New way to shape thin gel sheets proposed

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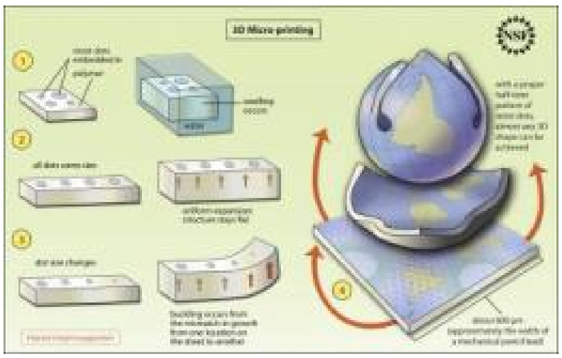

Controlling growth in a polymer system at the micro-scale with a technique akin to half-tone printing, the polymer swells like a sponge when exposed to water. Printing "resist dots" in the polymer substrate creates points that will not swell. When the dot size changes, buckling occurs from the mismatch in growth from one area to another. With a proper half-tone pattern of resist dots, almost any 3-D shape can be achieved. Credit: Zina Deretsky, National Science Foundation

Inspired by nature's ability to shape a petal, and building on simple techniques used in photolithography and printing, researchers at the University of Massachusetts Amherst have developed a new tool for manufacturing three-dimensional shapes easily and cheaply, to aid advances in biomedicine, robotics and tunable micro-optics.

Ryan Hayward, Christian Santangelo and colleagues describe their new method of halftone gel lithography for photo-patterning polymer gel sheets in the current issue of *Science*. They say the technique, among other applications, may someday help biomedical researchers to direct cells cultured in a laboratory to grow into the correct shape to form a blood vessel or a particular organ.

"We wanted to develop a strategy that would allow us to pattern growth with some of the same flexibility that nature does," Hayward explains. Many plants create curves, tubes and other shapes by varying growth in adjacent areas. While some leaf or petal cells expand, other nearby cells do not, and this contrast causes buckling into a variety of shapes, including cones or curly edges. A lily petal's curve, for example, arises from patterned areas of elongation that define a specific three-dimensional shape.

Building on this concept, Hayward and colleagues developed a method for exposing ultraviolet-sensitive thin polymer sheets to patterns of light. The amount of light absorbed at each position on the sheet programs the amount that this region will expand when placed in contact with water, thus mimicking nature's ability to direct certain cells to grow while suppressing the growth of others. The technique involves spreading a 10-micrometer-thick layer (about 5 times thinner than a human hair) of polymer onto a substrate before exposure.

Areas of the gel exposed to light become crosslinked, restricting their ability to expand, while nearby unexposed areas will swell like a sponge as they absorb water. As in nature, this patterned growth causes the gel to buckle into the desired shape. Unlike in nature, however, these materials can be repeatedly flattened and re-shaped by drying out and rehydrating the sheet.

To date, the UMass Amherst researchers have made a variety of simple shapes including spheres, saddles and cones, as well as more complex shapes such as minimal surfaces. Creating the latter represents a fundamental challenge that demonstrates basic principles of the method, Hayward says.

He adds, "Analogies to photography and printing are helpful here." When photographic film is exposed to patterns of light, a chemical pattern is encoded within the film. Later, the film is developed using several solvents that etch the exposed and unexposed regions differently to provide the image we see on the photographic negative. A very similar process is used by UMass Amherst researchers to pattern growth in gel sheets.

Santangelo and Hayward also borrowed an idea from the printing industry that allows them to make complicated patterns in a very simple way. In photolithography, just as in printing, it is expensive to print a picture using different color shades because each shade requires a different ink. Thus, most high-volume printing relies on "halftoning," in which only a few ink colors are used to print varied-sized dots. Smaller dots take up less space and allow more white light to reflect from the paper, so they appear as a lighter color shade than larger dots.

An important discovery by the UMass Amherst team is that this concept applies equally well to patterning the growth of their gel sheets. Rather than trying to make smooth patterns with many different levels of growth, they were able to simply print dots of highly restricted growth and vary the dot size to program a patterned shape.

"We're discovering new ways to plan or pattern growth in a soft polymer gel that's spread on a substrate to get any shape you want," Santangelo says. "By directly transferring the image onto the soft gel with half-tones of light, we direct its growth."

He adds, "We aren't sure yet how many shapes we can make this way, but for now it's exciting to explore and we're focused on understanding the process better. A model system like this helps us to watch how it unfolds. For biomedicine or bioengineering, one of the questions has been how to create tissues that could help to grow you a new blood vessel or a new organ. We now know a little more about how to go from a flat sheet of cells to a complex organism."

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