Bascom Professor, Voyles and collaborators on campus and at Yale University have made significant experimental strides in understanding how, when and where the constantly moving atoms in molten metal "lock" into place as the material transitions from liquid to solid glass.

They described what they observed about how those atoms rearrange at different temperatures over time in the March 19, 2018, edition of the journal *Nature Communications*.

It's knowledge that can add much-needed experimental clarity to several competing theories about how that process, called the glass transition, occurs. Ultimately it also could help reduce time and costs associated with developing new metallic glass materials and provide manufacturers greater insight into process design.

Read more: www.engr.wisc.edu/liquid-glass-transition-process-gains-clarity/

STRATEGY TO PREVENT MATERIALS FROM MIXING EARNS JASON KAWASAKI NSF CAREER AWARD



Some materials are like ham and cheese—two separate layers that don't intermingle. Other materials are like peanut butter and jelly—mixing and swirling together at their interface until it becomes impossible to distinguish where one spread ends and the other begins.

Combining peanut-butter-and-jelly-like materials in a manner more akin to ham and cheese could help pave the way toward quantum computers or spintronic devices.

"Many exotic and useful properties arise at the interface between two crystalline materials," says assistant professor Jason Kawasaki.

With support from a prestigious National Science Foundation CAREER award, Kawasaki is devising new strategies to sandwich together two materials while maintaining atomically sharp boundaries between the layers.

"You can't just grow one material on top of another and expect it to have a clean interface," says Kawasaki. "In the past we have had to rely on serendipity: specific material combinations provided by nature, that play nicely together."

Many materials are like peanut butter, tending to ooze into whatever's below. In particular, a potentially useful group of substances named magnetic Hesulers are especially prone to mixing and reacting with other materials, hampering the performance of real devices.

Kawasaki plans to slowly grow layers of semiconductors and magnets separated by graphene, closely watching the crystal structures for evidence of defects or mixing during every step of the way. His lab contains a specialized setup for the atom-by-atom material synthesis technique called molecular beam epitaxy, combined with advanced atomic-resolution imaging equipment including a scanning tunneling electron microscope. These experiments allow his group to watch the crystals as they grow, one atomic layer at a time.

"Atomic-scale control of interfaces is a longstanding challenge, but we are excited that we now have the potential tools to control it and design new material sandwiches not previously possible," says Kawasaki.

Read more: www.engr.wisc.edu/strategy-prevent-materials-mixing-earns-jason-kawasaki-nsf-career-award/

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ALUMNI GARY AND JEANNE GIGANTE ESTABLISH SCHOLARSHIP THROUGH FOUNDRY EDUCATIONAL FOUNDATION

Good foundry workers are hard to find, which is why Gary (BSMetE '78) and Jeanne Gigante (BSMetE '77), established a scholarship through the Foundry Educational Foundation of Schaumberg, Illinois, in hopes of enticing more students to pursue potentially rewarding careers in metal casting.

"It's tough to get good talent," says Gary Gigante, who retired from his position as president and CEO of Waupaca Foundry in 2016. "It's not a glamour industry."

Casting molten metal might not be glamorous, but the efforts of foundry workers are essential for making many everyday objects from frying pans to truck frames. The Gigantes intend for the new scholarship to draw more trainees toward metal casting.

Gary and Jeanne have fond memories of their undergraduate educations, especially the classes they took from Professors Carl Loper and Richard Heine. Both recall Loper's seemingly boundless energy and enthusiasm for teaching, even at 8 a.m. In fact, the couple first became acquainted during one of those early morning classes—Gary frequently borrowed Jeanne's meticulously written notes.

"I found out later that he was copying my notes and handing them out to his friends so that they could skip class on Fridays," says Jeanne.

She managed to forgive him, though, and the two have been happily married since 1979. Jeanne worked as a metallurgist for two years after graduation before deciding to focus her time on raising their children.

Looking back, Jeanne's only regret is that she didn't have the opportunity to do an internship when she was an undergraduate, noting that few opportunities existed for women to obtain hands-on metalworking experience during the late 1970s.

Gary urges current students to jump at the chance for internship opportunities, emphasizing that nothing, not even a top-notch UW-Madison education, can substitute for real-world practice.

The Gigantes' scholarship provides $5,000 for students to defray educational expenses.