Self-assembling structures open door to new class of materials

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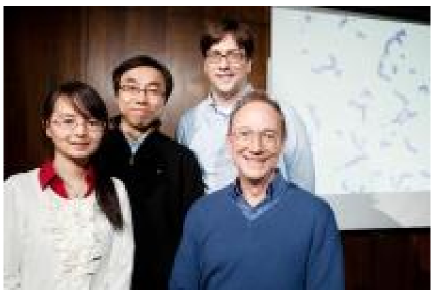

Illinois researchers developed tiny spheres that attract in water to form "supermolecule" structures. Pictured from L-R: Qian Chen, Sung Chul Bae, Jonathan Whitmer, Steve Granick. Credit: L. Brian Stauffer

Researchers at the University of Illinois and Northwestern University have demonstrated bio-inspired structures that self-assemble from simple building blocks: spheres.

The helical "supermolecules" are made of tiny colloid balls instead of atoms or molecules. Similar methods could be used to make new materials with the functionality of complex colloidal molecules. The team will publish its findings in the Jan. 14 issue of the journal *Science*.

"We can now make a whole new class of smart materials, which opens the door to new functionality that we couldn't imagine before," said Steve Granick, Founder Professor of Engineering at the University of Illinois and a professor of materials science and engineering, chemistry, and physics.

Granick's team developed tiny latex spheres, dubbed "Janus spheres," which attract each other in water on one side, but repel each other on the other side. The dual nature is what gives the spheres their ability to form unusual structures, in a similar way to atoms and molecules.

In pure water, the particles disperse completely because their charged sides repel one another. However, when salt is added to the solution, the salt ions soften the repulsion so the spheres can approach sufficiently closely for their hydrophobic ends to attract. The attraction between those ends draws the spheres together into clusters.

At low salt concentrations, small clusters of only a few particles form. At higher levels, larger clusters form, eventually self-assembling into chains with an intricate helical structure.

"Just like atoms growing into molecules, these particles can grow into supracolloids," Granick said. "Such pathways would be very conventional if we were talking about atoms and molecules reacting with each other chemically, but people haven't realized that particles can behave in this way also."

The team designed spheres with just the right amount of attraction between their hydrophobic halves so that they would stick to one another but still be dynamic enough to allow for motion, rearrangement, and cluster growth.

"The amount of stickiness really does matter a lot. You can end up with something that's disordered, just small clusters, or if the spheres are too sticky, you end up with a globular mess instead of these beautiful structures," said graduate student Jonathan Whitmer, a co-author of the paper.

One of the advantages of the team's supermolecules is that they are large enough to observe in real time using a microscope. The researchers were able to watch the Janus spheres come together and the clusters grow – whether one sphere at a time or by merging with other small clusters – and rearrange into different structural configurations the team calls isomers.

"We design these smart materials to fall into useful shapes that nature wouldn't choose," Granick said.

Surprisingly, theoretical calculations and computer simulations by Erik Luijten, Northwestern University professor of materials science and engineering and of engineering sciences and applied mathematics, and Whitmer, a student in his group, showed that the most common helical structures are not the most energetically favorable. Rather, the spheres come together in a way that is the most kinetically favorable – that is, the first good fit that they encounter.

Next, the researchers hope to continue to explore the colloid properties with a view toward engineering more unnatural structures. Janus particles of differing sizes or shapes could open the door to building other supermolecules and to greater control over their formation.

"These particular particles have preferred structures, but now that we realize the general mechanism, we can apply it to other systems – smaller particles, different interactions – and try to engineer clusters that switch in shape," Granick said.

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