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Self-assembling MEMS target biomed therapies

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Peterborough, N.H. - Techniques for building three-dimensional microelectromechanical systems are paying off in emerging biomedical applications at the Johns Hopkins University School of Medicine. In a recent experiment, physical chemist David Gracias and colleagues were able to build large numbers of metal cubes, about 100 microns in size, that could one day be used as drug delivery vehicles in the body.

While the cubes have not been tested in living systems, the basic process and its operation in fluidic systems have been demonstrated, Gracias said. "We're talking about an entirely new encapsulation and delivery device that could lead to a new generation of 'smart pills.' The long-term goal is to be able to implant a collection of these therapeutic containers directly at the site of an injury or an illness," he said.

Various MEMS researchers have developed sophisticated processes for creating three-dimensional shapes using lithographic patterning and etching, but Gracias decided to start fresh with a self-assembling approach. For the cube structures, he first defined planar metal patterns of squares, representing an unfolded cube, and then introduced solder at the boundaries between the squares. When the system was heated to the melting point of the solder, the surface tension in the liquid solder caused the squares to fold into a cube. Cooling then hardened the solder, cementing the three-dimensional shape.

Because lithography defines a large number of the metal patterns in a few steps, and because assembly is totally automatic, the method could be adapted to high-throughput manufacturing, Gracias said.

Metals array

A variety of metals can be used. The researchers chose nickel coated with gold for the experimental drug delivery application. The gold acts as a nonreactive outer layer to prevent any toxic reaction inside the body, and nickel's magnetic properties would allow the cubes to be scanned inside the body via magnetic resonance imaging. Indeed, imaging specialists at the university's School of Medicine verified that the experimental cubes could be tracked with an MRI system.

Gracias' inspiration to use self-assembly as a fabrication technique came from his work at George Whitesides' lab at Harvard University. Whitesides has pioneered a variety of molecular self-assembly techniques in two-dimensional films. While at the Harvard lab, Gracias developed some methods for self-assembling 3-D electronic components. When he moved to Johns Hopkins in 2003, Gracias set up a lab to develop the concept.

Gracias said he has found that natural processes such as molecular coupling or surface tension forces can be employed to create self-assembled structures ranging in size from from 1 nanometer to 1 millimeter. The basic structural forms are created in fluids by reducing interactions that lead to unwanted forms

while enhancing those that move the system toward a design goal.

Components include carbon nanotubes, semiconducting nanowires and large self-assembled structures. A current project seeks to integrate more than 10,000 electronic components in a 3-D configuration.

The next phase will be to introduce electronic components into the cubes. The components might be used as biosensors or might be controlled inside the body with wireless signals to perform various active functions.