Tiny device enables wide range of study at liquid-liquid interface

December 18 2006

Researchers at Washington University in St. Louis are putting a different kind of "foursome" together in hopes of someday developing smart materials called biomimetics that mimic nature.

Amy Shen, Ph.D., assistant professor of Mechanical and Aerospace Engineering, and her Washington University colleague William F. Pickard, Ph.D., senior professor of Electrical and Systems Engineering, are collaborating with Michael Knoblauch, Ph.D., of Washington State University, and Winfried S. Peters, Ph.D., of Indiana University/Purdue University in Fort Wayne, on understanding a novel plant protein structure called forisome.

Shen and Pickard are probing the biomechanical properties of the forisome, which, in a variety of plants, responds to injury by swelling up in reaction to an increase of calcium. The swelling of the proteins within transport cells protects the plant from hemorrhaging nutrients. Once the danger passes, the forisomes go back to their original shapes. The foursome's goal is to understand the system well enough to enable future collaborators to develop a chemically stable artificial forisome -- a non-living system that can integrate functions such as sensing, acting and logic in response to external stimuli. Such a smart material would be biomimetic.

One of the best examples of a natural system whose behavior researchers would like to synthesize -- a biomimetic -- is the famed Venus flytrap. Forisome is particularly attractive as a biomimetic smart material because, unlike most protein motors, it is not dependent on adenosine triphosphate (ATP) for its activation, making it more flexible. Shen used a microfluidic device - a soft lithography system of micro-channels embedded in fluids, so small it fits in the palm of a hand - to see how the forisome proteins would react to changes in calcium, pH and the hydrodynamic environment itself.

Swell protein

Shen and her collaborators found that they could induce swelling easily as well as reverse the swelling in the device, rather more easily than other systems used previously to study the proteins. "We're interested in the kinetics of the forisome proteins," Shen said. "We wanted to see how fast they change shape and also their potential as a smart material. We intend to do other experiments that might reveal the durability and actuation kinetics of forisomes."

Shen and her colleagues published their results in the July 2006 issue of *Smart Structures and Systems, An International Journal*, Vo. 2, Number 3, 225-236. A separate paper also was published on the prospective energy densities on forisome in 2006 in *Materials Science and Engineering: C Biomimetic and Supramolecular Systems*, 26 (1), 104-112, 2006.

Shen designs microfluidic devices to study a wide variety of complex fluids and how they behave hydrodynamically on a very small scale, anything" hard to see with the naked eye," she says. "The devices are useful for lots of applications, for making novel materials, drug delivery, and for studying the cellular and neuronal growth. We're able to observe interfacial phenomena under a microscope."

Shen has performed research for Procter & Gamble, for instance, to determine shelf life of shampoos and hair conditioners. If the company wants to blend a certain type of shampoo with a perfume, she can study the stability of the mixture inside a microfluidic device under the microscope instantaneously. Shen is also collaborating with Lars Angenent, Ph.D., Washington University assistant professor of chemical engineering, on the behavior of methanogens inside a microfluidic device, by imposing a concentration gradient to see what’s the optimal pH level methanogens prefer to grow. Their study can be applied in making microbial fuel cells and biofuel cells.

Shen also is working with medical doctors in the Washington University School of Medicine to see how cells and neurons behave by guided channel design in the microfluidic environment.

She also is making monodispersed liquid crystals droplets- which are the basis of computer and TV screens -- and polymer solutions (R. Sureshkumar, Ph.D., Washington University professor of chemical engineering) inside the micro channels.

"In general, microfluidic devices are pretty powerful," Shen said. "You can study anything from tiny droplets to mixing of multiple fluids. What would take months or years for macroscopic systems, can be done within seconds or minutes with microfluidic devices. We often find in these environments that surface properties and geometric confinement in liquid-liquid or liquid- gas systems behave much differently than they do in beakers or tanks. "And that’s very important in fabricating new materials for high tech applications, making sleek shampoos, drug delivery systems, or just improving the ice cream or ketch up texture.

A video interview with Amy Shen is available here. (WMV, 3 Mb)

Source: Washington University in St. Louis