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Polymer scientists jam nanoparticles, trapping liquids in useful shapes

October 24 2013

Sharp observation by doctoral student Mengmeng Cui in Thomas Russell's polymer science and engineering laboratory at the University of Massachusetts Amherst recently led her to discover how to kinetically trap and control one liquid within another, locking and separating them in a stable system over long periods, with the ability to tailor and manipulate the shapes and flow characteristics of each.

Russell, her advisor, points out that the advance holds promise for a wide range of different applications including in drug delivery, biosensing, fluidics, photovoltaics, encapsulation and bicontinuous media for energy applications and separations media.

He says, "It's very, very neat. We've tricked the system into remaining absolutely fixed, trapped in a certain state for as long as we like. Now we can take a material and encapsulate it in a droplet in an unusual shape for a very long time. Any system where I can have co-continuous materials and I can do things independently in both oil and water is interesting and potentially valuable."

Cui, with Russell and his colleague, synthetic chemist Todd Emrick, report their findings in the current issue of *Science*.

Russell's lab has long been interested in jamming phenomena and kinetically trapped materials, he says. When Cui noticed something unusual in routine experiments, rather than ignore it and start again she decided to investigate further. "This discovery is really a tribute to Cui's observational skills," Russell notes, "that she recognized this could be of importance."

Specifically, the polymer scientists applied an electric field to a system with two liquids to overcome the weak force that stabilizes nanoparticle assemblies at interfaces. Under the influence of the external field, a spherical drop changes shape to an ellipsoid with increased surface area, so it has many more nanoparticles attached to its surface.

When the external field is released, the higher number of surface nanoparticles jam the liquid system, stopping nanoparticle movement like Friday afternoon gridlock on an exit ramp or sand grains stuck in an hourglass, Russell explains. In its jammed state, the nanoparticle-covered droplet retains its ellipsoid shape and still carries many more nanoparticles on its surface, disordered and liquid-like, than it could as a simple spherical drop. This new shape can be permanently fixed. Cui, Russell and Emrick also accomplished the jamming using a mechanical method, stirring.

By generating these jammed nanoparticle surfactants at interfaces, fluid drops of arbitrary shape and size can be stabilized opening applications in fluidics, encapsulation and bicontinuous media for energy applications. Further stabilization is realized by replacing monofunctional ligands with difunctional ones that cross-link the assemblies, the authors note. The ability to generate and stabilize liquids with a prescribed shape poses opportunities for reactive liquid systems, packaging, delivery and storage.

More information: "Stabilizing Liquid Drops in Nonequilibrium Shapes by the Interfacial Jamming of Nanoparticles," by M. Cui; T. Emrick et al. *Science*, 2013.

Provided by University of Massachusetts Amherst