NOVEMBER ISSUE 1997

LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

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LOS ALAMOS

3-D SNAPSHOTS OF THE ATOMIC LANDSCAPE

HYBRID TECHNOLOGY LETS RESEARCHERS VIEW MATERIALS AT THE MICROSCOPIC LEVEL

A team of Los Alamos and Caltech scientists have made important breakthroughs in using a powerful new technique that marries two existing technologies to probe materials at a microscopic level. If researchers achieve their ultimate goals for this new technique, it could have important applications in magnetic information storage technology.

➔ Researcher Chris Hammel aligns the optical fiber with the cantilever in the magnetic resonance force microscope.

Their device combines the techniques of magnetic resonance imaging, which is widely used in the medical field to image soft tissue, and atomic force microscopy, which can measure the surface structure of materials with microscopic sensitivity. Researchers call the new approach "magnetic resonance force microscopy."

Although research into this technology at Los Alamos and elsewhere is still in the early stages, the technology has already matched the sensitivity of current state-of-the-art magnetic resonance imaging technology and promises to achieve even better results.

“The ultimate goal is to be able to create three-dimensional images of materials in slices as small as one atom wide,” says Los Alamos principal investigator Chris Hammel.

Magnetic resonance technology provides scientists with information about the electronic structure and magnetic spin dynamics of a sample, but it offers limited sensitivity, which in turn limits the resolution that can be achieved with the technique. On the other hand, the atomic force microscope measures forces with such high sensitivity that it can determine surface structure with atomic-scale resolution, but it can't look beyond a material's surface.

By combining MRI with AFM to create a magnetic resonance force microscope, researchers can study the interior of a sample — a crucial advantage over other high-resolution scanning probe microscopies which are sensitive to the surface only. If researchers reach their ultimate goal of single-spin sensitivity, then atomic-scale resolution with this technique will be within their reach.

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A MONTHLY PUBLICATION OF THE PUBLIC AFFAIRS OFFICE OF LOS ALAMOS NATIONAL LABORATORY

LOS ALAMOS NATIONAL LABORATORY, AN AFFIRMATIVE ACTION / EQUAL OPPORTUNITY EMPLOYER, IS OPERATED BY THE UNIVERSITY OF CALIFORNIA FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. W-7405-ENG-36

EDITOR
Kathy DeLucas

MANAGING EDITOR
Meredith Coonley

STAFF WRITER
Theresa Salazar

Send comments/questions to dateline@lanl.gov

CONTRIBUTING WRITERS
Gary Kliewer • Steve Sandoval

CONTRIBUTING PHOTOGRAPHERS
Phil Fresquez • Fred Rick • LeRoy N. Sanchez

PRINTING COORDINATOR
G.D. Archuleta

LOS ALAMOS NATIONAL LABORATORY
PUBLIC AFFAIRS OFFICE, MS P355
LOS ALAMOS, NM 87545

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The technique is particularly well adapted for studying the interfaces in multi-layered, thin-film materials, which are increasingly important in electronic applications, such as disk readers in computers.

In collaboration with their colleagues at the California Institute of Technology, the Los Alamos researchers are applying this powerful technology to the study of such materials.

Los Alamos postdoctoral researcher Byoung Jin Suh assembles the force detector. The inset shows a closeup of the piezo electric positioner, the optical fiber and the cantilever.

Researchers expect that studies with magnetic resonance force microscopy will clarify how the performance of electronic devices can be affected by such key properties as the precision with which the interfaces are formed, the electronic coupling between materials in adjacent layers, and interactions between magnetic properties of adjacent layers.

Magnetic resonance imaging, familiar for its medical applications, uses the selective absorption of very high-frequency radio waves, or resonance, by certain atomic nuclei to create three-dimensional images.

In contrast, magnetic force microscopy (a variant of atomic force microscopy) is a mechanical technique that uses a cantilever smaller than a human hair to reveal magnetic properties of a material's surface. The cantilever is bent slightly by the faint magnetic force generated by the electronic spin of atoms in a sample. The researchers exploit the fact that a radio frequency — similar to those generated for medical MRI — excites spins at targeted points inside the material under investigation.

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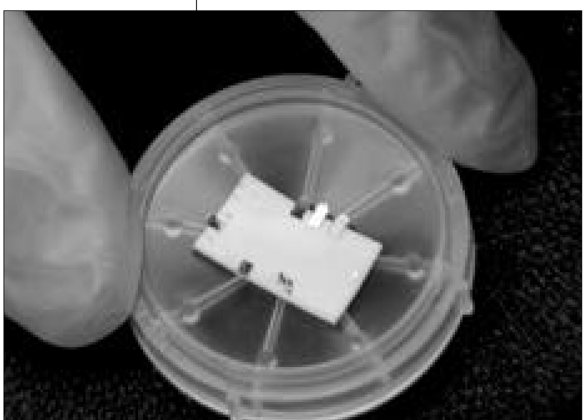
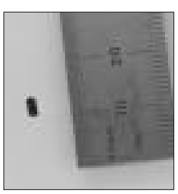
"When we add a radio-frequency excitation, the cantilever becomes specifically sensitive to subsurface regions," said Hammel. "We can then scan around inside the sample."

The device holds promise for applications in many fields. The researchers are focusing on analysis of multi-layered thin films used for reading the magnetic disks in computers. Layers of magnetic material sandwiched with layers of non-magnetic layers such as copper or gold are used as variable resistors. The thickness and roughness of the interface between layers affects the performance of such devices.





The cantilevers used in magnetic force microscopy are smaller than a human hair: 400 microns by 40 microns by 1 micron thick. From top to bottom: three cantilevers sitting on holders; a closeup of the same shot — the cantilever is the tiny hair-like projection protruding from the top of the holders; and a cantilever on its holder with a millimeter scale.

Magnetic resonance force microscopy will be able to reveal the irregularities between the layers and the related local magnetism and electrical properties without having to cut or destroy the samples. Understanding these interfaces is crucial for achieving increases in information storage density on magnetic disks.

Funding for the research has been provided by Los Alamos' Laboratory Directed Research and Development and the Center for Nonlinear Studies and from the Department of Energy Office of Basic Energy Sciences, Division of Materials Research.

CONTACT: P. CHRIS HAMMEL
CONDENSED MATTER AND THERMAL PHYSICS
(505) 665-0759 • E-MAIL: pch@lanl.gov

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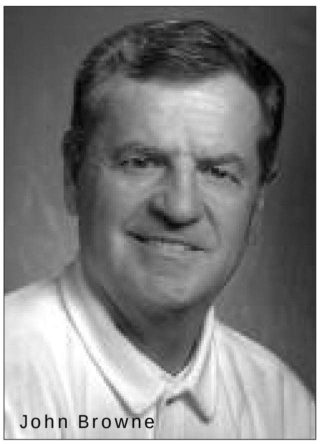
JOHN BROWNE NAMED LOS ALAMOS DIRECTOR

The University of California regents unanimously approved Los Alamos National Laboratory physicist John C. Browne for Laboratory director. Browne replaces outgoing director Sig Hecker, who stepped down in early November.


John Browne

Browne joined Los Alamos in 1979 after spending nine years in the physics program at Lawrence Livermore National Laboratory in California.

Before he became director, Browne was responsible for the scientific and operational management of the Los Alamos Neutron Science Center, which is at the forefront of neutron science research.

Browne previously served in a succession of positions, including physics division leader and several associate laboratory director positions. As associate director for experimental physics, he oversaw four technical divisions and programs in nuclear physics, magnetic fusion and solid-state physics. Serving as associate director for research, he led six technical divisions. He also served as associate director for defense research and applications responsible for four technical divisions and Department of Defense programs. Browne was associate director for computational and informational sciences, a position responsible for five divisions and programmatic oversight of the Laboratory's high-performance computing initiative, intelligence and non-proliferation programs.

Browne has served on various Laboratory oversight committees and a variety of external scientific and professional committees. He is a Fellow of the American Physical Society, a member of the American Association for the Advancement of Science and the author of numerous professional publications.

Browne received his bachelor's degree in physics from Drexel University in Philadelphia, Pa., and his doctorate in physics from Duke University in North Carolina.

CROPS CULTIVATED TO HARVEST INFORMATION

RESEARCHERS TEST URANIUM LEVELS OF VEGETABLES GROWN WITH WELL WATER

Researchers are cultivating crops in hopes of harvesting information about whether naturally occurring uranium can make its way into vegetables. Los Alamos scientists, in collaboration with the New Mexico Environment Department, are analyzing vegetables grown with water from wells in the Nambé-area of Northern New Mexico. The well water, in some areas, contains uranium levels more than 50 times higher than federal drinking water standards.

↑

Researcher Audrey Hayes harvests the vegetables, which were grown in a special enclosure and irrigated with water from different wells.

The researchers are attempting to determine how much uranium is taken up by vegetables grown in the area and what health risk, if any, could be associated with eating the vegetables as well as drinking the water.

The state Environment Department had previously tested wells in Nambé, Tesuque, Pojoaque and El Rancho, small communities east of Los Alamos. In a number of wells, the levels of naturally occurring uranium exceeded the federal safe drinking water standard, which is 20 parts-per-billion. The higher levels of uranium in well waters in these areas are attributed to geological features and water chemistry.

State officials contacted Los Alamos in March 1996 about doing a study. Laboratory researchers, with the permission of the property owners, conducted additional tests on Nambé water samples collected by the state. They identified several wells with levels of naturally occurring uranium greater than 1,000 parts-per-billion to use in the study.

In May, Laboratory researcher Phil Fresquez, graduate research assistant Audrey Hayes and undergraduate student David Honaberger planted lettuce, tomatoes, radishes and squash in pots in a 10-foot-by-25-foot fenced plot in Nambé. The soil in which the plants are grown is an amalgamation of soil from the Nambé area. Soil from several areas in the region was homogenized and placed in the pots to reduce variables that could be associated with different soils.

Undergraduate student David Honaberger places the washed vegetables in paper bags. The bags of vegetables were then sealed, labeled, placed in an oven to dry (bottom photo) and ground into powder for analysis.

The researchers irrigated the vegetables with water from different wells containing 1 part-per-billion, 153 parts-per-billion, 517 parts-per-billion and 1,153-parts-per-billion of naturally occurring uranium.

Throughout the growing season, the team harvested and thoroughly washed the plants to remove all soil particles. Harvested plants were dried and then ground into a powder, which was sent to New Mexico State University for analysis. Preliminary results are expected in December.

The analytical results will show how much uranium each plant assimilated through its roots and incorporated into the vegetables. Researchers, using standard risk-assessment models, will be able to use this information to calculate toxicological and radiological health risks associated with eating the vegetables and drinking the water.

"The Laboratory wants to study and understand uranium cycling in the food chain in Northern New Mexico," said Fresquez. "This is not only helping the community, it's helping Los Alamos gain knowledge in this field. And this is going to help increase overall knowledge of uranium uptake and transport, and subsequently, the human health risk."

CONTACT: PHILIP FRESQUEZ
ECOLOGY
(505) 667-0815 • E-MAIL: fresquezp@lanl.gov

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LOS ALAMOS-DEVELOPED EDUCATIONAL TOOL UNVEILED

DOCUMENTARY, TEACHING MATERIALS ON HANTAVIRUS TRANSLATED INTO NAVAJO

Members of Los Alamos' Science Education Program joined officials and educators from the Navajo Nation, NASA and the U.S. Air Force to unveil a new Navajo language-based educational resource developed at Los Alamos. The educational material, which includes a teacher's guide, a multimedia interactive program and an hour-long video about the hantavirus outbreak in the Four Corners area in 1993, is being piloted this fall in the Navajo Nation schools.

"This represents a year-long project that was done in collaboration with teachers and other educators from the Navajo community," said Los Alamos' Dolores Jacobs. "Los Alamos will now have contributed to the Navajo community an effective science education curriculum developed for Navajos."

Los Alamos became involved in the translation project three years ago when NASA wanted to do a project that would benefit Native Americans around the country, Jacobs said. NASA's Life Sciences Division contacted Argonne National Laboratory in Chicago, which in turn contacted the Laboratory; NASA gave the Department of Energy $60,000 for the project.

Los Alamos' choice of the Navajo language for the translation project was based on several factors, said Jacobs. Among them were that Navajo is a written and spoken language — it has an alphabet — and the

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Navajo Nation is focusing on revitalizing its native language. Another reason was that while the Laboratory and the Department of Energy have Memos of Understanding with local pueblos for specific services, no such formalized agreement existed with the Navajo Nation, and this was an opportunity to strengthen the Laboratory's relationship with the Navajo education community.

Laboratory employees used a Public Broadcasting Service "New Explorers" video documentary on hantavirus called "On the Trail of a Killer Virus" and an Argonne-produced teacher's guide in English on the illness called "On the Trail," which closely follows the video documentary, and worked with Navajo educators to translate the materials into Navajo. The Laboratory and NASA also hope to turn information based on Los Alamos hantavirus illness research into additional classroom material.

"The Laboratory is still very interested in this research and so it makes sense to do this type of translation project," Jacobs said. "Not only is it a literacy project whereby students actually learn about the topic and the medical and scientific aspects of the hantavirus, but they'll also enhance their capability of speaking their native language. The loss of this capability is a grave concern to Native Americans."

The 1993 hantavirus outbreak in the Four Corners area was not unique. Various strains of the disease occur throughout the world, with about 20,000 cases reported yearly in Asia. Some 2,500 U.S. soldiers fighting in the Korean War caught the virus and 121 died from it.

The virus is spread by contact with rodent urine and feces and causes flu-like symptoms and sometimes fatal lung or kidney disease. It is normally found only in rodents, especially deer mice. People can contract hantavirus illness when they breathe in the virus from the urine, saliva or droppings of infected rodents. It may also be possible to catch the virus by eating or drinking food or water soiled by rodents.

The collaborative effort has other benefits besides in the classroom, Jacobs added. She said the project exposes Navajo Nation students to potential careers in the health field, citing continued interest in the hantavirus disease by the National Institutes of Health, local medical centers, the federal Centers for Disease Control and the Laboratory.

CONTACT: DOLORES JACOBS
SCIENCE AND TECHNOLOGY BASE PROGRAMS
(505) 667-1919 • E-MAIL: dbj@lanl.gov

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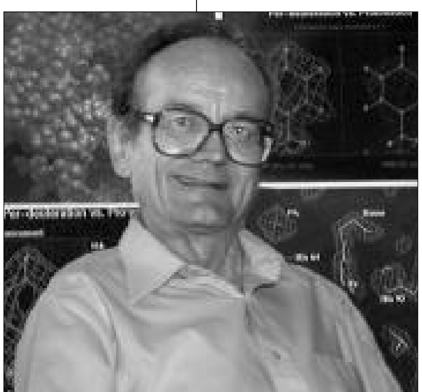
NEW RESEARCH FACILITY

ADDITION TO LOS ALAMOS ACCELERATOR WILL MAP STRUCTURES OF BIOLOGICAL MOLECULES IN 3-D

The Department of Energy is funding the construction and operation of a new research facility devoted to structural biology at the Los Alamos Neutron Science Center. The protein crystallography station at LANSCE will help scientists make three-dimensional maps of the molecular structure of proteins and membranes, including enzymes that trigger the chemical reactions of life.



Benno Schoenborn, primary investigator for Los Alamos' new protein crystallography station.

The station will focus bursts of neutrons — uncharged subatomic particles — through samples of proteins and membranes. As some neutrons are scattered in telltale patterns by the elements in a sample, three-dimensional "maps" of the sample's atomic structure will appear.

Neutron scattering is an essential tool for probing fundamental biological structures and is complementary to X-ray diffraction and other microscopic probes. But unlike X-rays, neutrons "see" heavy and light elements equally well, and detect atomic vibrations as well as average atomic positions. Scientists are most excited by the technology's capability to map light elements, especially hydrogen. The location of hydrogen in the structure reveals where water is bound in a protein. The way that water chemically or physically combines with a biological molecule influences the protein's function.

"One of the most outstanding problems in structural biology is the role of water in proteins," said Benno Schoenborn, primary investigator for Los Alamos' protein crystallography station. "X-ray studies cannot reveal hydrogen, but neutron diffraction can."

Until recently, neutron protein crystallography in the United States was primarily conducted using neutrons from the research reactor at Brookhaven National Laboratory in New York. That reactor recently was shut down and DOE has announced that a decision on whether to restart the reactor will be made by January.

As an alternative to reactor-based sources, scientists are developing techniques that employ neutrons from a linear accelerator, a system that produces far less radioactive waste and can be turned off at a moment's notice. Neutrons are generated at an accelerator by driving a highly energetic beam of particles, typically protons, into a target of heavy atoms, such as tungsten.

The protons knock neutrons loose from the nuclei of the target, a process called spallation, creating a pulse of neutrons that can be directed into numerous experimental stations at the end of the beam line. "The future of structural biology is in spallation sources," said Schoenborn.

To neutrons, solid matter is not very dense, because the size of a nucleus is typically 100,000 times smaller than the distance between the nuclei. And neutrons have no electrical charge; they react with atoms via nuclear rather than electrical forces. So only a very small fraction of the spallation neutrons are scattered or absorbed in the sample under investigation. But the neutrons that are scattered can be measured with high resolution detectors and computerized data acquisition and analysis systems.

One difficulty in the field has been the long time required — often three months or longer — to conduct a neutron crystallography experiment in structural biology. With the new machine at Los Alamos, experiments will take weeks instead of months. Quick turnaround will greatly increase the number of experiments that can be done and consequently attract more researchers involved in the field.

The protein crystallography station will be available to academic and industry researchers about 80 percent of the time, with the rest of the time devoted to maintenance, calibration and Los Alamos research. Experiment time will be allocated based on scientific peer review. Users of the station also will have office space available in the new wing of the Laboratory's health research laboratory.

X-ray based crystallography of biological molecules has been available at many DOE-supported user facilities, including Argonne National Laboratory, Stanford Synchrotron Radiation Laboratory and the National Synchrotron Light Source at Brookhaven National Laboratory in New York.

The DOE Office of Biology and Environmental Research will fund the fabrication of the Los Alamos station. Design and engineering for the project began in September.

CONTACT: BENNO SCHOENBORN
LIFE SCIENCES DIVISION
(505) 665-2033 • E-MAIL: schoenborn@lanl.gov

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BRIEFLY ...

LOS ALAMOS DIRECTOR SIG HECKER SIGNED A COOPERATIVE AGREEMENT ON OCT. 1 BETWEEN THE LABORATORY AND THE NORTHERN RIO GRANDE INTERGOVERNMENTAL COUNCIL. The agreement pledges that Los Alamos and the council will work together on issues of common interest and is intended to improve relations between Los Alamos and local governments. A regional association of local government organizations, the council includes officials from Rio Arriba, Santa Fe, Taos and Los Alamos counties. Taos Mayor Fred Peralta signed the agreement on behalf of the council during a ceremony at the Plaza de Española Mission Museum.

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DATELINE LOS ALAMOS

A Monthly Publication of the Public Affairs Office of Los Alamos National Laboratory

Nonprofit Organization
U.S. Postage Paid
Albuquerque, NM
Permit No. 532

LALP-97-1-11

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