'Smart' materials get smarter with ability to better control shape and size

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A dynamic way to alter the shape and size of microscopic three-dimensional structures built out of proteins has been developed by biological chemist Jason Shear and his former graduate student Bryan Kaehr at The University of Texas at Austin.

Shear and Kaehr fabricated a variety of detailed three-dimensional microstructures, known as hydrogels, and have shown that they can expand and bend the hydrogels by altering the chemistry of the environment in which they were built.

Hydrogels have been in development over the last couple of decades and are being used as parts in biology-based microdevices and medical diagnostic technologies, for drug delivery, and in tissue engineering. But the future utility of these "smart materials" relies on finding better ways to control their conformation.

Shear and Kaehr's work lays the foundation for more precise control of hydrogels. Among many applications, Shear says they will have the ability to better grow bacteria with the aim of understanding disease.

"This provides a significant new way of interacting with cultured cells," says Shear, an associate professor of chemistry and biochemistry. "The microstructures can be used to capture individual cells, and once isolated, clonal colonies of those cells can be grown and studied."

Their research appears in a paper published July 1 in *Proceedings of the*

National Academy of Sciences.

As a proof of concept, the researchers built a rectangular house-like structure with a roof in which they trapped and then released E. coli bacteria. The bacteria blundered into the house through a funnel shaped door, where they found themselves trapped in a ring-shaped chamber. The funnel made it difficult to get out of the house.

Once inside, "they moved around the space like they were running around a racetrack," says Shear.

When the researchers increased the pH of the cell culture, the chamber changed volume, causing the house to pop off its foundation and release the bacteria.

By increasing or decreasing the volume of microstructures dynamically, Shear hopes to be able to better understand a phenomenon known as quorum sensing, where bacteria coordinate their gene expression according to the density of their population. Quorum sensing is important in the pathology of some disease-causing bacteria, such as Pseudomonas aeruginosa.

The hydrogels created by Shear and Kaehr are made of protein molecules that have been chemically bound together using a focused laser beam, a process known as photofabrication.

The laser causes amino acid side chains to link en masse and this builds a solid protein matrix. The protein scaffold is built layer by layer, much like a raster scanner.

"It's a little bit like a three-dimensional Etch-a-Sketch," says Shear.

Other high resolution structures the researchers developed include tethers that connect microspheres to surfaces, flower- and fern-like structures, and micro-hands that are less than a quarter the diameter of a hair, pinky to thumb.

Experimenting with various chemical changes, Shear and Kaehr show that changing pH caused hydrogel bands to bow out at specific points along their length and caused other shapes, like the micro-hands and bacterial chamber, to expand.

Altering ion concentrations caused the fern-like structures to coil and unfurl like fiddleheads emerging from the ground in spring. Adding ions caused contraction of the tether holding the microsphere.

Structures such as these could be used to create better micro- and nano-valves, motors and optics.

Shear says a great advantage of the hydrogels is that they are well suited for controlling and growing cells dynamically and in the environments in which they live.

Waste from the cells can move out of the structures and nutrients and other chemicals, including those added by the researchers to manipulate the cells' biology, can move in. Other microfabrication materials, such as glass, do not have such permeability.

Source: University of Texas at Austin

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