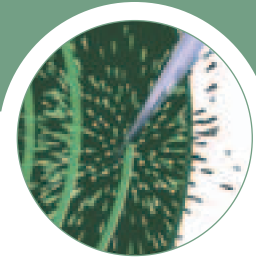

Microparticles of all shapes and chemistries

Photolithography and microfluidics are combined to synthesize a variety of microparticles.

Microparticles are used in a plethora of applications: Biosensors, medical diagnostics, drug delivery, and biomaterials are just a few. But commercial microparticles tend to be either spherical or rod-like, with limited chemical functionality. Patrick Doyle and colleagues at the Massachusetts Institute of Technology have now combined photolithography and microfluidics to generate microparticles with a variety of shapes and chemistries (*Nat. Mater.* **2006**, *5*, 365–369).

The new technique, called continuous-flow lithography (CFL), works on laminar-flowing streams of solutions inside a PDMS microchannel instead of on a stationary polymer film as in conventional photolithography. A mercury lamp projects a UV beam into the microchannel. A mask, in which the shape of interest for the microparticles is outlined, sits under the microchannel like a stencil. Solutions with the precursor oligomers are introduced into the microchannel by laminar flow. As pulses of light hit the flowing oligomer streams, the oligomers react by photopolymerization and form solid polymeric microparticles in <0.1 s in the shape dictated by the mask.

Microparticles can be configured into just about any 2D shape by changing the outlines etched in the mask—the investigators created posts with square cross-sections, triangles, hexagons, nonsymmetrical shapes, and curved objects. Although the reported microparticles were >3 µm in diameter, Doyle and colleagues indicated that smaller particles of ~1-µm-diam could be created by stopping the flow during the photopolymerization reaction.

To prevent the microparticles from polymerizing all the way across the microchannel and thus blocking it, the researchers took advantage of PDMS's natural permeability to oxygen. Oxygen is an inhibitor of the photopolymerization reactions. Its diffusion through the PDMS inhibited polymerization close to the surface of the microchannel.

CFL allows nonspherical particles to be fabricated quickly and easily. Scale bar = 100 µm.

Doyle and colleagues manipulated the chemical functionalities of the microparticles by having solutions with different chemistries flow side by side within the microchannel. They then synthesized bifunctional microparticles called Janus particles, after the Roman god with two faces.

The number of chemical functionalities wasn't restricted to two. "To date, we've [fabricated] particles that have four [functionalities]," says Doyle. "Many people show examples in microfluidics [of] bringing various streams together and having them stay side by side very nicely. We're limited by how much molecular diffusion makes the boundaries fuzzy between the two [streams]."

But when multiple streams of different chemistries are used, interactions with the surface of the microchannel can become an issue. An example is when the microchannel surface is hydrophilic, and two streams—one hydrophilic and one hydrophobic—are introduced into the microchannel. The hydrophilic stream will then attempt to envelop the hydrophobic stream, so it doesn't see the surface of the channel. But Doyle points out, "You can turn this lemon into lemonade and say, 'I've now created a 3D structure. If I polymerize that, I've now created something that has a core, which has a different chemistry [than] the outside.'"

Experts describe the CFL approach as a clever, innovative way to fashion nonspherical microparticles. The investigators "have captured several of the features you'd like in small devices—monodispersity, continuous flow, multiple materials, control of composition—many of the things that make microfluidics attractive for thinking about novel materials," says Howard Stone at Harvard University.

And the timing for the production of nonspherical particles is just right. David Weitz of Harvard University explains, "You engineer new structures using colloidal particles as the precursors or building blocks. We know a lot about how to build things with spheres. . . . But to really make [colloid science] into a broader field, I think you have to go beyond spheres as building blocks."

Doyle and colleagues see several possible directions for CFL to take. For one, they are considering applying the technique to single-cell analyses. "When a certain cell of interest flows by, we can detect it within one-hundredth of a second," says Doyle. "[We] can create a cage around it or completely enclose it in [a] gel and shuttle it off for further analysis."

—Rajendrani Mukhopadhyay