

# Nanolayering Improves Materials

Stronger, lighter materials increase security and efficiency

## Quick read

Lab scientists have discovered how to layer metals to make them stronger and lighter, improving cars, airplanes, computers, and nuclear power plants.

Nations worldwide are striving to replace traditional fossil fuels with cleaner, more abundant power sources. Recently, the Department of Energy concluded there is one common need to all future energy technologies: improved materials.

To meet that need, lightweight materials that resist corrosion, decay and failure—and that heal themselves—are being developed at Los Alamos National Laboratory (LANL).

These improved materials will also make our cars, airplanes, computers, and power transmission lines lighter, stronger and more damage-resistant. "Of course, if an aircraft or automobile is lighter, it will decrease fuel costs," says Amit Misra of the Center for Integrated Nanotechnologies (CINT) of the Lab's Materials Physics and Applications (MPA) division.

### Making Metals Thinner and Stronger

Misra, who recently won the LANL Fellows Prize for his research, is nanostructuring metals that are simultaneously stronger and damage-resistant. His team's new technology combines two metals into a composite made up of ultra-thin layers; this nanolayering makes the composite extraordinarily strong and highly damage-resistant.

"The nanolayered composites have strengths that are over two orders of magnitude higher than high-purity metals in the single crystal form," Misra says.

In contrast to nanostructured materials, conventionally-engineered steel, aluminum, copper and other metals have low strengths and poor damage tolerance. In order to withstand high loads or extreme environments—high pressure, soaring temperature or long-term radiation—engineers must overdesign the structural components, for example, making a metal container thicker and heavier.

### Making Power Plants Safer

Fossil fuels are scarce and efforts to curb greenhouse gases are increasing. Clean power sources such as nuclear power plants can help meet the world's future energy needs, but safety and economical concerns remain. According to the U.S. Nuclear Regulatory Commission, the 1986 accident at the nuclear power station in Chernobyl, Ukraine may ultimately cause approximately 4,000 radiation-related cancer deaths of its workers and residents.

In a nuclear power plant, constant exposure to radiation degrades the structural materials over time. For example, the metal containers used to hold nuclear fuel can experience radiation-induced swelling and creep (deformation). The swelling is caused when helium-filled cavities produced by radiation inflate inside the metal. Currently, engineers design around these limitations. The containers are made very thick, and the components are replaced frequently, making the process expensive and dangerous.

The Lab's research—which will help to design structural materials that better withstand the degrading effects of radiation—could help address those concerns.

### Interfaces Protect Against Radiation Damage

The new nanolayered composites could dramatically improve the performance and reliability of materials in nuclear reactors. The key to damage resistance is the interface, or junction,

between the layers in the composite. When the right kinds of metals are bonded, the interface between them has unprecedented, self-healing properties. The interfaces attract, absorb and annihilate radiation-induced defects.

Because the attraction of defects to interfaces only works when an interface is close to a damaged area, very thin nanolayers—just a few dozen atoms thick—must be used.

The right combination of metals is key. The combination of Copper and Niobium works well, Misra says; this combination produces the remarkable tolerance to radiation damage as well as the very high strength characteristics of nanolayered composites. "This is one combination, but is it the best one?" Misra says. "We don't know yet."

More research is needed to find the ideal materials that will help build tomorrow's power plants, cars, airplanes, computer components and electrical transmission lines, Misra says. The technology is still in the early development stages but the Laboratory is on the cutting edge for materials that enhance our lives.

## Pushing Frontiers

In the second half of 2008, Los Alamos National Laboratory made significant advances in its primary mission: safeguarding the U.S. nuclear deterrent and pushing the frontiers of science on multiple fronts.

The national stockpile stewardship program achieved a major milestone in September with the production of the first life-extended W76-1 ballistic missile warhead for Trident submarines. The achievement culminated more than a decade of work by scientists and engineers at Los Alamos and across the nuclear weapons complex—including two crucial experiments conducted by the Laboratory's Hydrodynamic Experiments Division.

Another highlight: Roadrunner reached a new performance record of 1.105 petaflops, keeping it atop the list of the world's fastest supercomputers. Built by IBM for the Lab, Roadrunner was the first computer to crack the petaflop barrier: one thousand TRILLION operations per second. Initial applications will range widely: studying in great detail the evolution of HIV... exploring deeply the formation—as well as deformation—of metallic nanowires...and-toward producing biofuels more efficiently-unraveling the processes by which bacteria break down cellulose.

Safety and environmental stewardship were again a major theme for our work in the latter half of 2008. In November, the last group of unvented high-activity drums left Los Alamos for the Waste Isolation Pilot Plant near Carlsbad. That shipment fulfilled a commitment to the Defense Nuclear Facilities Safety Board to prioritize disposal of the highest-activity transuranic wastes stored at the Lab.

Los Alamos also strengthened security, ensuring that nearly six dozen classified and unclassified computing systems are managed and operated securely. The Lab has now complied with all 14 security actions mandated two years ago by the Department of Energy. And, through our program to recruit cognizant systems engineers, we met the crucial need for sufficient numbers of engineers to keep vital mechanical and electrical safety systems functioning properly in our nuclear facilities.

The latter half of 2008 proved once again why Los Alamos is the nation's premier institution for scientific research. Capping the list of accomplishments was a new technology called MagViz that could eventually provide increased security at major airports. Based on medical MRI technology, MagViz can identify contents of bottles and other containers, distinguishing potentially hazardous liquids from the harmless shampoos and perfumes a traveler might carry onboard a jet. MagViz was demonstrated successfully in December at Albuquerque's airport.

We continued a long tradition of supporting U.S. space exploration. A NASA mission, launched in October to probe the far edge of the solar system from a high Earth orbit, carried a Los Alamos device called the High Energy Neutral Atom Imager. Its goal: to detect atoms emitted from a region where the outermost reaches of our solar system meet the vast interstellar space—giving us a panoramic view of this gateway to the galaxy.

Closer to home, Los Alamos continues to explore solutions to the energy needs of tomorrow. For example, scientists at the Lab hope to use tiny semiconductors called quantum dots to convert sunlight to electricity more efficiently than is possible with current solar panels—and to create new, efficient solid-state lighting.

Equally electrifying, Los Alamos materials scientists are helping unravel the mysteries of superconductivity. During the latter half of the year, LANL researchers identified entirely new mechanisms for superconductivity that could form the basis for new superconducting

materials.

Underscoring the wealth of scientific talent at the Lab, Bob Albers, Paul Johnson, and Kurt Sickafus were named Laboratory Fellows in December. These three Fellows represent diverse disciplines, including theoretical physics, energy science, and geophysics.

Los Alamos may be one of the world's great technology incubators, yet we also strive to help others develop new ideas and products. In January, the Lab selected four young local companies as the newest recipients of awards from the LANS Venture Acceleration Fund. LANS, which manages and operates the Lab, supports the fund through donations from its earnings.

The Lab and LANS also teamed last September with a venture capital firm and a local venture capital fund to spin off technology developed by Lab scientists, with an emphasis on creating companies in Northern New Mexico. The Lab could contribute up to one million dollars to the initiative over the first three years.

We also are pushing to build top-flight research facilities for the future. In July 2008, workers hoisted the final steel beam atop the skeleton of what will be the Radiological Laboratory Utility Office Building, part of the Lab's Chemistry and Metallurgy Research Replacement Project. Once completed, the CMRR nuclear facility will house several of the Lab's mission-critical projects, including analytical chemistry, materials characterization, and actinide research and development capabilities. They'll be relocated from their current location in the historic—yet antiquated—Chemical and Metallurgy Research building at Technical Area 3.

In December, Los Alamos welcomed hundreds of employees who transferred from KSL, the subcontractor whose work the Lab brought in-house. The move was geared to improve efficiency and reduce costs associated with site-support services, including maintenance, waste removal, and custodial work.

Throughout the Lab's history, Los Alamos has helped play a vital role in the surrounding communities, and in 2008, that tradition continued. Lab employees pledged a million dollars, and LANS matched one hundred percent: a record Los Alamos contribution to United Way of TWO MILLION dollars. Contributions from the Lab and LANS also helped fund dozens of nonprofit organizations and scholarship programs, including a LANS donation of \$500,000 to a LANL Foundation scholarship named for former long-time New Mexico Senator Pete Domenici.

These accomplishments and many more added up to a strong year. Our customer, the National Nuclear Security Administration, reached the same conclusion in its very favorable assessment of the Lab's performance for fiscal year 2008. It's unmistakable: the extraordinary talent, commitment, and creativity that Los Alamos employees dedicate every day to national security science and the betterment of their communities.

## About Our Capabilities, Facilities, and Staff

"Los Alamos National Laboratory plays an indispensable role in building America as a science and technology powerhouse, and our staff are an incredible resource to the nation and the world." Michael Anastasio, Dir.

Solving Complex R&D Problems with Special Blend of Staff, Capabilities and Facilities  
Now in its seventh decade, LANL is one of the few laboratories that can bring great breadth of fundamental and discovery science, technology, and engineering rapidly together to create tangible solutions for national security needs.

Our staff, working with partners throughout science and industry, must be able to deliver today's solutions while maintaining the depth of capabilities to deliver the next generation of discoveries.

Los Alamos has demonstrated a cycle of innovation where we have developed world-leading capabilities and facilities in response to urgent, unique missions. Our new discoveries continue to respond to emerging missions.

Being able to integrate and apply our capabilities rapidly to new challenges will be a key advantage in an increasingly competitive landscape.

Our Science, Technology and Engineering Priorities  
Science that Matters

Information science and technology enabling integrative and predictive science  
Experimental science focused on materials for the future

Fundamental forensic science for nuclear, biological, and chemical threats

How We Work

Collaborate, partner and team to make decisive contributions to our sponsors  
Outstanding operational excellence for safety, security, and efficient pursuit of ST&E  
for our missions

Transform Our Scientific Campus

Campus for 2020 (consistent with complex transformation)  
Modern science facilities: LANSCE refurbishment, CMR replacement, Science Complex  
Signature facilities