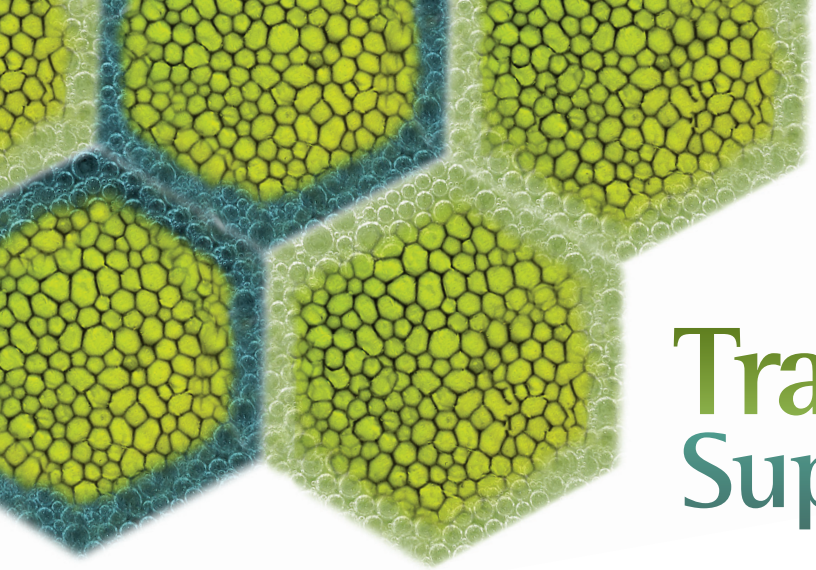


BY BREEHAN GERLEMAN LUCCHESI

Tracing the Image of Superconductivity

SUPERCONDUCTIVITY. EXPERIMENTATION. Analysis. Andrew Fidler learned a lot about all of these during his internship at Ames Laboratory. But he also learned that sometimes it takes some old-fashioned materials and techniques to make some brand new discoveries. Fidler, a 2007 participant in the Department of Energy's Science Undergraduate Laboratory Internship, or SULI, program, contributed to the groundbreaking discovery that the bubble-like arrangement of magnetic domains in superconducting lead exhibits patterns very similar to conventional froths. And Fidler's work was done with an office supply of the past: carbon paper.

Fidler used the carbon paper to gather the data Ames Lab physicist Ruslan Prozorov needed to analyze the polygon cells that make up the superconducting froths, called suprafroths. The process started with images of suprafroths taken with a magneto-optic microscope in Prozorov's lab that showed rough outlines of the froth's cells. Fidler's task was to take a pen and a piece of carbon paper and trace the microscope image to produce a clear picture of the polygons.

"In order to compare the suprafroths with conventional froths, we needed to identify the types and the amount of the polygons in each microscope image of the froth," says Prozorov. "We tried using computer programs to do it, but they failed. The images are very complex with gradients of intensity and some scratches and artifacts. There was no other way to do what Andrew did visually and manually, starting with the carbon paper."

"I actually had a hard time finding carbon paper," adds Prozorov. "I went to an office supply store, and they had to dig it out of the storage room somewhere."

Fidler traced each image by hand — twice.

"I traced once with carbon paper and once with black pen to make sure the lines would be read by the scanner, and then I scanned each tracing into the computer. I looked at the froth images on the computer screen and identified each type of polygon cell. Then I tabulated how many of each type of polygon was in each image," says Fidler.

Each image consisted of approximately 200-300 polygon cells, and Fidler repeated the process on 528 images, with each image representing a different point of temperature and magnetic field.

"It was a tremendous amount of work," says Prozorov.

Fidler and Prozorov's efforts — combined with the contributions of Ames Lab physicist Paul Canfield and Iowa State University graduate student Jake Hoberg — paid off. The group published their findings in *Nature Physics* in April 2008. Their paper proposed suprafroths as a model system for all froths.

"There are certain statistical laws that govern the behavior of froths, and we found that suprafroths satisfy these laws," says Prozorov. "We can now apply what we know of suprafroths to all other froths and complex froth-like systems."

Suprafroths offer reversibility, a significant benefit over conventional froths.

"In everyday froths, like soap foam, the agent of change is time," says Prozorov. "You have to wait for bubbles to simply dry out, and that takes days. And it's not reversible. You cannot reverse time."

But achieving an ideal froth experiment is possible with suprafroths because the agents that create the superconducting phase cells are magnetic field and temperature, both reversible parameters.

"Magnetic field and temperature can be tuned in the lab," says Prozorov. "They can be increased or decreased, and therefore we are able to study the pure statistical properties of froth without problems associated with the irreversibility of time or with chemical property changes."

Prozorov's comparison of suprafroths is also an important contribution to the study of superconductors.

"The statistical analysis shows suprafroths behave just like normal froth, which is also new for superconductivity," says Prozorov. "Just last year we found this new pattern in superconductors, and now we've proven that the froth state is really an intrinsic property of superconducting lead. It's a big deal for both the general physics of froth and the growing physics of superconductors."

Fidler wasn't expecting to be involved with such a "big deal" when he applied for the SULI program.

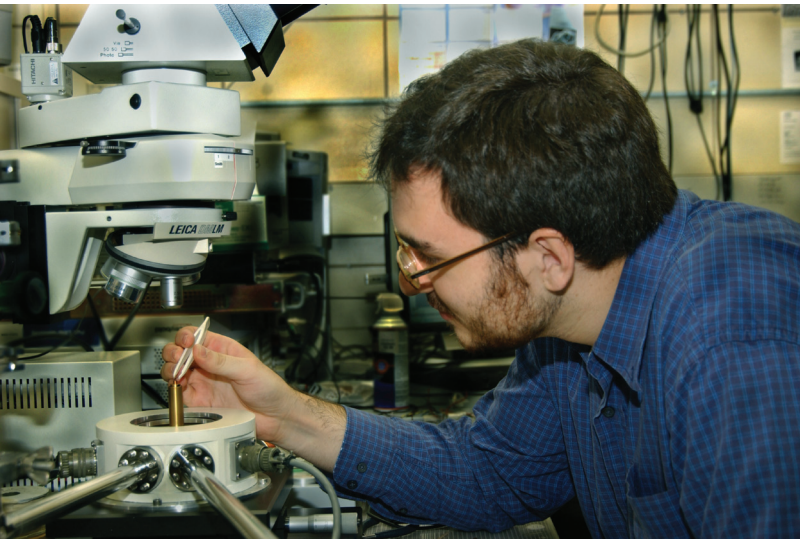
"I was never expecting to be able to get a journal article

published, let alone in such a reputable journal as *Nature Physics*," says Fidler. "I still don't think I have fully realized how significant it is to be published in such a good journal as an undergraduate. I'm really thrilled to be a published author.

"I learned so much working with Dr. Prozorov and his graduate students," adds Fidler. "Dr. Prozorov was always available to help, and the students in his lab explained everything I had questions about."

Following his internship at Ames Lab, Fidler nominated Prozorov for a SULI Outstanding Mentor award.

Fidler's nomination reads, in part, "Since my first day at Ames Laboratory, Dr. Prozorov has given me the opportunity to work on a challenging and interesting project,



Andrew Fidler prepares a sample for study in the low-temperature magnetism laboratory.

and he has provided insights and has been an effective instructional coach during my internship."

The next stop for Fidler is graduate study in physics at the University of Chicago.

"SULI definitely helped me attain my goal of attending graduate school," says Fidler, "and it validated my continued interest in the sciences, too."

suprafroth \ `sü-prä `froth \ **n**
pl. **suprafroths** \ `sü-prä `froths, frothz

A Supra New Science Term

Why are Ruslan Prozorov's *super*conducting froths called *supra*froths? The term was born of necessity but is based on history.

"Originally we wanted to call the new froth 'superfroth' simply because of the term 'superconductor,'" says Prozorov. "But if you do a Web search for superfroth, you see the term is already taken by some totally unrelated materials like plastics, milk for coffee drinks and even ice. And the term superfroth is even trademarked by one company."

"So we invented the term 'suprafroth' to avoid any trademark troubles and because when superconductors were first invented they were called 'supraconductors,'" Prozorov continues. "Well, the term was originally in German, but as the science of what is now called 'superconductors' spread across Europe, they were most often called supraconductors."

"Many people like the term suprafroth now, and the term is clearly distinct," he adds. "A Google search gives only results for what we have come up with. And while the term is already propagating through the scientific community, all references to the work will point back to our work. It's not really often you can coin a term, but we managed to do just that."