WINTER 2018

MATERIALS SCIENCE AND ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

NEW SPACES, ENHANCED LEARNING OPPORTUNITIES

CHAIR'S MESSAGE

Paul Voyles

Hello, and thank you for reading this edition of the Department of Materials Science and Engineering newsletter. We are proud to announce that the UW-Madison Materials Research Science and Engineering Center has been funded by the National Science Foundation for another six years. The center consists of two interdisciplinary research groups and an interdisciplinary education group, all with significant participation from MS&E faculty and faculty affiliates. This renewed support is an excellent indicator of the strength and interdisciplinary breadth of materials research at UW-Madison. In other research news, a discovery from Professor Xudong Wang's lab could help set the stage for a black silicon-powered revolution in clean fuel production. Additionally, Professor Mike Arnold received international recognition for his innovative research in carbon nanomaterials.

The other major new development in the department is the renovation of our main instructional spaces inside the MS&E building. We have updated our primary classroom space, Room 265, with lightweight, movable furniture, wall-mounted displays, and lots of power outlets to enable project- and group-based active learning activities using technology and to create an attractive, after-hours study space for our students. And we have converted our other primary classroom, Room 235, into a mixed-use laboratory and lecture space, which represents a 50-percent increase in the square footage devoted to instructional lab space. The MS&E undergraduate enrollment has grown significantly in the past few years, so adding resources to our instructional labs is critical to maintaining our commitment to hands-on education of tomorrow's engineers.

I'm also very pleased to announce the creation of the John H. Perepezko Student Support Fund. A group of Professor Perepezko's alumni gathered in Madison over the summer, and they decided that the best way to honor his enduring commitment to our department's students was to establish a fund dedicated to supporting students' research and scholarly activities. The first disbursement from the fund will help undergraduate students from our Materials Advantage chapter attend the upcoming TMS Annual Meeting in Phoenix, Arizona. If you would like to contribute to the fund, in honor of John and in support of our current and future students, please visit AllWaysForward.org and enter "John H. Perepezko Student Support Fund" in the gift designation field.

Finally, I'd like to draw your attention to the publication of the English translation of the biography of Professor Y. Austin Chang. I know Professor Chang influenced the work of materials engineers around the world through his discoveries in thermodynamics, and that he touched the lives of many of our alumni through his teaching and mentoring. If you would like to learn more about his inspiring life story, please consider ordering a copy of the book.

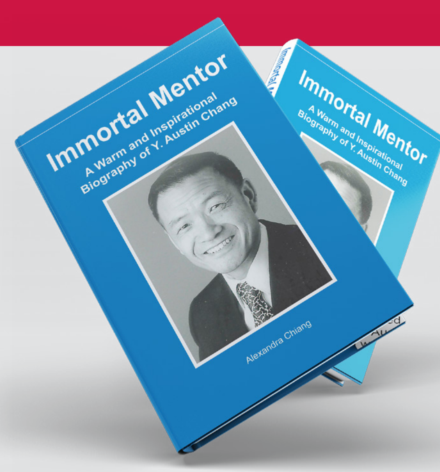
I hope you enjoy the rest of the newsletter.

ON, WISCONSIN!

Paul Voyles

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

BIOGRAPHY OF Y. AUSTIN CHANG TRANSLATED INTO ENGLISH



The biography of Professor Emeritus Y. Austin Chang, who passed away in 2011, has been translated into English. *Immortal Mentor: A Warm and Inspirational Biography of Y. Austin Chang* is the translation of the Chinese book, *A Person Having Stories—Academician Yong-Shan Chang*. From his boyhood in war-torn China, to his international recognition as an engineer, the story of Chang's life is told in this book.

Born in 1932 to a poor family in Goon Village in the Henan Province of China, Chang immigrated to the United States in 1950. After obtaining a PhD in metallurgy from the University of California, Berkeley, he began his academic career at UW-Milwaukee in 1967. He joined the UW-Madison faculty in what then known as the Department of Metallurgical and Mineral Engineering in 1980. For many years, he held the title of Wisconsin Distinguished Professor.

In addition to outstanding accomplishments as a teacher and mentor, Chang was a world expert in metal alloy thermodynamics; he was inducted into the National Academy of Engineering in 1996.

To order a copy of the book, send an email order to P. Jean Chang (pjhchang@gmail.com) and a personal/cashier's check for $50 payable to: P. Jean Chang 100 Hahnemann Trl. Apt. 311 Pittsford, NY 14534.

DISCOVERY BRINGS RENEWABLE FUEL PRODUCTION ONE STEP CLOSER TO REALITY

Professor Xudong Wang (left) and graduate student Yanhao Yu use advanced black silicon to convert sunlight and water into hydrogen fuel. *Photo by Stephanie Precourt.*

Silicon is the element of the electronic age. From tiny microchips to mammoth LCD television screens, the semiconducting metalloid plays a central role in the devices that define modern life.

But silicon's uses go well beyond computing and consumer electronics. It is handy in all sorts of industrial and technological applications, including solar technology. Black silicon, a variant that absorbs 99 percent of light, makes for powerful solar panels.

Now, UW-Madison researchers, led by Professor Xudong Wang and graduate student Yanhao Yu, and their collaborators at the University of Science and Technology Beijing, Professors Yue Zhang and Zheng Zhang, are reporting a nanotechnology breakthrough that could help set the stage for a black silicon-powered revolution in clean fuel production.

The promise—and challenge—lies in black silicon's special nanostructure. Typical silicon has a nanostructure that's relatively smooth. Meanwhile, black silicon's nanostructure is very rough. This coarse texture causes incoming light to bounce back into the silicon rather than reflect out as it would with typical silicon.

The light-absorbing quality makes black silicon an attractive material for solar panels, which need to absorb as much solar energy in the form of light as possible to maximize their efficiency. The technology is well-developed, and there are other ways that black silicon's light absorption properties could be useful.

That's if researchers can figure out how to overcome a key obstacle posed by black silicon's rough nanostructure.

Wang's research is focused on this obstacle. He hopes to use black silicon as a solar-powered generator of chemical energy such as hydrogen fuel. The idea is that the power black silicon derives from its efficient solar absorption could be harnessed to split water molecules and create hydrogen fuel through a photo-electro-chemical process. This would represent an efficient, renewable and clean alternative to present methods of hydrogen fuel production.

There's one catch: Black silicon's surface, while advantageous in its light absorption properties, is very unstable and reactive—precisely because of its rough texture.

This reactive surface is especially problematic in the context of hydrogen fuel production because the best liquid to produce hydrogen fuel by splitting hydrogen and oxygen atoms is not actually pure water. Rather, electrolyte solutions like sodium hydroxide, which are more conductive than water, are much more efficient in the photo-electro-chemical process that converts solar energy into hydrogen fuel.

But sodium hydroxide is highly corrosive. When black silicon comes into contact with the solution—as it must to initiate the photo-electro-chemical process that creates hydrogen fuel—its reactive surface quickly corrodes and becomes useless.

To solve this problem, Wang's team sought to give black silicon's rough and reactive surface a protective coating by depositing a 10-nanometer-thick layer of titanium dioxide onto the black silicon's surface. The results were very promising.

Not only does the titanium dioxide provide a protective coating that prevents the corrosive electrolyte from reacting with the silicon, it's so thin that it doesn't affect light absorption. It also enhances the efficiency of the whole energy conversion process by reducing the black silicon's surface defects, according to Wang.

"This development really shows the feasibility of this technology," says Wang. "This was a fundamental study in a very active research field that I think can lead to major research opportunities."

RENOVATED CLASSROOMS ENRICH STUDENTS' LEARNING EXPERIENCE

Students use the renovated Room 265 as a study space outside of class.

Renovations to the two primary classrooms in the Materials Science and Engineering Building are supporting the department's efforts to enhance student learning by enabling more active and participatory learning opportunities.

For professors to deploy innovative learning technology and techniques like "blended" learning—which combines traditional lecture formats with more in-class opportunities for students to work together in small groups and actively apply the concepts they're learning—a classroom with rigid rows of desks all facing the same way isn't ideal.

So in addition to giving the rooms a facelift in summer 2017, the department outfitted the renovated spaces with new chairs and free-standing tables that can be easily rearranged, allowing professors and students to configure the rooms for a variety of teaching approaches and activities.

"With these renovations, we wanted to allow students to work together in teams and on problems and projects and to give faculty the flexibility to switch back and forth between different formats for instruction in the class," says Beckwith-Bascom Professor and Chair Paul Voyles.

Professor Don Stone says that by making the classrooms more versatile, the revamps have made these spaces more useful for professors and students alike.

"Faculty in the department enjoy working with small groups of students while teaching, and these more flexible spaces enable closer interaction between the instructor and students and more individualized attention as students work on problems," Stone says.

The department converted Room 235 from a lecture room to a mixed-use laboratory and lecture space, a 50-percent increase the department's instructional laboratory space. Undergraduate enrollment has increased significantly in the past few years, and this new instructional laboratory space allows the department to better accommodate its growing number of students while maintaining and improving the critical hands-on laboratory activities and skills.

The building's primary lecture space, Room 265, also received major upgrades in the renovation. Students can now easily arrange tables and chairs around any of the several new computer monitors mounted on walls around the room, forming convenient workstations for group study and projects. And new charging stations installed throughout the room make it easy for students to keep their devices powered during long study sessions.

"We wanted to allow students to work together in teams and on problems and projects and to give faculty the flexibility to switch back and forth between different formats for instruction in the class."

The renovations are earning high marks from students. "It has been a big improvement," says senior Jon Gessert. "The rooms look brighter and more inviting, and the new chairs and tables are quite good. The monitors and tables make great group workstations, and the space can be reorganized to fit nearly any academic or extracurricular need."

The department also sought to create an inviting space for students to study together outside of normal class hours. All materials science and engineering students have 24-hour access to the building, so it was important to create a space in which they could work together even after the building closes at night, Voyles says.

"That's particularly important to creating a welcoming and engaging environment for new students from different backgrounds who might not have other social connections to their classmates outside of class," Voyles says.

Gessert, who is president of the Materials Advantage student organization, says the new spaces are perfect for studying in small groups or alone. Materials Advantage also holds its monthly meetings in Room 265, and he says the changes make it easier to prepare for a variety of speakers or events in the space.

"I think the existence of this kind of space in MS&E, both for club activities or studying, is critical," Gessert says. "Having free space dedicated to MS&E alone helps build connections between students in the department, even if they don't share the same classes or years in school.

MS&E Lab & Lecture Classroom Renovations

All photos by Renee Meiller.

STUDENT FINDS HER VOICE—AND THE CONFIDENCE TO BE A LEADER

Janerra Allen

It can be challenging for some students to make new social connections when they start college, especially as they try to find their place on a large, unfamiliar campus.

That was the case for Janerra Allen, who moved from her home in Brooklyn, New York, to attend the University of Wisconsin-Madison.

"Coming from New York City and trying to get acclimatized to Wisconsin was a culture shock," Allen says. "And in my engineering classes, I didn't see people who looked like me. Initially it was hard for me to really branch out and find my voice."

Allen says the Leaders in Engineering Excellence and Diversity (LEED) Scholars Program offered a crucial support system and the opportunity to connect with other engineering students from diverse backgrounds.

The LEED program, which is run through the College of Engineering's Diversity Affairs Office, is designed to support and retain academically talented undergraduate students from historically underrepresented groups in engineering. Students in the program attend monthly meetings and have access to a variety of opportunities for academic, personal and career development, social networking and mentoring.

Allen says the meetings also give students an opportunity to candidly discuss pressing issues beyond their engineering studies, such as social life and staying safe on campus, and the campus climate.

"Providing a space for us to speak out on how we feel about these issues was really valuable," she says. "By creating a supportive community, the LEED program helped me find my voice on campus. Finding that cohort of LEED scholars was very important for me to succeed within engineering."

As Allen became more self-confident, she pursued leadership roles on campus. Throughout her undergraduate career, she was active in the Wisconsin Black Engineering Student Society (WBESS) student chapter affiliated with the National Society of Black Engineers, and she became president of WBESS in her senior year. Allen says the student organization was a major factor in her success at UW-Madison by providing a tight-knit group of peers who encourage each other to excel.

To explore her interests and possible career paths, Allen took the initiative to find undergraduate research opportunities outside of class.

After connecting with Biomedical Engineering Professor Elizabeth Meyerand, she began working in a UW-Madison radiology lab focused on using brain imaging for studies on stroke and epilepsy. Through that experience she met Dr. Vivek Prabhakaran, an associate professor of radiology and one of Meyerand's collaborators, and went on to work in Prabhakaran's lab as an assistant researcher.

Allen worked on Prabhakaran's stroke rehabilitation project, in which the team used a brain-computer interface system to drive neuroplastic brain changes in stroke patients, and used brain imaging to monitor changes in the brain during patients' motor function rehabilitation.

The experience was highly rewarding, and it influenced Allen's career path. "I really enjoyed interacting with the stroke patients who participated in the study," she says. "It was great to see how they responded to the therapy and improved over time."

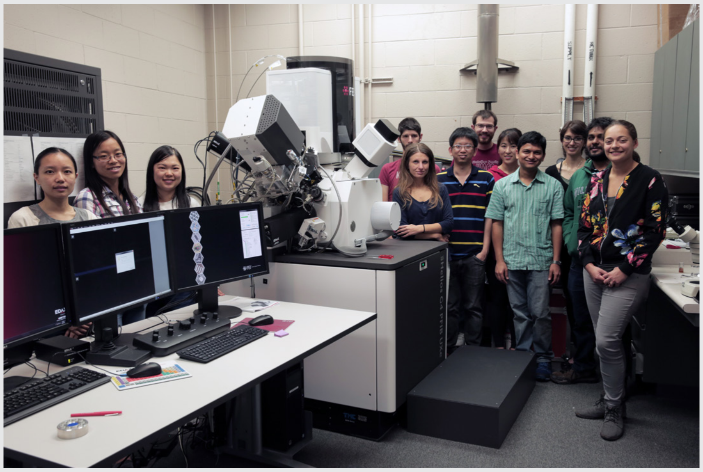
Allen became so invested in the research that, after graduating in May 2017 with a bachelor's degree in materials science and engineering, she took a job as a radiology research intern in Prabhakaran's lab to continue working on the project. In the future, she plans to pursue a career in industry where she can help further develop motor function rehabilitation systems and devices using virtual reality, games and physical therapy.

20+ YEARS OF FUNDING FOR FUNDAMENTAL MATERIALS RESEARCH

With $15.6 million, the National Science Foundation has renewed the UW-Madison Materials Research Science and Engineering Center. Directed through the College of Engineering, MRSEC includes 30 affiliated faculty from nine departments across the university.

The funding marks more than two decades of NSF support for UW-Madison researchers' quest to investigate fundamental, large-scale and complex questions in materials science.

This long-term commitment has also produced pioneering research breakthroughs—for example, liquid crystals for sensing, with applications in wearable technologies that detect airborne toxic gases. MRSEC researchers also have characterized the extremely efficient energy transfer capacity of carbon nanotubes; that property makes them a promising candidate for next-generation solar energy harvesting.



Graduate students from the MRSEC interdisciplinary research groups are pictured in the Materials Science Center with a plasma focused ion beam microscope. This particular microscope was the first next-generation instrument of this type installed in the United States. *Photo: Renee Meiller.*

And MRSEC faculty, which includes many MS&E faculty and faculty affiliates, are pursuing breakthroughs in other materials.

One of those advances could come by way of glassy materials, which have a disordered atomic structure. Better understanding of these materials could lead to new glasses that might extend the life of machine tools, enable advances in quantum computing, or lead to better cell phone displays, for example.

Beckwith-Bascom Professor Paul Voyles co-leads the interdisciplinary research group (IRG 1) studying glassy materials with Chemistry Professor Mark Ediger.

Several MS&E faculty are also involved in IRG 1 research projects. Harvey D. Spangler Professor Dane Morgan is using high-throughput ab initio methods to better understand the mechanism of glass formation and growth during deposition. Morgan is also co-leader, with Harvey D. Spangler Professor Izabela Szlufarska, of the interdisciplinary computational group, which brings together MRSEC faculty, students and postdocs who work in the area of broadly defined computational materials science.

Professor John Perepezko's IRG 1 research on amorphous materials is focused on two areas: surface diffusion and polyamorphism. He says little is known about surface diffusion in amorphous materials, but it is expected to impact their stability. Perepezko and his collaborators will measure surface diffusion by monitoring the changes of a patterned surface grating during annealing below the glass transition.

Another major area of MRSEC research seeks to fabricate films out of complex oxides, which also has the potential to impact quantum information technologies, including quantum computing.

Complex oxides are oxygen-containing materials, often with unusual crystal structures, that exhibit surprising electronic, magnetic and optical properties when they are formed in a thin film. These materials would be useful for electronics and optics applications. Professor Paul Evans co-leads that research team (IRG 2), along with Tom Kuech, the Milton J. and A. Maude Shoemaker and Beckwith-Bascom Professor in chemical and biological engineering.

Professor Susan Babcock is contributing to IRG 2 research and is investigating new methods for growing nanoscale complex oxide materials. The team is focusing on solid-phase epitaxy of these complex oxides, where single crystalline oxides are formed from an amorphous solid with the same chemical composition. Evans is studying the crystallization process and the structure of the materials that the team synthesizes.

Theodore H. Geballe Professor and Harvey D. Spangler Distinguished Professor Chang-Beom Eom's IRG 2 research involves the synthesis of complex oxide thin films for understanding fundamental solid state phenomena and developing potential devices.

And Max Lagally, the Erwin W. Mueller Professor and Bascom Professor of Surface Science, is working to make oxide membrane sheets of 100 nanometers or less.

Assistant Professor Jason Kawasaki is working on a MRSEC seed project. He is investigating the use of epitaxial strain to stabilize new intermetallic compounds and tune their magnetic, electronic and thermoelectric properties.

MRSEC's broad impact on campus also is tangible, says director Nicholas Abbott, the John T. and Magdalen L. Sobota Professor and Hilldale Professor of chemical and biological engineering. He notes that millions of dollars' worth of scientific equipment has been purchased through MRSEC funds, including equipment that is available for use by industry and researchers both on and off the UW-Madison campus.

Read more: www.engr.wisc.edu/major-nsf-sponsored-materials-research-collaboration-receives-15-6m-grant/

ARNOLD RECEIVES INTERNATIONAL HONOR FOR INNOVATION IN RESEARCH AND EDUCATION

(from left to right): Wendell Albright, state director of the Bureau of East Asian and Pacific Affairs, U.S. Department of State; Mike Arnold; and Jonathan Margolis, deputy assistant secretary for science, space, and health, U.S. Department of State. *Photo credit: Tracy Huang.*

Professor Mike Arnold was named a U.S. runner-up for the ASPIRE international prize for innovation in research and education sponsored by the Asia-Pacific Economic Cooperation (APEC).

Arnold also received $1,500 for his runner-up placement. The U.S. State Department, which sponsored Arnold's nomination for the ASPIRE (APEC Science Prize for Innovation, Research and Education) honor, flew Arnold to Washington, D.C., in June 2017, where he gave a presentation on his research.

The ASPIRE prize is open to scientists under age 40 who have demonstrated excellence in a specific research field, which changes every year. In 2017, the prize theme—chosen by APEC member states Vietnam and Peru—was "new material technologies."

The theme fit well with Arnold's research in materials, so he applied for the award, which required an extensive overview of his research to date. "I applied because I'm really excited about the research my group has been doing," Arnold says. At the center of his application was Arnold's research on synthesizing and processing of carbon nanomaterials, including carbon nanotubes and graphene. These nanomaterials have long held potential to outperform traditional semiconductors, but they've proven difficult to work with, which has limited their industrial application.

But Arnold's research group has solved some of the major challenges in synthesizing and processing carbon nanotubes, breakthroughs that will help pave the way for their eventual use as advanced semiconductors in circuitry. Arnold's group has also made breakthroughs in understanding and synthesizing graphene.

It was these achievements and his many others—Arnold's research has been cited more than 8,000 times and his work has received 15 patents—that resulted in his selection as a runner-up for the highly competitive international prize.

And it reflects Arnold's progress toward one of his major career goals—to use basic science to tackle big, fundamental problems in materials research and eventually produce technology that can be commercialized and widely used in products.

"In my nine years, we've made tremendous progress toward that goal," Arnold says. "I'm excited for the future."

ENGINEERS' DAY 2017 DISTINGUISHED ACHIEVEMENT AWARD RECIPIENT

Sharon Farrens

Director of Process Integration, Quora Technology Inc. • MSNE '83, MSMatSci '85, PhDMatSci '89 (BS physics '81, Nebraska Wesleyan University)

We honored Farrens for pioneering significant innovations in wafer bonding and advanced packaging technologies that are critical processing steps in semiconductor device manufacturing.

Early in her career, as a faculty member at the University of California, Davis, Sharon Farrens and her student invented a process called plasma-activated wafer bonding. When the university declined to patent it, they built the equipment, patented it, sold it to her first startup company, and installed it several at Fortune 500 companies worldwide. Today an internationally recognized expert in wafer bonding theory and technologies, Sharon is known by many colleagues simply as "Dr. Bond."

Read more about Farrens:
www.engr.wisc.edu/sharon-farrens-2017-distinguished-achievement-award-recipient/

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Valerie.Chesnik@supportuw.org

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ALUMNI AND FRIENDS CREATE JOHN H. PEREPEZKO STUDENT SUPPORT FUND

Alumni and friends of Professor John H. Perepezko have created the John H. Perepezko Student Support Fund in honor of Perepezko and his dedication to the students of the materials science and engineering department. Perepezko joined the department as an assistant professor in 1975 and is currently the IBM Bascom Professor of Materials Science and Engineering. He is a world leader in physical metallurgy and was elected to the National Academy of Engineering in 2004 for innovations in solidification processing to obtain useful microstructured, nanostructured and amorphous materials.

In addition to excellence in research, the other hallmark of his work is his devotion to students. He has been the faculty advisor to Materials Advantage, the department's undergraduate student organization, for decades. He has mentored a remarkable number of undergraduate researchers and has helped fund their travel to conferences or abroad for internships.

Perepezko group alumni gathered for a reunion in Madison in August 2017. Gifts from the alumni created the Perepezko Student Support Fund. *Photo credit: Page Metcalf.*

Students Casey Brown and Brooklyn Carlson from the Materials Advantage student organization were recipients of the first disbursement from the Perepezko fund. Pictured from left: Professor Mike Arnold, Professor John Perepezko, Casey Brown, Brooklyn Carlson and Professor and Chair Paul Voyles. *Photo credit: Annie Anderson.*

In August 2017, department faculty member, Grainger Institute for Engineering director and Perepezko alumnus Dan Thoma organized a Perepezko group alumni reunion in Madison. Led by Thoma, gifts from those alumni created the Perepezko Student Support Fund. The fund honors Perepezko's ongoing work with MS&E students by providing financial support for undergraduate and graduate research, conference travel and other scholastic activities within the department. At the department's scholarship reception, Chair Paul Voyles announced the first disbursement from the fund, which will support Materials Advantage members' travel to the 2018 TMS annual meeting, in Phoenix, Arizona, in March 2018.

To make a gift to the Perepezko fund, please visit **AllWaysForward.org** and enter "John H. Perepezko Student Support Fund" in the gift designation field.