MECHANICAL ENGINEERING
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The MEssenger

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The MEssenger

Top: Tilt test during competition
Bottom: 2009-10 car

FSAE: *Best Finish* Ever!

UW Formula SAE Team 21 entered competition last June with a great car and high hopes. They returned with a $1,750 cash prize and the trophy for third place overall, the highest finish ever for a UW team. More than 50 teams from around the world competed in the FSAE California competition held June 16 to 19 at the Auto Club Speedway in Fontana. The UW placed seventh in the Design competition, eleventh in Skidpad, sixth in Autocross, second in Acceleration (missing first place by 0.01 second), and third in the Business Presentation. Completing the final event, the grueling 22-kilometer endurance event, had caused the most problems for recent UW teams. The diligent checks, careful maintenance, and long hours of training and practice paid off this year with a successful fifth place finish in Endurance. With that finish the car placed second in the Dynamic events and third overall. Congratulations, Team 21!

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The MEssenger

IN THIS ISSUE

ME Students Win Innovation Challenge

Grant Marchelli, Renuka Prabhakar

"To invent, you need a good imagination and a pile of junk," said Thomas A. Edison. These elements both figured into the development of EnVitrum's prototype, a living wall made of porous recycled glass, developed by Mechanical Engineering students Renuka Prabhakar and Grant Marchelli. Their invention won the $10,000 Grand Prize in the University of Washington 2010 Environmental Innovation Challenge, and has led to additional honors and awards.

The idea developed out of their work in the Solheim Rapid Prototyping/Rapid Manufacturing Lab codirected by Professors Mark Ganter and Duane Storti. Prabhakar and Marchelli were struck by the fact that only 23% of the glass collected through municipal recycling programs can be reused, with the remaining 77%, or 9.4 million tons, going to landfills. Here was the pile of junk.

"We wanted to find a way to use that 77% to make a useful product so it didn't just go into landfills," Prabhakar explained.

In the lab, Marchelli was experimenting with rapid prototyping glass and searching for novel applications. Some of the glass being produced, he noticed, had the ability to wick water by capillary action, an unexpected effect.

As a separate project, Prabhakar had been working on a rooftop garden with the idea of replacing the vegetation footprint eliminated when a building is constructed. Maintaining living roofs is a problem, as water runs down and plants dry out. Then the good imagination came into play. If living roofs could be made of recycled glass that could wick the water up to the plants, the living roofs could be self-sustaining. Prabhakar and Marchelli were aware of the UW Environmental Challenge, and decided to work towards an entry in that competition. Their first challenge was to develop a commercially viable formula and a way to mass produce the wicking glass bricks. After much experimentation, they developed a kiln-fired brick, composed of approximately 95% recycled glass and 5% binding agents.

"For the Innovation Challenge, we needed to demonstrate that a wall of our bricks could support plant life by diverting and wicking gray water (essentially any water coming off a building that is not a biohazard) to the plants," said Marchelli. In nine weeks of long hours and hard work, they moved from concept to a working prototype, a modular system that met their

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Per Reinhall, ME chair

As the new chair of ME, I'm thrilled to welcome a new class of very bright students into the department. The high demand for our profession led to a record number of sophomore applicants. This summer, 392 undergraduate candidates applied for 120 openings. Our new students are highly accomplished, with an average GPA of 3.52. The faculty and I look forward to seeing them succeed in our department, and we encourage them to take advantage of the diversity of academic life here at UW, and develop into young engineers and life-long learners.

The high number of applications means that many students will not get a chance to study mechanical engineering at the UW. No one enjoys turning away bright and creative students who are eager to learn and could become future leaders in the field. For students, being told you cannot continue to pursue your educational goal at the UW, after taking courses and getting good grades, is a devastating blow. Unfortunately this is the cruel reality we face.

Severe cuts in state funding to the University continue to limit the size of our department, including the number of undergraduate students, TAs, advisors, and lab support. In addition, our ability to increase the number of undergraduates is further constrained by the comparably small size of our faculty (26 core members). This situation cannot be allowed to continue without a fight.

We are all committed to creating other revenue streams so that we can be independent of changes in state funding. The department needs to grow to allow more students to participate in the world-class ME education they deserve here at UW. The solution requires us to identify non-state revenue sources such as overhead funds from research, fee-based educational programs, royalties from patents, private gifts, and endowments.

We are working hard to increase the number of undergraduate scholarships and graduate fellowships. They are by far the most important ingredient in the successful recruitment of talented and creative students. We are fortunate to be able to offer scholarships to many undergraduate students due to the great generosity of our alumni and industry partners. Our undergraduate program would not be the same without this wonderful support. It allows us to attract students who otherwise would have gone elsewhere or who would not have been able to pursue a mechanical engineering degree. It is now my goal to replicate this success in graduate fellowships. Every scholarship and fellowship we offer results in the recruitment of a top student and moves us one step closer to our goal of becoming the best ME department at a public university in the country.

Revenue from our research programs has seen impressive growth. Research awards are up 67% since 2006. A highly successful research program benefits everyone. The students get exposure to laboratories and the latest technology developments in a wide range of areas. The department receives more revenue for student and TA support. The state economy benefits through the graduation of better trained engineers and the creation of more start-up companies, bringing research to the marketplace. Society benefits through advancing the technology base in areas such as medical devices, sustainable energy, and advanced materials.

Our research has increasingly focused on health and energy during the last five years. This focus is consistent with the National Academy of Engineering's Grand Challenges for Engineering and is moving the department to the next level in national and international stature. This focus has also allowed us to diversify our curriculum with the addition of courses in biomechanics, nanotechnology, cell mechanics, microfluidics, active and sensing materials, microelectromechanical systems, energy conversion and design, design for the environment, and acoustics.

The ME department has been fortunate to hire new junior faculty members of exceptional quality. Since joining the faculty, they have all won prestigious Career Awards from the National Science Foundation and have the potential to become superstars. The younger faculty members are complemented by a world-class senior faculty. The resulting synergy positions the department

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Honors, Awards & Transitions

Bruce Adee was named Fellow in the Society of Naval Architects and Marine Engineers.

Chris Bassett and **Danny Sale**, ME graduate students with the Northwest National Marine Renewable Energy Center, have both received National Science Foundation Graduate Research Fellowships for work in sustainable marine renewable energy.

John E. Chandler, a graduate student working in **Eric Seibel's** group, has been awarded a Washington Research Foundation Fellowship for 2010–11.

Sue Chen, ME administrator, received the 2010 College of Engineering Staff Innovator Award.

Alex Chillman, (PhD '10), received an Honorable Mention and a $500 award for his paper entitled "A Novel Approach to Energy Based Evaluations of Ultra High Pressure Waterjets." The award was presented at the ASME PVP/K-PVP Conference in Seattle in July 2010. He also won the best paper award for "Alpha Case Removal for Superplastically Formed (SPF) Titanium Alloy," by A. Chillman, **M. Hashish** and **M. Ramulu**, at the 18th International Conference on WATTERJETTING held in Graz, Austria in October.

Peter H. Dahl was promoted to Professor.

PhD candidate **Jason Frye** will receive a Washington NASA Space Grant Consortium graduate fellowship for winter 2011. He is studying under **Brian Fabien.**

Albert S. Kobayashi received the ASME Nadai Medal for significant achievement in the field of material engineering. He was cited for outstanding contributions to the fields of experimental stress analysis, finite element analysis, and biomechanics, and for fundamental contributions to fracture mechanics and fatigue.

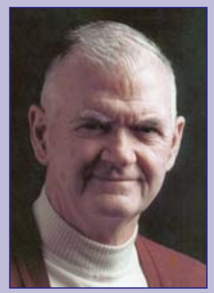
PhD candidate **Ken Faires** led a team that won second prize in the UW Environmental Innovation Challenge on April 1.

MicroGREEN Polymers, Inc., won the 2010 Washington Manufacturing Innovation of the Year (Small Companies) Award presented by Seattle Business Magazine. **Krishna Nadella**, (PhD '09), is MicroGREEN's co-founder and vice-president. MicroGREEN's technology was developed by **Vipin Kumar** and his UW group.

James J. Riley was a plenary speaker at the American Physical Society Division of Fluid Dynamics conference in California. He also will be a plenary speaker at the ASME/JSME/KSME Joint Fluids Engineering Conference in Japan, in July 2011. He was elected vice chair of the Division of Fluid Dynamics of the American Physical Society for 2011. He will serve as chair elect, chair and past chair in consecutive years. The division is the preeminent organization in Fluid Dynamics. The University of Washington hosted the division's annual meeting in November 2004.

Minoru Taya's research group on Zero-Energy Building has received a two million dollar award for developing electrochromic windows and energy harvesting windows to reduce heating and cooling loads in buildings. Four UW colleagues, including **Joyce Cooper**, share in this award.

In Memoriam

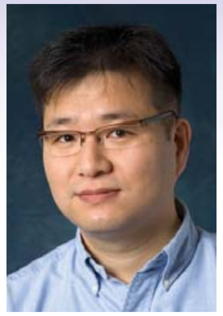


Professor Emeritus Daniel E. Alexander passed away on October 26. He was a member of the General Engineering faculty from 1954 to 1971, and of the ME faculty from 1971 until his retirement in 1993.

■ ■ ■

Roderick R. "Rod" Kirkwood passed away on May 6. Rod was a former ME student and member of the department's Visiting Committee. He retired in 1998 as president of John Graham and Company, Seattle. Kirkwood viewed his work on constructing the Space Needle as his most significant professional achievement.

Jaehyun Chung *Named McMinn Research Professor*



Jaehyun Chung

Assistant Professor Jaehyun Chung has been named the recipient of the Bryan T. McMinn Endowed Research Professorship in Mechanical Engineering. This endowed professorship recognizes and supports the research of promising junior faculty. "The research of our junior faculty marks the department's path to the future," said Per Reinhall, ME chair. "It is crucial that we recognize and support their efforts. The McMinn Endowed Chair is an important way we do this."

The McMinn Endowed Professorship was established in 2006. In that year, an estate gift from Richard and Janice Odell in memory of her brother, Bryan McMinn, was augmented by department discretionary funds to create the endowed chair. The endowment provides an annual sum which the chairholder may use to further his or her research.

Professor Chung's research field is nanoengineering for low-cost, rapid diagnosis of infectious diseases. Low-cost diagnosis is challenging, because disease screening or profiling must be conducted using simple operations that do not compromise the performance of laboratory devices. By using nanostructures, toxins and pathogens can be concentrated and detected with high sensitivity and specificity. Chung's research holds great promise, employing advanced technology to develop inexpensive devices that could help save countless lives in poor and underdeveloped countries.

"It is a great honor to receive the McMinn Professorship," said Chung. He plans to use this funding to enhance research efficiency by filling the gap between initial ideas and preliminary results, purchasing materials for undergraduate education, and as matching funds to purchase equipment for the ME department and his laboratory. "This funding will provide crucial support to allow me to develop new ideas and innovations to the point where outside funding can be pursued," he said. ■

Kipple Scholarship Plans *Accelerated*

William "Bill" Kipple put himself through the university by working in the building trades during the depression and at Boeing throughout World War II. He completed a bachelor's degree in mechanical engineering in 1946. Later that year, Bill met Dorothy at Mt. Rainier, where both happened to be taking a short vacation. Their courtship was also short, as they married ten weeks later.

After the war Bill started a building and contracting business for residential homes and commercial space in the Seattle Metro area. Until he retired and closed the company in 1983, Bill considered himself a hands-on craftsman who found joy in working with tools and seeing the products of his labor.

Bill and Dorothy Kipple

Dorothy worked for Dr. Ernest Jones, a dentist who helped establish the UW School of Dentistry in 1946. She assisted in this endeavor and served as Jones' secretary during his tenure as the first dean. Dorothy later was appointed the school's administrative secretary with faculty status. She worked under two additional deans until her retirement in 1974.

Bill and Dorothy created a legacy at the University of Washington by establishing a charitable gift annuity through the sale of their home in 1991. The annuity provided annual income and tax deductions, and the remainder created two separate, endowed scholarship funds, one in Dentistry and the other in Mechanical Engineering.

As tuition has steadily increased, Bill keenly understands that "students can no longer work to put themselves through college" the way he and others did. In response, Bill decided to advance their estate plans to see their scholarship support in action this year. Joseph A. Jonathan, who will receive his BSME this December, is the first recipient of the William F. and Dorothy D. Kipple Endowed Scholarship in ME.

The ME Department proactively seeks opportunities to address the financial needs of students including areas that enhance their educational experience, such as funding for teaching assistants, developing new courses, and increasing the quality of the design curriculum. Gifts such as the Kipples' play a critical role in addressing the financial needs of current ME students.

If you would like to learn more about supporting ME students and the work of the department, please contact April Johnson by phone at 206-543-8779 or by e-mail at aprijohn@uw.edu. ■

Chair's Corner *Continued from page 2*

to move forward and to meet the challenges of a rapidly changing technology base.

Recent successes include establishing large research centers in intelligent materials and systems, advanced composite materials, marine renewable energy, human photonics, and quantum system engineering. The department is now the College of Engineering's leading force for intellectual property creation based on issued patents and filed disclosures.

I welcome your ideas and input. Please feel free to contact me or drop by my office when you are visiting the UW campus. ■

Charles J. "Kip" Kippenhan

Professor Emeritus Charles J. Kippenhan, passed away on September 23. He was an ME faculty member from 1963 to 1988. He was recruited from Washington University in St. Louis, and hired as professor and chair of mechanical engineering. Kippenhan's research specialization was in heat transfer and thermodynamics, and he frequently collaborated with faculty in architecture in these areas. "Kip" was an early practitioner of numerical analysis. He was respected for an amazing breadth of knowledge, even in areas such as art, which lay outside his professional expertise. After stepping down as chair in 1973, Kippenhan continued to teach for another 15 years, retiring in 1988.

After retirement, he continued to keep informed on department matters and for many years he regularly attended the annual Faculty Advance in September. Wine making was also one of his interests in retirement. During his teaching years he began making wine with colleagues Ashley Emery and John Bodoia. His interest led him to purchase a vineyard, which he ran with his son.

EnVitrum *Continued from page 1*

Plants growing in an EnVitrum wall.

expectations. They also developed a business plan required by the competition.

For the competition, they had to deliver their marketing pitch in three minutes and explain their technology in a five-minute presentation. Prabhakar, with a background in small business management and ownership, executed the marketing pitch, while Marchelli performed the prototype demonstration. "We have exceptional team dynamics," said Prabhakar, and "several of the judges thought I was an MBA student, not a mechanical engineer." They repeated the pitch and demonstration to three groups of around 30 judges each. They included industry professionals, lawyers, angel investors, and venture capitalists, and they rotated among the 19 teams entered in the statewide competition. An hour after their final presentation, Prabhakar and Marchelli were front and center accepting the Grand Prize.

They added two MBA students to their team and five days later entered the UW Business Plan Competition sponsored by the Foster School of Business. They placed among the top 16 of 92 teams in this competition, winning a $2,500 award for the best clean technology idea. Prabhakar and Marchelli also applied for and received a Washington Research Foundation MBA Fellowship to assist with market research and a commercialization path for their inventions.

The end of this story is not yet written. "We are still working on building EnVitrum as a company and refining our products for commercialization," said Marchelli. In June, EnVitrum was named a semi-finalist in the Pacific Northwest Cleantech Open. Renuka and Grant are refining their business plan in preparation for the next round of judging, with hopes of making it to the national competition. What started with imagination, a pile of junk, and a whole lot of experimentation and hard work could soon become a green product used in building construction. ■

Building *a* Molecular Observatory

Direct observation of molecular structure is a long-standing dream. In 1959, physicist Richard Feynman said: "It is very easy to answer many of these fundamental biological questions; you just need to look at the thing! …I put this out as a challenge: Is there no way to make the electron microscope more powerful?"

The answer to Feynman's question, it turns out, is no. But there are other possible ways to accomplish the goal. "I believe the realization of Feynman's dream may be close at hand," said Professor Joseph Garbini. He is a member of the UW Quantum Systems Engineering (QSE) group, a collaboration between the departments of Mechanical Engineering and Orthopaedics. QSE's goal is quantum microscopy: the direct observation of single biomolecules; in situ, in their native conformation; with 3D Angstrom-scale resolution; and by a non-destructive process.

The QSE group is pursuing magnetic resonance force microscopy (MRFM), a combination of three technologies: magnetic resonance imaging, Angstrom-scale probe microscopy, and continuous quantum observation. The aim is to provide medical researchers observational access to every object in molecular biospace.

MRFM is based on the detection of magnetic spin resonance. In the familiar MRI medical scanner, nuclear spins are modulated to produce small variations in the local magnetic field. An electrical oscillator is coupled to the magnetic field to detect the distribution of nuclei and produce an image. One approach to molecular-scale imaging might have been to build an MRI scanner sufficiently small to image a molecule. Unfortunately, as an MRI is scaled down, the electrical oscillator becomes impractically small to detect the tiny magnetic field.

MRFM was invented when another member of the QSE group, Professor John Sidles, suggested using a mechanical rather than electrical oscillator to detect the magnetic field. The mechanical oscillator consists of a cantilevered beam with a magnet at the tip. As the mechanical oscillator is scaled down it works better because its sensitivity to the small magnetic forces increases, and the damping decreases.

L to R: Rico Picone, Jonathan Jacky, John Sidles, Joseph Garbini, Doug Mounce

An MRFM experiment is pictured above. The gray square is the sample being imaged.

MRFM experiment

The coil at right supplies the radio frequency magnetic field used to modulate the spins. The modulated spins exert forces through the magnetic tip on the cantilever. The fiber optic interferometer above the cantilever measures the motion. An image is produced by scanning the sample in three dimensions relative to the cantilever, and observing the resulting cantilever motion. In this configuration, the cantilever is 100 micrometers long. The experiments are performed in a vacuum to minimize damping, and at cryogenic temperatures (10 mK–10K) to reduce Brownian motion.

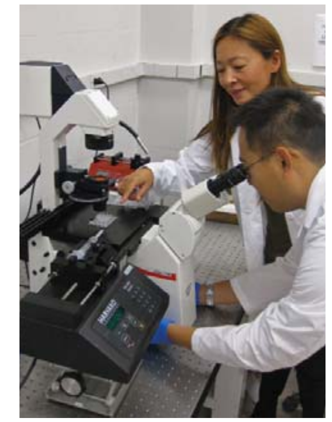
You might ask, "I've seen images of individual atoms made with atomic force microscopes (AFM). How is MRFM different?'' AFM can detect atoms only on the surface of a sample. Because the magnetic resonance occurs at a fixed distance from the magnetic tip, MRFM is able to "see" into the sample to resolve the structure below the surface. Forces exerted on the cantilever in MRFM are one million times smaller than those in an AFM. Achieving this force sensitivity is among the many challenges of designing a practical MRFM imager. "About 15 research groups around the world are working on MRFM, and progress has been steady," said Garbini.

At the UW, QSE is concentrating its efforts on a specific MRFM sensing enhancement: dynamic nuclear polarization (DNP). The attractiveness of DNP is based on the recent realization that single-proton resolution (~0.1 nm) may not be necessary to resolve atomic structure. Advances in simulation are making it possible for an image with resolution of approximately 5 nm to be ``pulled in'' to its final conformation by means of molecular modeling.

The challenge of DNP research is that the fundamental physical framework needed to design the imaging instruments and to plan experiments is not available through semi-classical analysis previously used. Quantum simulations of large numbers of interacting spins are necessary to predict, for example, the spin diffusion tensor in a large magnetic field gradient. Professor Garbini believes that the UW QSE group is uniquely positioned to provide that theory, to perform the required experiments, and to coordinate that work with other MRFM researchers.

See http://courses.washington.edu/goodall/MRFM/ ■

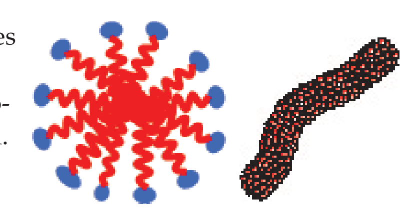
Soft Matter *and* Microfluidics Lab



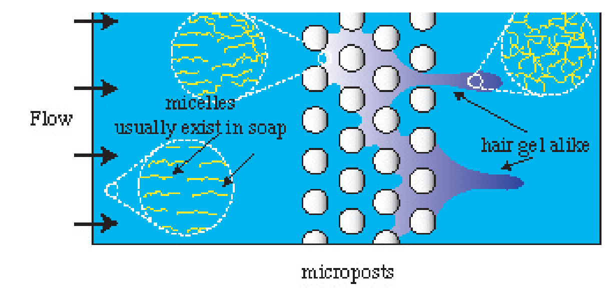
Amy Shen and Perry Cheung viewing a microfluidic device using an inverted microscope

What do ice cream, paint, tree saps, laundry detergent, blood, lava flows, and shaving cream have in common? They are all complex fluids, which are ubiquitous and play an integral role in our daily lives. Manufactured complex fluids have wide application in pharmaceuticals and consumer products such as shampoo, paint, glue, and liquid-crystal-based displays. A standard shampoo contains as many as 25 ingredients such as polymers, surfactants, colloids, oils, and solvents. It is this combination of components that gives these systems their interesting properties and behavior, including a hierarchy of length and time scales not seen in conventional fluids.

Associate Professor Amy Shen's research centers on complex fluids and the processing of these fascinating materials to create morphologies and structures for applications in nanotechnology, biotechnology, and novel materials. "This important class of soft materials is characterized by intermolecular/particle forces that give rise to time and length scale distributions that are easily accessed by processing flows," said Shen. Consequently, external processing forces can create a host of nano-morphologies and bulk properties that are central to their end-use applications. In Shen's lab, researchers couple self-assembly type complex fluids with spatial confinement by using microfluidics to achieve exquisite morphological control of soft materials.



A recent project involves surfactant-based nanoporous scaffolds for biomolecule encapsulation. Surfactant molecules (e.g., in soap and detergent) contain hydrophilic heads (blue) and hydrophobic tails (red), shown in the image above. When dissolved in solvents, such systems can self-assemble into aggregates (micelles) in which hydrophobic portions are oriented within the cluster and the hydrophilic ones are exposed to the solvent (imagine an oil droplet in a polar coat). Micelles can exist in a variety shapes, such as spherical and wormlike (shown above), and lamellar. These shapes can be controlled by the proper temperature, pH, and concentrations. These self-assembled structures are not permanent: surfactant molecules are constantly breaking up and reforming. Therefore, using these micelles as templates for nanostructures has been challenging. Shen's team observed that using microfluidics under ambient conditions, wormlike micelles can serve as a stable template. Pumping the wormlike micellar system through a microchannel (see image below, in blue) with microposts results in the formation of a stable gel with nanopores. This irreversible gelation is induced under pure mechanical force with ambient conditions, and thus offers a novel approach for synthesis of biocompatible porous scaffolds and biomolecular encapsulations.



Shen's team recently conducted proof-of-concept studies of horseradish peroxidase (HRP) enzyme immobilization in nanoporous scaffolds in collaboration with Professor Guozhong Cao in Materials Science & Engineering. Using HRP immobilized nanoporous scaffolds to coat the electrode, the team tested a nanogel-coated ITO-based electrochemical sensor for H_2O_2 detection. The sensor showed high sensitivity, stability, and selectivity in comparison to existing sensors. Shen's group plans to use the knowledge gained in synthesizing biocompatible and stable nanoporous scaffolds via microfluidics to develop robust biomolecule immobilization techniques to enhance biosensor performance. One possible application is an improved glucose sensor for use in the diagnosis of diabetic patients.

"Microfluidics deals with the behavior, precise control, and manipulation of fluids that are geometrically constrained to the dimension of a single hair strand. "Microfluidic devices can be a versatile and powerful tool to study a range of complex fluids, and how they behave on a very small scale," Shen said. The microfluidic devices she designs can be used in many applications, including ink-jet printing, drug delivery, biosensors, microreactors, lab-on-a-chip, and bio-diagnostics.

See http://microfluidics.me.washington.edu/ ■