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From Quonset huts to dancers: Scientists solve a nanotech mystery

by Teresa Riordan · Posted January 29, 2006; 12:52 p.m.

Princeton researchers have untangled the mystery behind a puzzling phenomenon first observed more than a decade ago in the ultra-small world of nanotechnology.

Why is it, researchers wondered, that tiny aggregates of soap molecules, known as surfactant micelles, congregate as long, low arches resembling Quonset huts once they are placed on a graphite surface?

To fellow scientists and engineers, this question and the researchers' answer is tantalizing since the discovery gives insight into "guided self-assembly," an important technique in nanotechnology where molecules arrange themselves spontaneously into certain structures. It also may lead one day to valuable technological applications such as the creation of anti-corrosion coatings for metals and biomedical applications involving plaque formation with proteins.

In a paper appearing in the Jan. 13 issue of Physical Review Letters, a premier physics journal, Dudley Saville, Ilhan Aksay, Roberto Car and their colleagues explain how they unraveled the mystery. Saville and Aksay are members of the chemical engineering faculty, and Car is a professor of chemistry and the Princeton Institute for the Science and Technology of Materials.

The scientists discovered they and others had been operating on the flawed assumption that -- in response to the texture of the graphite beneath them -- surfactant molecules assembled themselves into Quonset hut shapes that stayed put.

Using atomic force microscope imaging by research associate Hannes Schniepp, the Princeton scientists were able to see that the micelle structures were not static but, rather, constantly on the move, building and rebuilding themselves into the same structures.

The researchers began to think of the images under their microscopes not as Quonset huts, but dancers.

"We spent a year trying to describe why these rods orient themselves on the graphite surface," Saville said. "But it turns out that we had imaged the dancers in freeze-frame. What we did not take into account in our original thinking was that micelles on the surface are in constant rotary motion."

Under most conditions, small particles make tiny random movements known as Brownian motion. Powered by Brownian motion, a single surfactant can be thought of as a dancer spinning about on her own; it is impossible to predict the precise pattern of movement.

The researchers discovered that, when assembled on a graphite “stage,” the micelle dancers no longer moved randomly, but fell into a choreographed pattern of movement.

What was overriding the Brownian motion?

The answer turned out to be a phenomenon known as van der Waals forces, which are weak interactions between molecules caused by slight imbalances of electric charges. The van der Waals forces are just strong enough to overcome the random Brownian motion and twist each micelle into a specific orientation.

Basic work by research associates Je-Luen Li and Jaehun Chun provided a description of the angular variation of the van der Waals interaction, and this enabled the group to cinch their argument.

The scientists said their work opens new horizons to explore. “You need a critical number of dancers for this to happen, but we have no idea *how* many,” Aksay said. Moreover, he noted, the researchers can move on to other interesting questions, now that they know that the micelles are dynamic and understand the time frame in which they move. “This opens up the prospect for even more rigorous thinking.”

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