DATELINE LOS ALAMOS

U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

SCIENTISTS PEER DEEPER INTO THE MYSTERIES OF THE UNIVERSE

NEW IMAGING APPROACH CAN DETECT PHYSICAL DETERIORATION IN NUCLEAR WEAPONS BEFORE VISIBLE SIGNS APPEAR

The end of the 20th century has seen the introduction and refinement of some of the most powerful scientific imaging technologies ever known. Microscopic and spectroscopic technologies like infrared and Raman imaging, X-ray fluorescence and scanning electron microscopy have allowed scientists to peer deeper into the chemical mysteries of the universe than ever before. Until recently, however, these were all disparate analytical technologies with a rather diverse group of uses and users. In the future, this may not be the case.

➔ A sample and a microscopic view of its structure using a new technique called Mesoscale Chemical Imaging.

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Los Alamos scientists Jon Schoonover and George Havrilla have developed an imaging approach called Mesoscale Chemical Imaging that successfully integrates micro X-ray fluorescence spectroscopy and scanning electron microscopy, both elemental analysis technologies, with infrared and Raman spectroscopy — molecular analysis technologies.

For years researchers have used these four analytical techniques separately to provide insights into nature's elemental and molecular nature.

The new imaging technique is taking the two researchers' work in some interesting and unexpected directions. Most noteworthy is the technology's potential for supporting the Laboratory's role in the Department of Energy's Science-Based Stockpile Stewardship Program.

An analysis using Mesoscale Chemical Imaging can detect the slightest physical deterioration of certain metals, polymers and other materials used in nuclear weapons or in stored nuclear materials long before any visible signs of deterioration might appear. Recently the researchers used the approach to help resolve a Significant Finding Investigation associated with weapons in the nuclear stockpile.

Using micro X-ray fluorescence spectroscopy, researchers expose a sample to an X-ray beam and capture the resulting fluorescence, or X-ray

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George Havrilla (left) and Jon Schoonover set up the Raman imaging microscope to analyze a sample.

emission, in the form of spectral lines. The intensity of these spectral lines reveals the concentration of an element in the sample. The principle advantage of MXRF, in addition to the fact that it is a non-destructive analysis method, is that there is little or no sample preparation needed.

In infrared microscopy, a small beam of infrared radiation is directed at a material and the transmitted light is processed to produce a spectrum. Researchers use the resulting spectrum to measure the vibrations, or energies, of specific functional groups of molecules in specific areas on the sample. A matrix of spectra can then provide a "fingerprint" of molecular species present in the sample along with their spatial distribution.

Raman spectroscopy on the microscopic level takes advantage of a phenomenon known as Raman scattering, where light changes in phase and frequency as it interacts with a material, to determine the molecular structure of different components within a sample.

The Mesoscale Chemical Imaging approach combines two, or more, conventional imaging technologies to provide detailed information on the identity and spatial distribution of a sample's components. Each technology provides its own unique and important elemental or spatial information to the analysis.

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This novel approach to integrating different imaging technologies also is finding uses in such diverse technical applications as measuring the distribution of various elements in alloys or identifying problematic inorganic compounds in the storage of nuclear waste materials.

While the technology currently is only being used for the analysis of inorganic materials, the researchers also are studying applications for organic, biological and environmental systems as a part of a core technology developed in response to the Defense Nuclear Facilities Safety Board's 94-1 Recommendation.

Since the Mesoscale Chemical Imaging technology currently exists as several discrete analytical instruments, future development work in this area will involve integrating the separate imaging technologies into one instrument, as well as refining current imaging approaches.

To this end, Havrilla and Schoonover are working closely with Patrick Treado from ChemIcon Inc. in Pittsburgh. Funding is coming from a Cooperative Research and Development Agreement through Los Alamos' Civilian and Industrial Technology Program Office.

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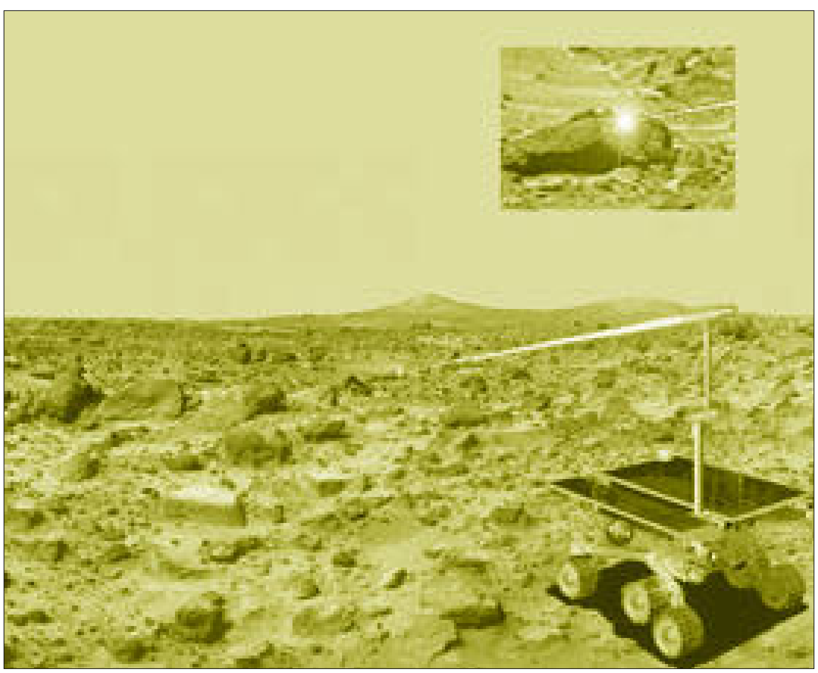
LASER PROBES PLANETARY SURFACES

PROTOTYPE INSTRUMENT CAN ANALYZE SAMPLES FROM A DISTANCE

Zap! With a spark from a small laser, researchers can analyze soils and rocks from more than 50 feet away. Los Alamos is developing a prototype instrument for planetary exploration that combines a laser the size of a small flashlight, optics and a spectral analyzer into a compact, low-power package.

The laser can be fired every five seconds and within three minutes sends enough data for an accurate measurement. "The scientific returns for planetary exploration increase dramatically when you can conduct such rapid analyses," said David Cremers, Los Alamos principal investigator on the NASA-funded development effort.

Cremers' laser-induced breakdown spectroscopy technology — or LIBS — has been under development at Los Alamos for 18 years, but up to now has been applied to Earth-based purposes. It has been field tested



An artist's conception of a Martian rover equipped with LIBS analyzing a sample. The laser beam is projected from the mast on the rover and the light is collected back along the same path.

for elemental analysis of rocks, soils, gases and airborne aerosol particles. A private company is developing a field-portable LIBS unit for mining and environmental monitoring applications.

LIBS works by firing a brief, intense laser pulse at the surface of an object. The laser heats and vaporizes a small spot — about as wide as a pencil eraser — on the surface. A small telescope co-mounted with the laser captures light from the glowing vapor and feeds it into the spectral analyzer. Elements create unique spectral signatures that signal their presence; with correct calibration, the intensity of the emissions reveals the relative abundance of the elements.

Cremers and his colleagues have shown in lab tests they can get accurate measurements for a variety of key elements from a sample some 60 feet away, and expect the technique would be even more effective in the thin atmosphere of Mars.

"We didn't know going in how well we'd do with such a small laser," Cremers said. "This time nature was nice to us."

The LIBS technique could be especially useful for planetary exploration because of its ability to conduct analyses at a distance. A rover would not have to cross hazardous terrain to sample important rocks or strata. LIBS could reach up to cliff faces or across craters or peek inside cracks and crevices.

The laser also can blast through the weathered veneer on a rock and reveal the true composition hidden beneath.

The product of the three-year, $1.1 million development effort will be a prototype LIBS instrument for field tests in the Mojave Desert. A flight model of the instrument would require additional development work to reduce its size and power requirements and increase its ruggedness.

The U.S. Geological Survey also is participating in the research.

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SAME LASER, DIFFERENT USE

COMPLEMENTARY RESEARCH

USES MASS SPECTROMETER TO STUDY ASTEROIDS

In related work, researchers are combining a laser and a mass spectrometer into an instrument designed for analysis on asteroids or other airless bodies.

Roger Wiens leads a development effort for LIMS, or laser ionization mass spectrometry. In this system, the laser vaporizes material from the surface of an object, and the freed, ionized atoms enter a mass spectrometer, which can provide compositional measurements based on the mass of an ion.

The LIMS and laser-induced breakdown spectroscopy (LIBS) techniques are complementary, and both can use the same laser to vaporize a sample for analysis.

Los Alamos has a history of advances in lightweight, low-power mass spectrometers and currently has such instruments flying on NASA's Cassini and Deep Space 1 instruments.

"In fact, our development work will make use of spares from the space plasma mass spectrometers on Cassini and Deep Space 1," said Wiens.

Stephen Ritzau and other members of the Los Alamos team have installed rock and soil targets and a mass spectrometer in a vacuum system and started gathering initial data. A more complicated spectrometer will be used starting in a few months.

The team will use the test results to optimize the overall system for effective collection of ions kicked free by the laser and high-resolution mass measurements. The team also will study tradeoffs between the distance at which the instrument can make reliable measurements and overall mass and cost.

"Our intention is to come up with an instrument that eventually could be incorporated into a lander craft for the moon, an asteroid or an outer solar system body," Wiens said.

NASA funding for LIMS totals $360,000 over two years.

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KREEP SHOW

SPECTACULAR NEW LUNAR PROSPECTOR DATA REVEAL THORIUM HOT SPOTS

NASA's Lunar Prospector mission has drawn great acclaim for its measurements of water ice at the moon's poles, but equally important has been its steady effort mapping geologic deposits around the surface of the cratered globe. New data coming back from the mission are spectacular, according to researchers, and have resulted in elemental distribution maps with more than twice the resolution of previous Lunar Prospector results.

➔ Researcher David Lawrence looks at a computer model of the thorium hot spots that trace the outer rim of Mare Imbrium on the lunar surface.

The data show thorium hot spots on the lunar surface, which are associated with certain craters. The data are giving scientists the first estimates of the abundance of thorium on the lunar surface, which is invaluable when modeling lunar evolution.

Thorium is an important element for study because it is a constituent of KREEP, the acronym for potassium (symbol "K"), rare Earth elements and phosphorous. KREEP is the last material to solidify from a geologic melt. The moon once was hot and molten and as it cooled, minerals crystallized and sank to form the core, if they were heavy, or floated upward to form the crust, if they were light. The elements in KREEP do not readily incorporate into minerals and so the mixture remains molten the longest.

These elements, then, are signatures of the original material under the moon's crust, and their presence on the surface indicates some process — volcanic events or impacts strong enough to punch through the crust — must have dredged them up from the interior.

Thorium emits gamma rays — a high-energy form of light — of a distinct energy. A Los Alamos team built Lunar Prospector's gamma-ray spectrometer, which counts and measures gamma rays as Lunar Prospector swings around the moon. The information is used by researchers to create maps showing the abundance of thorium in different locations.

"Because thorium is a tracer for KREEP-rich material, these data provide fundamental information regarding the locations and importance of geologic formations that are rich in KREEP-bearing materials," said Los Alamos scientist David Lawrence.

And they show that the moon's evolution was a complicated story.

Thorium emissions neatly trace out the outer rim of Mare Imbrium, one of the distinctive features on the moon's Earthward-facing side. Lawrence said this signal "provides a telltale sign of deposition by ejecta. This indicates that around Mare Imbrium the dredge-up process, at least in part, was related to an impact."

By contrast, the South-Pole Aitkin basin shows much less thorium-rich material although it is the largest known impact crater in the solar system. The impact presumably was large enough to poke through the lunar crust to the moon's mantle material, but it did not encounter as much thorium-rich material.

In addition to the gamma-ray spectrometer, the Los Alamos team built Lunar Prospector's neutron spectrometer and alpha particle spectrometer. Data from the neutron spectrometer point to large quantities of water ice at the moon's poles.

Neutron spectrometer data also is being used to map the rare earth elements gadolinium and samarium, which like thorium, are constituents of KREEP. The gadolinium and samarium maps confirm that KREEP is concentrated in hot spots in and around Imbrium basin.

The alpha particle data could show signals of outgassing and geologic activity, but analysis has not yet yielded definitive evidence of such events.

Alan Binder of the Lunar Research Institute in Gilroy, Calif., proposed and leads the Lunar Prospector mission. NASA's Ames Research Center in Moffett Field, Calif., controls mission operations.

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PEOPLE IN THE NEWS . . .

STAFF MEMBER GENE TAYLOR WAS RECENTLY HONORED AT THE WHITE HOUSE IN A CEREMONY AT WHICH HE RECEIVED THE KILLIAN AWARD FROM THE PRESIDENT'S FOREIGN INTELLIGENCE ADVISORY COMMITTEE. Taylor was part of a joint Defense Intelligence Agency-National Imagery and Mapping Agency team selected for the honor. Gen. Henry Shelton, chairman of the Joint Chiefs of Staff, nominated the team for the award.

The Killian award, named after James Killian, the first chairman of the advisory committee, is regarded as the Oscar of the intelligence community.

Criteria for the award include "demonstrating an unwavering commitment to excellence and achievement, perseverance in the face of great challenge, and an extraordinary dedication to service in the interest of national security," according to a congratulatory letter sent to Taylor by Warren Rudman, current committee chairman.

"The commendation recognizes especially outstanding performance by U.S. intelligence professional in areas particularly critical to the national security interests of the United States," Rudman wrote.

FIVE LOS ALAMOS STAFF MEMBERS HAVE BEEN ELECTED 1998 FELLOWS OF THE AMERICAN PHYSICAL SOCIETY. APS fellows are recognized for original research, for significant and innovative contributions in the application of physics to science and technology, or for significant contributions to the teaching of physics. Each year, no more than one-half of 1 percent of the current members are recognized by their peers for election as fellows.

Joseph Carlson, a theoretical physicist in Medium Energy Physics, was recognized for developing novel algorithms and applying them to calculations of the structure and response of nuclei of lighter elements such as helium and lithium. The computationally intensive work has applications in electron scattering and other low-energy reactions including those that produce solar neutrinos.

Chris Hammel, a condensed matter physicist in Condensed Matter and Thermal Physics, was cited by the APS for his use of nuclear magnetic resonance to study properties of high-temperature superconducting materials at the atomic level. The research revealed the importance of magnetism in materials that become superconducting.

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The APS recognized Patrick McGaughey of Subatomic Physics for his contributions to a number of experiments involving subatomic particles. McGaughey was cited for organizing an experiment at Fermilab to measure anti-quarks in atomic nuclei, for helping develop the conceptual design of a particle detector at Brookhaven National Laboratory's Relativistic Heavy Ion Collider and for contributing to the understanding of particles containing charm quarks.

Robert Robinson of the Manuel Lujan Jr. Neutron Scattering Center was recognized for pioneering the use of pulsed spallation neutron sources to determine the complex magnetic structure of materials such as uranium intermetallic compounds. Robinson also is principal investigator for a project to build a unique high-field, high-repetition-rate pulsed magnet at LANSCE in conjunction with the National High Magnetic Field Laboratory.

Harvey A. Rose, a theoretical physicist in Complex Systems, was cited by the society for his seminal contributions to linear and nonlinear theory of instabilities that occur when coherent laser beams interact with plasma. The instabilities degrade the coherence of laser beams, adversely affecting the ability to control them, and Rose's work is aimed at helping to control these effects.

SUE GOFF HAS BEEN RE-ELECTED TO THE BOARD OF DIRECTORS OF THE GEOTHERMAL RESOURCES COUNCIL AND ELECTED TO THE BOARD OF DIRECTORS OF THE INTERNATIONAL GEOTHERMAL ASSOCIATION. Both organizations advocate geothermal energy research, exploration and development; offer educational opportunities for the worldwide geothermal community; and provide a forum for interaction on geothermal development issues.

Goff is a senior adviser in Los Alamos' Civilian and Industrial Technology Programs Office. She now will serve her second two-year term for the GRC as she becomes its first vice president. Goff's term on the IGA's board is for three years; she also was selected chair of the association's By-laws Committee.

Goff's areas of expertise include mineral and geothermal exploration, continental scientific drilling, environmental restoration, energy program development and international projects.

She also is the Department of Energy's representative on the environmental impacts of geothermal development for the International Energy Association. Her work has taken her to Honduras, Guatemala, Russia, China and other places worldwide on behalf of Los Alamos and other institutions.

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BRIEFLY ...

FIRST SHIPMENT SENT TO WIPP. After 20 years of controversy, litigation and debate, and a 20-hour delay due to fog, the first shipment of transuranic waste was made to the Waste Isolation Pilot Plant. Around 8 p.m. on Thursday, March 25, a flatbed truck loaded with three canisters (called TRUPACT-IIs) left Los Alamos for the nine-hour trip to WIPP, located near Carlsbad, N.M. Once at WIPP, the “payload” containers, which are filled with contaminated gloves, clothing, tools and equipment, will be placed in ancient salt beds 2,150 feet under ground. The Department of Energy developed WIPP to permanently house 850,000 55-gallon drums of radioactive debris. Over the next 30 years, WIPP is expected to receive 37,000 shipments from DOE nuclear weapons facilities around the country.

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