The Driving Force

By Janelle Weaver

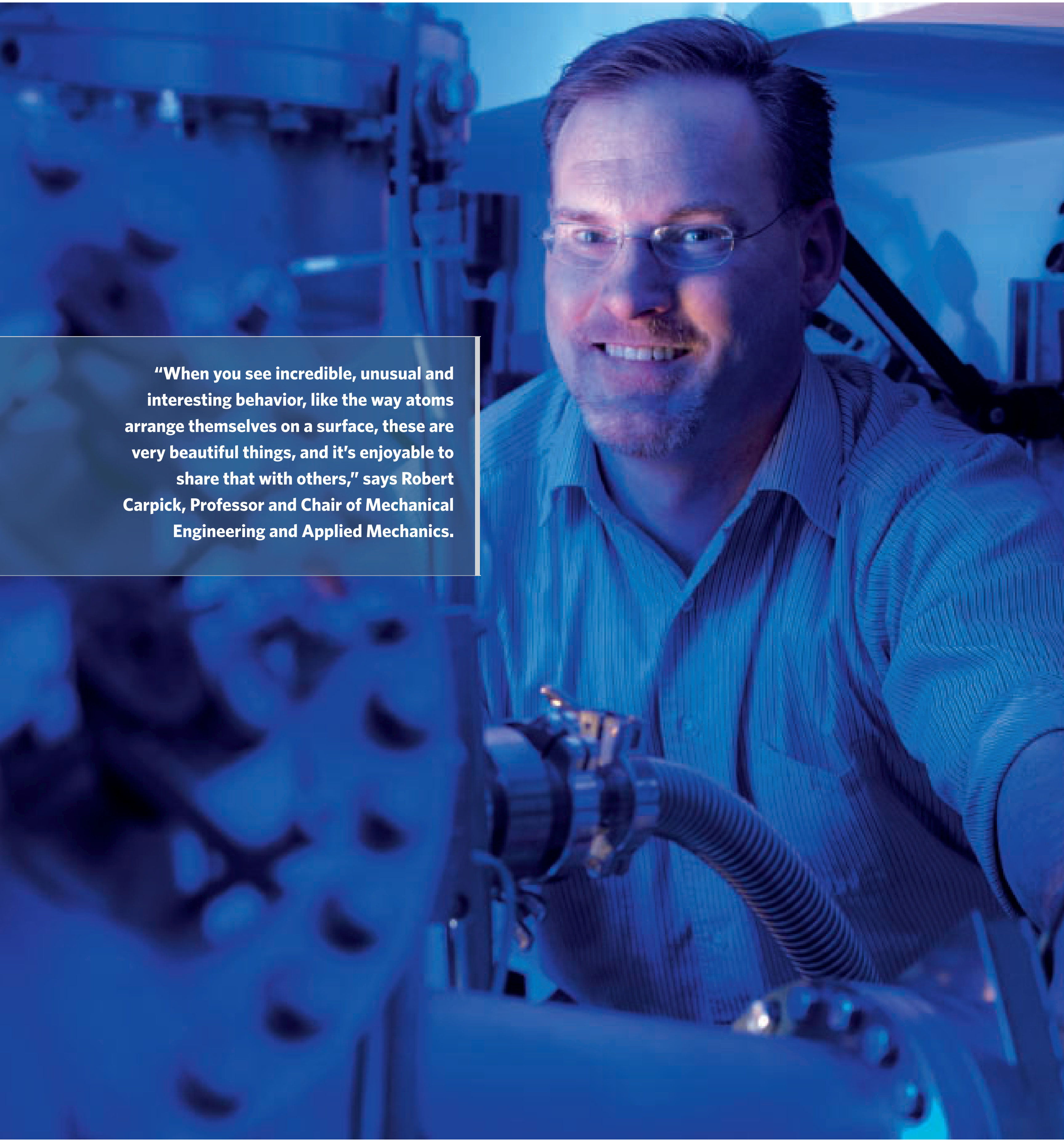
Sitting next to a state-of-the-art atomic force microscope, Robert Carpick and doctoral student Xin Liu carefully steer a sharp silicon tip 1/5,000th the thickness of a human hair, making it slide across a one-atom-thick sheet of graphene—the material found in pencils. The tip deflects as it presses against the thin flakes, measuring minuscule forces between itself and the surface. The two scientists marvel at the resulting image: a honeycomb lattice of densely packed carbon atoms.

"When you see incredible, unusual and interesting behavior, like the way atoms arrange themselves on a surface, these are very beautiful things, and it's enjoyable to share that with others," says Carpick, Professor and Chair of Mechanical Engineering and Applied Mechanics (MEAM) and Professor of Materials Science and Engineering.

Coupling microscopy with modeling, they found that the friction of the graphene sheets decreased as the number of layers within them increased. When the sheet contains a single layer, it crumples around the tip because it's so flexible, similar to a sheet of paper. But with more layers, the thick sheet is similar to a hardback book, so the tip slides more easily across the surface. "Nobody had seen this before, nobody had measured it, and nobody had predicted it," Carpick says.

This novel nanoscale property of friction was evident in all sorts of materials, and it could have implications for designing better data storage devices, semiconductors, and nanoelectromechanical systems. The discovery earned Carpick and his collaborators a coveted *Science* publication in 2010.

"Carpick has a strong track record of elucidating key physical principles at the atomic level, which could lead to the construction of more robust materials and devices," says Eduardo Glandt, Dean of the School of Engineering and Applied Science.



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Making a Difference

To share his sense of wonder at the nanoscale world with students in the classroom, Carpick actively engages them. He poses questions using the Socratic method and provides students with remote clickers to allow them to respond to multiple-choice problems without putting them on the spot. "I want to challenge them and I enjoy seeing them succeed, whether it's in the classroom or in the laboratory," says Carpick, who won the 2003 American Society for Engineering Education (ASEE) Outstanding New Mechanics Educator Award.

Beyond encouraging active participation, Carpick accommodates different learning styles by clearly explaining complex, abstract principles in as many ways as possible—through visualizations, equations, and especially real-world applications. "The students are hungry to see how what they're learning matters, and how they then can use it themselves to make a difference," he says.

As a child growing up in Winnipeg, Canada, Carpick was a natural math whiz who wanted to make a difference. Eager to apply his knack for numbers to solving problems, he studied physics at the University of Toronto and later earned a Ph.D. in Physics at the University of California, Berkeley. That's where he became intrigued by friction, by means of his advisor, Miquel Salmeron, Director of the Materials Science Division at the Lawrence Berkeley National Laboratory, who was investigating the origins of this mysterious force. "I found it amazing that friction is such a common phenomenon, but we did not understand it well and we weren't able to predict it," Carpick says. "I got excited about addressing fundamental questions and providing answers that could potentially have a very beneficial impact by reducing wasted energy and making materials last longer."

Call to Duty

After studying friction for seven years at the University of Wisconsin-Madison, Carpick joined Penn in 2007, and last summer became department chair. In anticipation of next year's opening of the Krishna P. Singh Center for Nanotechnology, Carpick is tasked with hiring faculty in the areas of energy research and nanotechnology. "The facility will be a great magnet to draw more top-name people to Penn," Carpick says.

In addition to recruiting professors, one of Carpick's primary goals is to promote diversity among faculty and students. Penn Engineering is already ahead of the curve, with this year's entering class consisting of about 37 percent women, compared with about 20 percent nationally. "I want to continue to ensure that all underrepresented groups have opportunities here, feel welcome, and know that the excellence that we have to offer is available to everyone," he says.

Moreover, an important part of Carpick's duties is to sing Penn's praises. "It's my job to promote MEAM and our vision to the greater community within Penn and to the science and engineering community externally," he says. "That's not hard to do, because there are so many incredible people here and so many great accomplishments to brag about to the outside world."

Ultimately, the role of department chair is about supporting current faculty and students at Penn. Carpick is charged with overseeing the tenure process and improving the curriculum based on feedback from students. "I try to create and foster an environment where the incredibly talented members of our faculty and the extremely bright and motivated students and postdocs in our midst can be as successful as possible," he says. "It's a wonderful service to be called to do."