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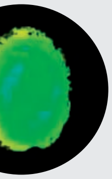

Naturally Inspired Materials

By Janelle Weaver

Geckos can climb walls because of millions of tiny pillars on their toe pads, and lotus leaves stay dry, thanks to microscopic bumps dotting their surface. The way that minuscule patterns in nature give rise to unique attributes, such as stickiness and water resistance, has always fascinated Shu Yang, associate professor of Materials Science and Engineering.

As a high school student in China, Yang applied to colleges with the goal of learning about polymers—large molecules that make up everything from Styrofoam to rubber. After her undergraduate education, she merged her background in materials science and chemistry with engineering to work on practical applications. During her doctoral training in chemistry and materials science at Cornell University, Yang developed environmentally friendly adhesives and coatings for computer chips, and for four years while working at Bell Labs, she extended her research on polymers to optical communications.

Yang came to Penn in 2004 not only because of its long-standing reputation in materials science and engineering, but also to enhance the caliber of her research by collaborating with scientists across disciplines. One such collaboration was made with Douglas H. Smith, the Director of the Center for Brain Injury and Repair and professor of Neurosurgery at Penn. Smith was searching for an objective way to measure explosions during conflict and to assess soldiers' risk for subsequent traumatic brain injury (TBI), which sometimes occurs without overt symptoms.

Flying Colors

Inspired by crystal-like structures that make butterfly wings shimmer, Yang devised an inexpensive, durable and power-free patch that signals the presence and strength of blasts by changing colors. Made of three-dimensional arrays of crystals that reflect different wavelengths of light, the shiny badge is strong and porous, similar to bone. Because it's only a few millimeters wide and a few microns thick, it's easy to carry on a helmet or uniform.

In the lab, Yang showed that the patch can detect ultrasonic waves and explosions in a shock tube. Heat and vibrations forced the layers to erode and collapse and the pores to widen or contract, causing the reflective properties to change. Low-energy blasts transformed stickers, for example, from red-orange to yellow-blue, while greater forces and repeated insults

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turned them white or gray. Yang envisions a day when soldiers will wear multiple stickers that register either single or cumulative explosions. To this end, she is teaming up with Daniel Gianola, Skirkanich Assistant Professor of Materials Science and Engineering, who studies how materials deform and degrade in extreme situations and uses this knowledge to create resilient materials. They will try to predict the effect of explosions on the mechanical behavior and color change of the crystals so they can tune them to sense blasts of varying intensities.

Next, Yang plans to use the badge to determine the pressure thresholds necessary to trigger TBI. This information could be used to design better helmets and body armor that can withstand these forces. She also hopes the technique will warn soldiers when it's too risky for them to return to combat and convince them to seek medical attention. "I want my research to have an impact outside the lab," she says. "I think we can use these materials to actually save people's lives."

Spreading Wings

Since arriving at Penn, Yang has earned several prestigious accolades. In 2004, she was listed among the World's 100 Top Young Innovators in *Technology Review*, and two years later she received an NSF CAREER Award. Last year, she accepted the NSF's Emerging Frontiers in Research and Innovation award for a proposal to construct an environmentally responsive skin for buildings to improve their energy efficiency.

Yang urges the next generation of scientists to set high goals. "I encourage my students to go beyond what they learn in the classroom, not to simply swallow the material, but to digest it and think about different applications," she says. Pausing to reflect on her own experience of fashioning a medical tool from objects she had worked with for years, she adds, "You never know. You may end up with something better than what you originally thought about."


Shu Yang, Associate Professor of Materials Science and Engineering