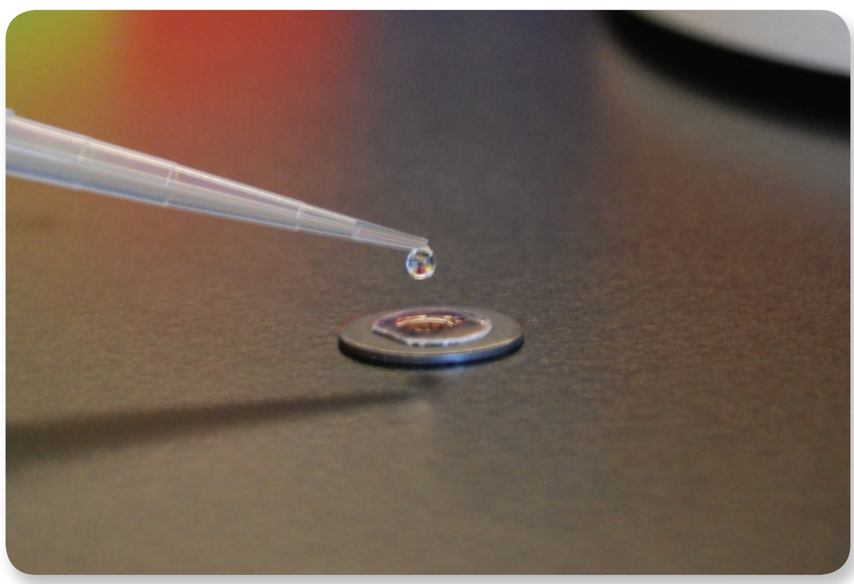
CASE Study

Bruker AFMs Help Boise State University Students Perform Unique DNA Project

CS502

As part of a project involving the manipulation and control of matter at the nanoscale, Boise State University researchers created a nanoscale logo from DNA, and Bruker's MultiMode® 8 and Dimension FastScan® were part of the team.

The project at Boise State was led by Dr. Elton Graugnard, an assistant professor in the Department of Materials Science and Engineering (MSE). His research focus includes atomic layer deposition (ALD), scanning probe microscopy, and DNA-based nanotechnology, which he pursues as a member of the Nanoscale Materials and Device Group.



Mica prep for DNA origami.
Photo by Kelly Schutt.

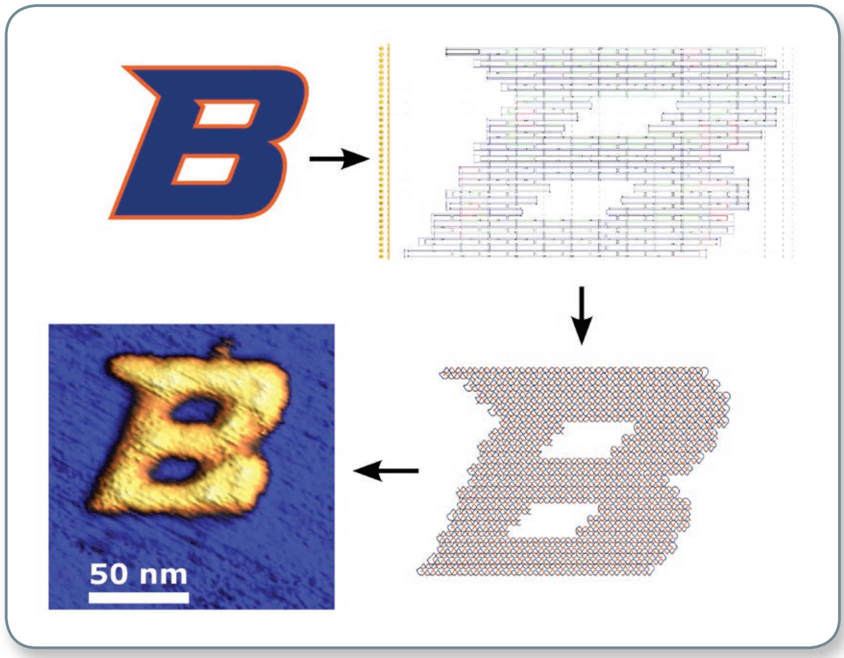
The Boise State researchers used a technique known as "DNA origami," invented by Paul Rothemund at the California Institute of Technology. The Boise "B" DNA origami project was conceived to help students learn how to produce DNA origami. Dr. Graugnard thought this would be a fun way for them to learn.

"The logo synthesis was really a training exercise in this technique of DNA origami," he says. "You use DNA as a programmable sort of breadboard for organizing nanoparticles at a scale that is difficult to achieve with other techniques. If you can make something that looks like a "B" it demonstrates that you can make arbitrary shapes."

The DNA origami project was led by undergraduate MSE student Kelly Schutt. Schutt laid out DNA into the shape of the B logo using computer-aided design (CAD) software called caDNAno that is specifically for DNA origami. "Once you establish what you think is a viable design," Graugnard explained, "then you purchase the DNA staple strands from a company that makes synthetic DNA, and from another company you purchase the scaffold strand, which is harvested from a bacteriophage."

Brett Ward, an MSE doctorate student in the group, worked with Schutt to synthesize the DNA origami Bs. The students mixed the 170 separate DNA strands in solution, and about one trillion identical Bs made from synthetic DNA were produced in about four hours.

And how did they know that this worked? Research validation requires some form of microscopy, and Graugnard says his group relies heavily on atomic force microscopy. "For this project the students utilized both the MultiMode 8,



DNA origami project stages, from design to final DNA "B."
Photo by Kelly Schutt.

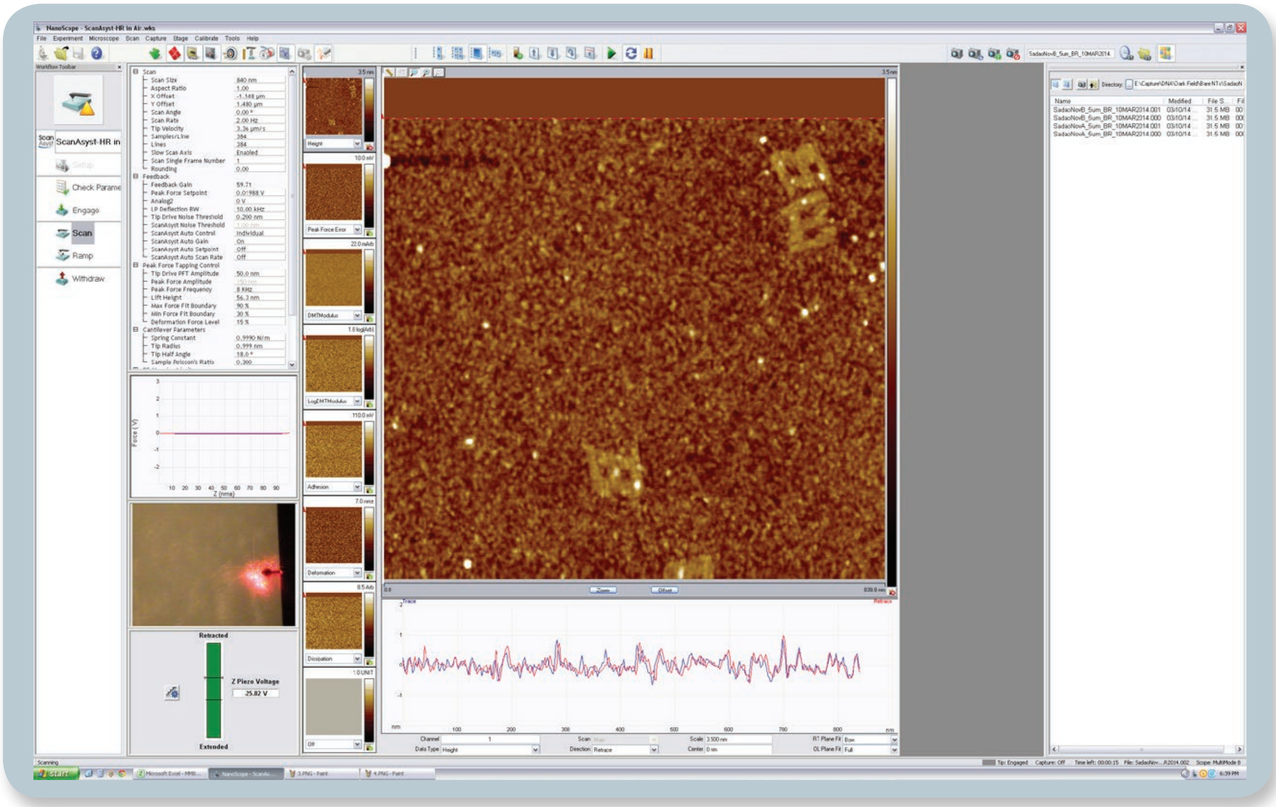
Origami B 2D image from the MultiMode.

Origami B 3D image from the MultiMode.

which they used to get the image in the Boise State newsfeed, as well as the Dimension FastScan," he said. "For both, the low noise floor is important for being able to see the origami, which is 2 nanometers in height when they're on a mica surface, and only about 80 nanometers wide for this design. If you're going to be able to resolve the little holes inside the Bs you need a sharp probe and a low noise floor."

The MultiMode 8 is equally well suited for imaging in both air and fluid, but the students did fluid imaging with the MultiMode 8 to achieve the highest resolution of the origami. The project researchers also took advantage of Bruker's PeakForce Tapping® mode on the MultiMode 8, which protects fragile samples without loss of resolution. Dr. Graugnard says one of the advantages of the MultiMode is the longevity of the platform. He originally worked on the platform when he was in graduate school. "It's nice that it's been continually upgraded," he says. "It's a familiar design, and it's been proven. Training students on equipment they're likely to see in other labs gives them an advantage; they can immediately get great imaging results and focus on difficult research questions rather than learning the nuances of new equipment."

Working with students is the biggest motivator for Dr. Graugnard, and he says there is a particularly strong emphasis on undergraduate research at Boise State and in the MSE department. "We have a group of about 30 students, faculty, and staff that are part of the research group," Graugnard says. "We all share equipment, and we collaborate very closely. There are a lot of students here that get trained on Bruker equipment. Bruker is actually in the process of reviewing



Formation of Boise "B" DNA displayed on screen of the MultiMode 8.
Photo by Kelly Schutt.

our training program as a model for other user facilities."

This strong emphasis on projects and lab experience help students leverage their research to get jobs and positions in other labs. "We are very careful about how we spend time and money to make our students competitive with students from the big research schools. Having that familiarity with instruments they're very likely to use in the future, such as the MultiMode 8, is important."

The research group's lab at Boise State is set up as a shared user facility, and they often train external users on a Bruker Dimension 3100, which is coupled with a nanomechanical test instrument. In the lab's busy environment with so many researchers using the AFMs, accidents and repairs are inevitable, but Graugnard says they have very little downtime as a result.

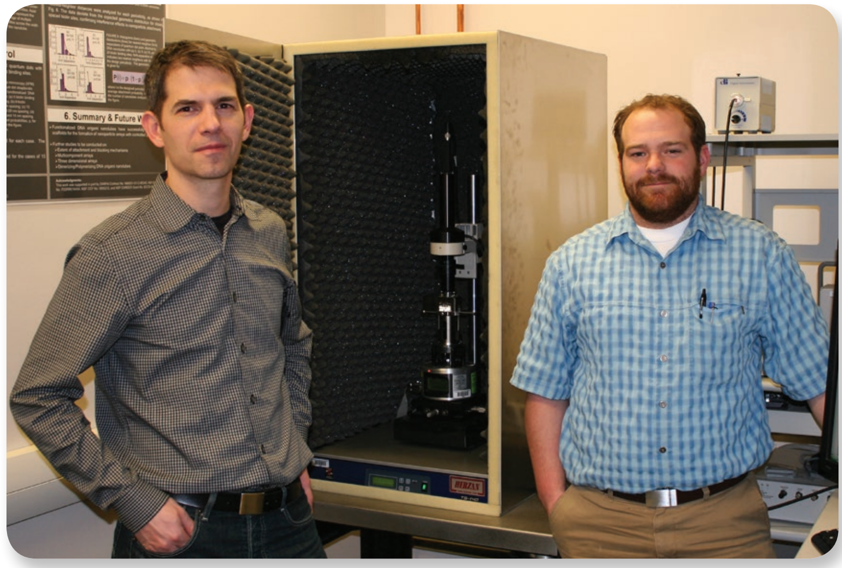
"We've had great service from Bruker, and we have a really good track record with getting quick turnaround," he says. Graugnard explained that they have a full time research engineer, Dr. Paul Davis, who manages the lab. "Paul's very skilled at debugging the systems, doing all the checks and working with the Bruker engineers to make sure everything is working as it should. This close working relationship with Bruker often helps us avoid shipping equipment for things we can fix here."

So what's next for the Boise researchers? Similar DNA structures are being developed in Boise State's Nanoscale Materials and Device Group as novel materials for building future electronic and optical computer circuits from molecules. Graugnard says they're trying to use DNA origami to pattern semiconductor surfaces for future memory devices and that they have a research program in collaboration with Micron Technology, which is headquartered in Boise and makes DRAM and flash memory.

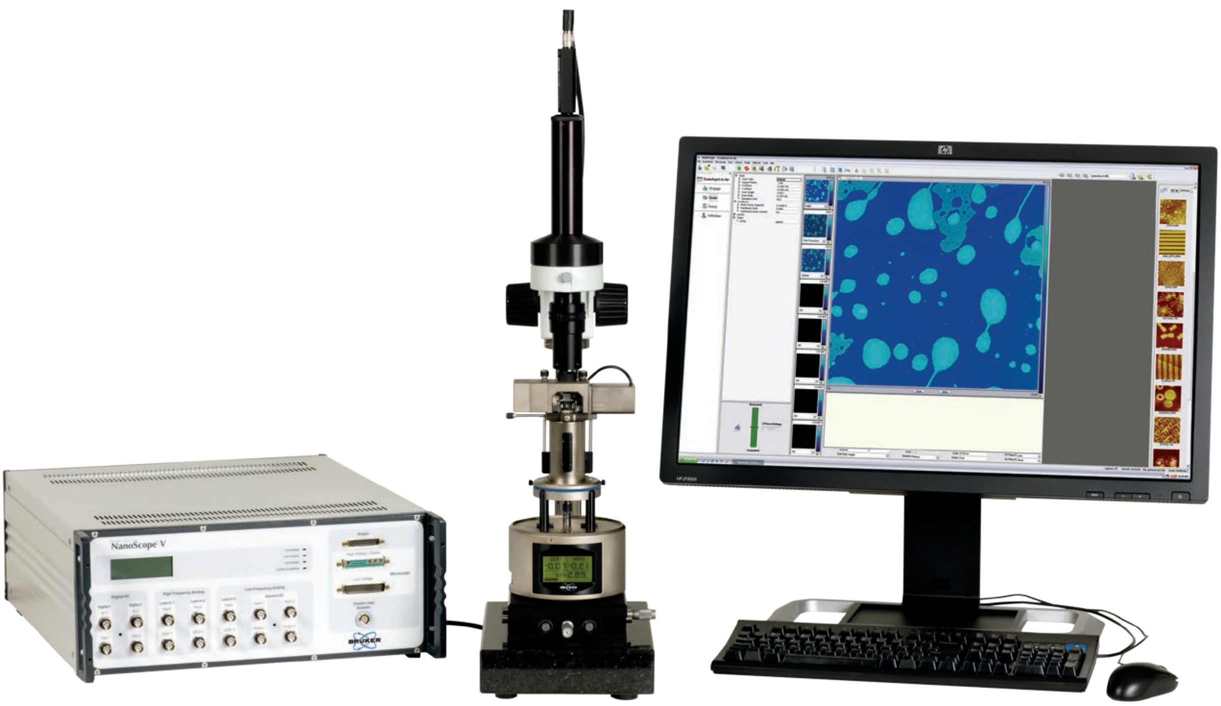
"DRAM and flash memory tend to be at the leading edge of the size for semiconductor devices," explains Graugnard. "The semiconductor industry is always working at the limit of what can be done with photolithography, so people are looking at how to make smaller and smaller patterns.

We've got a way to build patterns from the molecular scale up, and the idea is to then merge with larger patterns that are made with photolithography. So the fine scale would be controlled by the origami shapes rather than by a photo pattern."

The DNA Origami Project was supported by Boise State's Osher Lifelong Learning Institute, the National Science Foundation (IDR No. 1014922), NIH Grant P20 RR016454 from the INBRE Program of the National Center for Research Resources, and the W. M. Keck Foundation. To learn more, visit nano.boisestate.edu.



Dr.Graugnard (left) and doctorate student Brett Ward working on the DNA Origami project in the Boise State lab with the MultiMode 8. Photo by Paul H. Davis.



Bruker's MultiMode 8 system.

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