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Researchers show new way of assembling particles into complex structures

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(Phys.org) -- Many recent advances in microtechnology and nanotechnology depend on microscopic spherical particles self-assembling into large-scale aggregates to form a relatively limited range of crystalline structures. Directed assembly is a new branch of this field, where scientists figure out how to make particles assemble to form a broad range of structures at given locations.

Current techniques for directed assembly typically use an applied field, such as an electric or magnetic field, to move particles and to assemble them into well-defined structures. Now, researchers at the University of Pennsylvania have identified a simple new method to direct particle assembly based only on surface tension and particle shape.

The research, led by Kathleen J. Stebe, professor in the Department of Chemical and Biomolecular Engineering and the school's Deputy Dean for Research, was performed by a team of researchers in her laboratory, Marcello Cavallaro Jr., Lorenzo Botto, Eric P. Lewandowski and Marisa Wang. It was published in the *Proceedings of the National Academy of Sciences*.

Their results rely on the simple fact that a liquid surface will tend to minimize its surface area.

"It's the same reason that surface tension makes a drop of water want to be a sphere," Stebe said. "But we can tune that phenomenon to do astonishing things."

Self-assembling spherical particles have been used to make new materials with unique optical and mechanical properties, but non-spherical, or anisotropic, particles may hold even greater promise. By having a definable directionality, the properties of the materials the particles make up can be altered based on their orientations.

In the study, Stebe's lab used cylindrical particles made out of a common polymer. When placed on the surface of a thin film of water, the cylinders produce a saddle-shaped deformation: the water's surface dips at each end of a particle and rises up along their sides.

The Stebe lab had previously demonstrated that this saddle-shape can be used to orient two cylindrical particles end-to-end. As the depressions at their ends come in contact, surface tension causes the area of the space between them to contract, bringing the ends together.

In the new study, instead of two particles interacting, particles interact with a stationary post. The post pokes through the water's surface, causing the surface to curve upward around it. The interaction between a particle's deformation and this curve is governed by the same phenomenon of surface tension shown in the earlier study; the particles move so as to make the surface area as small as possible.

"This means that as soon as the particles hit the surface of the water, they change their alignment and start moving rapidly uphill toward the post," Cavallaro said. "We were also able to predict the lines they would travel for three different post shapes."

By changing the cross-sectional shape of the posts, the researchers were able to show fine control over how the particles moved and oriented. A circular post attracted particles in straight lines, whereas an elliptical post drew particles to the elongated ends. A square post produced the most complex behavior, drawing particles strongly to the corners, leaving the sides open.

The lab's choice of particle shape and material was only to help the researchers observe the particles' orientation and position; any non-spherical particle, on any liquid-liquid or liquid-vapor surface, would be governed by the same principles and produce the same type of deformation. This makes this research particularly powerful: it does not depend on the particle having a certain shape or being made from a certain material.

Surfaces studded with strategically placed and shaped posts could direct and orient particles into almost any configuration. And because the mechanism behind the particles' movement is simply the surface curvature, their movement could be "programmed" by changing the arrangement of the posts or the shape of the interface.

"I could go in with needle, for example, and dynamically pull the surface up at different locations, or over different times," Stebe said.

"Very often when we think about using micro- or nanotechnology, we're not thinking about properties on that tiny scale: It's going to be the organized structure made from micro- or nanoparticles that's going to be useful, perhaps as a lens or a smart surface," she said. "This phenomenon could be used to make new structures by sending particles to certain locations. We could define paths and say 'here's a docking site: go there' or 'here's a spot where we want nothing; don't go there.'

"This is a clear demonstration of directed assembly. Like self-assembly, things come together from the bottom up, but here they come together exactly where we want them to."

More information: Research abstract:
www.pnas.org/content/108/52/20923.full