Shining a light on tiny polymer shapes

Visiting graduate student studies high-throughput manufacturing of precisely shaped microparticles.

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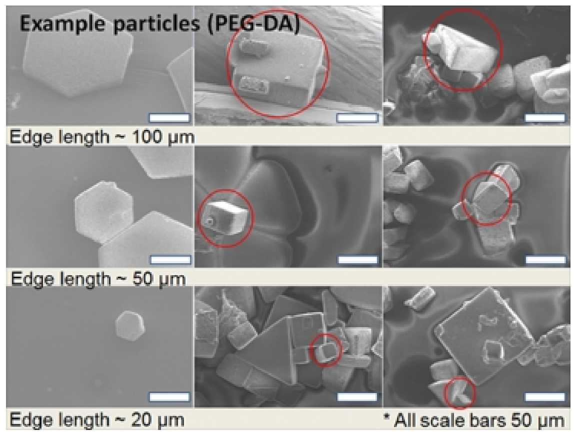
Ryan Oliver, a visiting graduate student in the lab of associate professor of mechanical engineering A. John Hart, is developing a technique called maskless fluidic lithography that creates unique shapes in a liquid polymer by exposing it to patterned ultraviolet light, a process known as photopolymerization.



Shown here are examples of micro shapes polymerized by ultraviolet light in polyethylene glycol diacrylate (PEG-DA).

IMAGE COURTESY OF RYAN OLIVER/MECHANOSYNTHESIS GROUP

For example, Oliver uses a projector to pattern shapes in polyethylene glycol diacrylate (PEG-DA), a common biocompatible polymer. Unlike semiconductor processing, which uses wafer masks produced as single-use items, the integrated projection system allows for rapid change of the pattern.

Key to the system is a Texas Instruments digital micromirror device (DMD) that can turn micromirrors on and off 32,552 times a second. “Because the mirrors are so fast, we can make decisions very quickly, which is hard to do with a masked system,” Oliver says. “You would spend several days ordering or fabricating a mask rather than milliseconds if you needed a new pattern." By controlling how long each mirror is switched on during a single second, the system varies the intensity of the projection to form two-dimensional or three-dimensional structures. Oliver likens the process to layer-by-layer assembly in a single step.

Ryan and Hart chose the stop-flow lithography approach, inspired by research from Professor Patrick Doyle's group at MIT, while they were at the University of Michigan as a platform for studying the manufacture of large quantities of custom microparticles. Their vision is to use particles that are designed to work together and act as a sensitive biosensor. To realize the vision, Ryan has a goal to produce microparticles from about 250 nanometers to about 100 microns in a library of shapes such as diamonds, triangles, squares, and octagons. "We're exploring methods of taking them down to the nanoscale, but the current system produces microparticles," Oliver says. “What sets this method apart is, one, high throughput; two, flexibility using the DMD chip; and three, the fact that you can control the shape as well as the size of the particles, and possibly the chemistry.”

Oliver is studying how to manipulate a collection of polymer particles on a liquid surface in order to assemble them in specific ways. “We needed a platform in order to synthesize microparticles that we could perform self-assembly experiments on, because that promises to allow us to build sensors that we can’t build now, that are too complex — they’re made out of too many types of materials to fabricate using traditional

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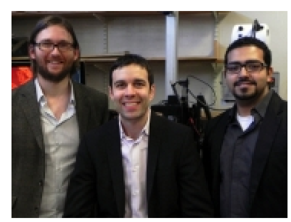
Visiting graduate student Ryan Oliver with a microscope. Oliver's projects under Associate Professor of Mechanical Engineering A. John Hart include the Robofurnace, an automated system for making carbon nanotube forests and studying their growth, and high-throughput manufacturing of polymer microstructures for biosensing.

PHOTO: DENIS PAISTE/MATERIALS PROCESSING CENTER



The Mechanosynthesis group includes visiting graduate student Ryan Oliver (left), associate professor of mechanical engineering A. John Hart, and postdoc associate Mostafa Bedewy.

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manufacturing methods," Oliver says. "A lot of applications may require control over the shape, the surface finish, the chemistry, and the size of microparticles, so we've been exploring this as a method toward that end, as well as understanding how to improve the shape accuracy while increasing throughput."

Such templated polymers can be used for a range of processes, from drug delivery to cell culture assays to casting molds. Researchers in Hart's Mechanosynthesis Lab also adapted the ultraviolet-light-based polymerization to a roll-to-roll system in addition to the microfluidic system.

One drawback with PEG, which is a hydrogel, is that it readily absorbs water, so it can swell or change shape in wet environments.

"Beyond the manufacturing process, we are interested in secondary means to assemble the particles into complex, hierarchical structures, such as those including cells," Oliver says. "These assemblies could be very useful for performing high-throughput bioassays or building novel tissue-like structures."

Oliver followed Hart to MIT from the University of Michigan. He led work on the Robofurnace project, an automated bench-top chemical vapor deposition system for growing carbon nanotubes and other nanomaterials. He hopes to finish his PhD through Michigan in August. His dissertation will focus on a suite of tools for high-throughput polymer micromanufacturing and manipulation, including the direct-write fluidic lithography method. Oliver presented his work on polymers at a Materials Research Society meeting and at the Enabling Nanofabrication for Rapid Innovation workshop in 2013.

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