

MATERIALS ARE EVERYTHING

RESEARCHERS PUSH THE LIMIT WITH NOVEL MATERIALS

By Mike Journee

“Materials are everything, right?”

The question – more of a statement, really – is less obvious than it sounds. It is a simple way for Darryl Butt, head of Boise State’s Department of Materials Science and Engineering, to illustrate the complexity and wide-open potential of novel materials research.

Like Butt’s question, the study of materials and their uses seems fairly straightforward and routine on the surface. But under the surface, at the molecular level, the creation and study of new or novel materials is having a profound impact on the development of everything from next-generation microelectronics and space vehicles, to medical diagnostics and surgical tools, to nuclear energy and solar power.

Novel materials are newly engineered materials that have properties allowing them to function in ways conventional materials cannot. Much of this work is done at the nanoscale level – between one and 999 nanometers (a human hair is about 100,000 nanometers

wide) – where even familiar materials do unexpected things.

“It’s like cutting an apple in half and getting an orange,” says Jeunghoon Lee, an assistant professor of chemistry and one of several Boise State researchers who create novel materials in their laboratories in support of research initiatives on campus.

By learning the characteristics of materials at nanoscale, researchers can manipulate them to enhance qualities needed for a certain purpose, deemphasize unfavorable properties or create entirely new materials.

‘Pushing the Limits’

In many ways, novel materials research is a world of trial-and-error coupled with highly educated guesses.

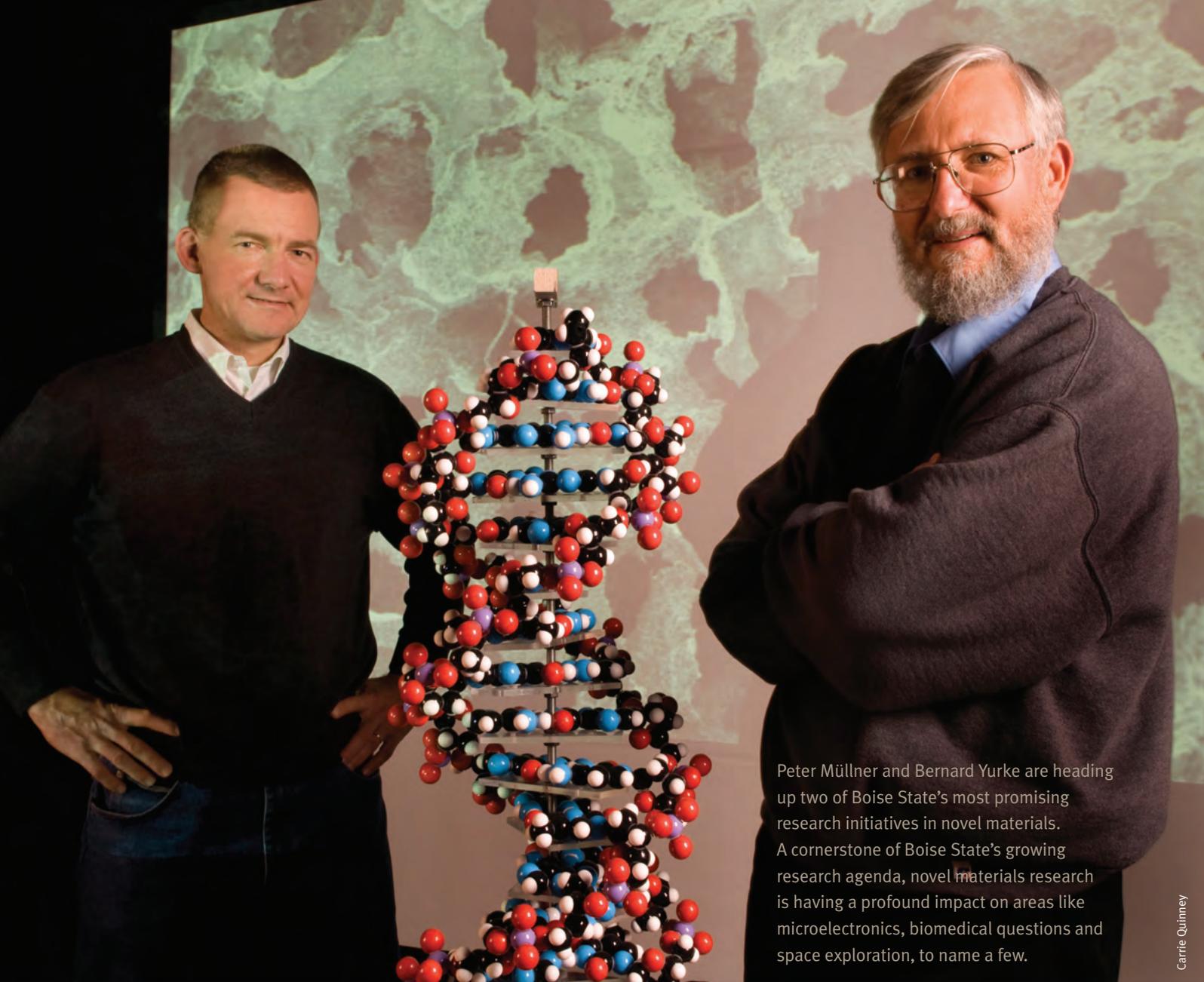
“In my work, I try to find out how a

material works and then find a system where its attributes can be optimally used,” says Peter Müllner, director of Boise State’s Center for Materials Characterization and a professor of materials science and engineering. “I ask the question, ‘What can this material do and why does it do that?’ and go from there.”

From iPod to tennis racquet to advanced armored systems and the batteries powering hybrid vehicles, novel materials are behind the advancements that make the things we use every day smaller, faster, stronger or less expensive to manufacture. They also are making possible what once was impossible.

“We are pushing the limits of materials to operate in regimes and ways that they could not before,” says Butt, who works with oxides of uranium, plutonium and other similar materials. His work explores possible nuclear energy fuels that cannot be used in weapons and have very little or no waste stream – potentially eliminating the proliferation of nuclear weapons and disposal of nuclear waste as hurdles to nuclear energy’s use on a large scale.





Peter Müllner and Bernard Yurke are heading up two of Boise State's most promising research initiatives in novel materials. A cornerstone of Boise State's growing research agenda, novel materials research is having a profound impact on areas like microelectronics, biomedical questions and space exploration, to name a few.

Carrie Quimney

Airbags, Cartilage, Satellites and Cancer

Work being done by materials science faculty forms the heart of novel materials research at Boise State. Butt quickly points out, however, that the most creative and promising progress being made in novel materials research is happening in areas where traditional science disciplines overlap, allowing the unique perspectives of researchers from a wide range of disciplines to impact the work.

Novel materials work can be so versatile that Boise State researchers can mention a microelectronics project

they are working on in one sentence and their contributions to a potential cancer treatment in another. The interdisciplinary nature of the work allows the unique properties of these materials to be applied to questions in an ever-broadening range of fields.

Dmitri Tenne, an assistant professor of physics, works with piezoelectric materials – materials that convert electrical energy into mechanical energy – that could have applications for use in automobile airbags and ultrasound machines.

Julia Oxford, director of Boise State's Biomolecular Research Center and

a professor of biology, uses special scaffolds made of various materials to foster the growth of cartilage. Oxford studies the molecular organization of cartilage so she can understand how it functions as a tissue. Arthritis or joint pain sufferers could one day benefit from her work, which is funded by the National Institutes of Health and the Idaho State Board of Education, among others.

Engineering professors Don Plumlee, Jim Browning, Amy Moll, Sin Ming Loo and Inanc Senocak are part of a team working on electric propulsion in low-temperature, co-fired ceramic (LTCC) materials. Bringing together

materials science, mechanical, electrical and computer engineering, the collaborative project is focused on developing an affordable, micro-propulsion system that could strategically point small satellites and enable them to maintain position while in orbit much more inexpensively than traditional chemical rockets.

And a group of physicists, biologists, engineers and chemists continues its work using zinc oxide nanoparticles to preferentially kill immune cell cancers and fight infections that kill thousands of people. Using nanobiotechnology, these researchers are building on the work of physics professor Alex Punnoose, who started down the path to cancer research by working on semiconductors and nanoelectronics (See Winter 2009 FOCUS).

A New Way to See DNA

One of the most promising and visionary research initiatives at Boise State is work led by Bernard Yurke, a materials science and engineering research professor. His aim is to build micro devices on tubes made out of strands of DNA, a cutting-edge concept that could take the inexpensive miniaturization of electronics to a new level – well beyond the soon-to-be reached limits of silicon-based electronics and computers.

In research funded by the Defense Advanced Research Projects Agency and the National Science Foundation, Yurke's team uses DNA's ability to "self-assemble" to fold a single long

strand of DNA, called a "scaffold," several times and bind it together with shorter "staple" DNA strands.

By chemically attaching individual gold nanoparticles to the ends of the short DNA strands, the team hopes to fuse the nanoparticles to rows alongside these DNA nanotubes, essentially creating nanoscale-sized gold wires that could be electrified.

The team also has attached miniscule semiconductors called quantum dots to the DNA nanotubes. By running a pair of the gold nanowires to a quantum dot, Yurke hopes to create a "nano light bulb" that can be illuminated by an electric current flowing through the wires.

"The main reason to do this is to demonstrate a technology by which we can make electrical devices with components that are a few nanometers in size," Yurke said. While he knows his work one day could be used to make smaller more powerful computers, he's near certain that "other applications will be found that we're not clever enough to think about yet."

Metal Foam with a 'Memory'

Müllner's work with magnetic shape-memory foam is another of Boise State's most successful materials research initiatives and likely makes him one of the top experts in the world on the subject. Müllner and his collaborator at Northwestern University recently published dramatic new research results in Nature

Materials, the leading research journal in materials science.

The research is focused on a nickel-manganese-gallium alloy that changes shape when exposed to a magnetic field. The alloy retains its new shape when the field is turned off but returns to its original shape if the field is rotated 90 degrees, demonstrating magnetic shape-memory. The alloy can be activated millions of times and has potential applications in next generation printers, green car engines and surgical tools, and it will enable innovations in such fields as biomedicine and microrobotics.

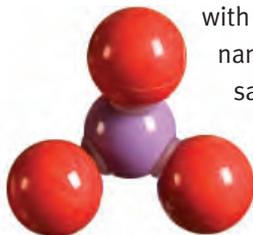
Not New, But Still Novel

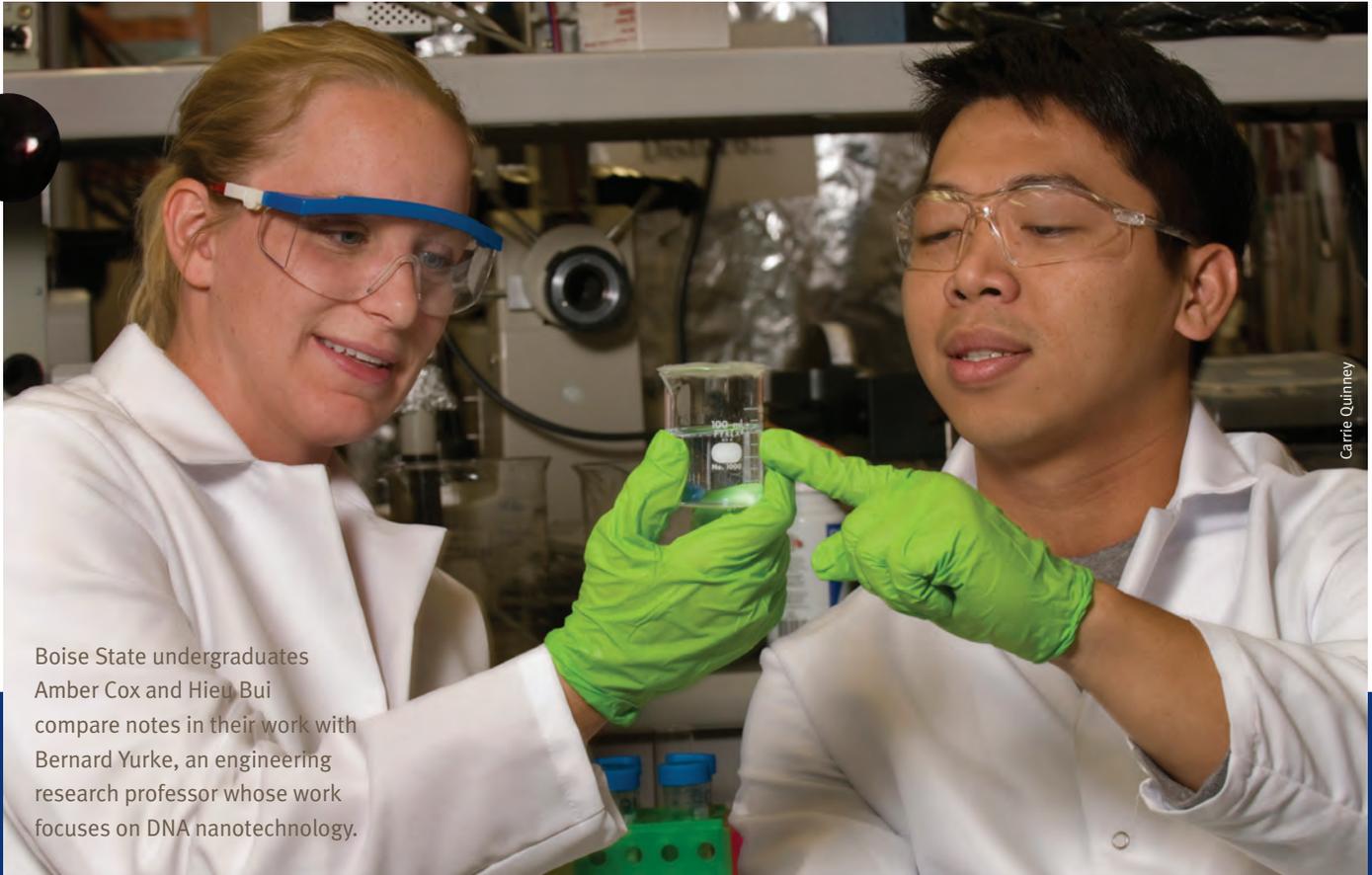
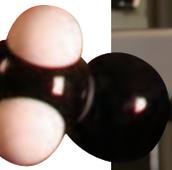
Müllner says that the wide-open potential of novel materials research is one of the main reasons for the attractiveness to scientists and the government agencies, companies and others that fund their work. In theory, every material known could have some hidden potential that could add value to their goals.

Nothing has really changed since humans first began assessing materials and how to use them – today, just as then, everything around us is made of materials, as Butt's simple question illustrates. Yet it's clear that the excitement of discovery is just as keen as it ever was, and that Boise State novel materials researchers are just scratching the surface of possibility.

"This is not a new science," says Müllner. "There are probably hundreds of papers published each week on materials research. Still, when the right ideas come together, the novelty of the endless possibilities materials offer is revealed."

"It's like cutting an apple in half and getting an orange."





Carrie Quinney

Boise State undergraduates Amber Cox and Hieu Bui compare notes in their work with Bernard Yurke, an engineering research professor whose work focuses on DNA nanotechnology.

Boise State research builds reputation for undergraduate opportunities and local investment

Boise State Vice President for Research Mark Rudin is fond of saying that at Boise State, laboratories are classrooms. His point is that very few universities offer undergraduates the opportunity to stand shoulder to shoulder with top-flight researchers working on some of society's most important questions and challenges.

Rudin selected his undergraduate alma mater for that very reason, and he thinks Boise State is becoming a similar school of choice for high-achieving students who crave the hands-on learning and achievement that only research experience can offer.

Novel materials research is one of the cornerstones Boise State is building

that growing reputation around, and it is attracting the attention of more than undergraduates looking for something extra from their college education.

As the university's reputation for high-quality research grows, Rudin says, its ability to attract more funding, build better facilities, hire bench researchers into the faculty and foster advanced degree programs that further contribute to its mission will grow, too.

And its good for local business, Rudin says. Local companies and agencies are benefactors and beneficiaries of the work being done in Boise State labs. In fiscal year 2009, the Department of Materials Science and Engineering alone accounted for

\$5.9 million in research investments by a number of interested entities, including federal funding agencies such as the National Science Foundation, National Institutes of Health, the Department of Defense, NASA and others.

And as Boise State's newly created Office of Technology Transfer ramps up, more and more Boise State research will contribute to the local, state and national economy's bottom line, Rudin says.

"As Boise State's stature grows," Rudin says, "we'll continue our success at bringing in more and more talent – faculty, students and staff."