Water lilies inspire scientists to create large-scale graphene films

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In the world of nanomaterials, scientists and engineers can create new structures with tiny building blocks as small as one billionth of a meter.

But in order to construct new materials and devices, researchers first need to understand how these tiny units interact with each other.

One such building block is graphite oxide, which is often used to make graphene — a hotly studied material that scientists believe could be used to produce low-cost carbon-based transparent and flexible electronics. Like graphene, graphite oxide is essentially a sheet that is only one atom thick, but can be as wide as tens of micrometers.

Jiaxing Huang, assistant professor of materials science and engineering at Northwestern University, and his research group at the McCormick School of Engineering and Applied Science set out to investigate how these graphite-oxide sheets assemble. Their results, published as the cover article in the Jan. 26 issue of the *Journal of the American Chemical Society*, surprised them.

"We were very curious how these extremely thin two-dimensional sheets interact with each other," Huang says. "This knowledge can also help to prepare better graphene thin films."

Huang and his group studied the sheets by putting them onto a water surface — a process called Langmuir-Blodgett assembly, which makes the sheets stay flat and allows scientists to move them around.

The effect reminded the researchers of water lilies on a pond, and Huang asked his sister to help to create a Chinese water painting similar to that of Claude Monet's series of paintings "Water Lilies" to demonstrate the idea. The artwork was chosen as one of the first illustrated covers for the 130-year-old journal.

Researchers used a barrier to push the sheets together to see how they would interact and then "fished" the interacting sheets off the water surface using glass slides or silicon wafers. Huang and his colleagues expected to see that individual sheets had stacked one upon the other, like a shuffled deck of cards. Instead they found that the edges of the graphite oxide sheets rumpled as they were pushed together.

"This was quite a surprise for us," Huang says. "Now we understand that electrostatic repulsion is the dominant interaction when these sheets are pushed together in this edge-to-edge geometry. This prevents graphite oxide layers from overlapping with each other."

When squeezed even further, the sheets eventually formed an interlocking structure that becomes a continuous membrane.

This film — consisting of flat, non-overlapping single layers tiling over large areas — has been very difficult to achieve by conventional thin-film processing techniques such as drop casting or spraying.

This breakthrough could have two immediate technological impacts. "Because we can keep them close to each other and still keep them flat, it provides high coverage of the surface with the single layers — which in turn will translate into high successful yield in graphene device fabrication," Huang says. "On the other hand, the continuous graphite oxide monolayer can be made into a transparent conductor after conversion to graphene."

Now, after studying how they interact edge-to-edge, Huang hopes to study face-to-face contact of the graphene-based materials. Stacking graphene sheets directly on top of each other will form graphite and lose the advantages of the single-atom-thick graphene materials. But Huang hopes to find a way to stack graphene without making graphite, which could create functional materials for energy-related applications such as electrodes for batteries, ultracapacitors and fuel cells.

"If we are good at making these tiny building blocks and if we can control how they assemble, we will create a lot of wonderful new things," Huang says.

In addition to Huang, co-authors of the paper include National Science Foundation graduate research fellow Laura Cote and postdoctoral fellow Franklin Kim, both of whom, according to Huang, "did a wonderful job" to create the high-quality graphite oxide sheets used in the experiment.

Source: Northwestern University

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