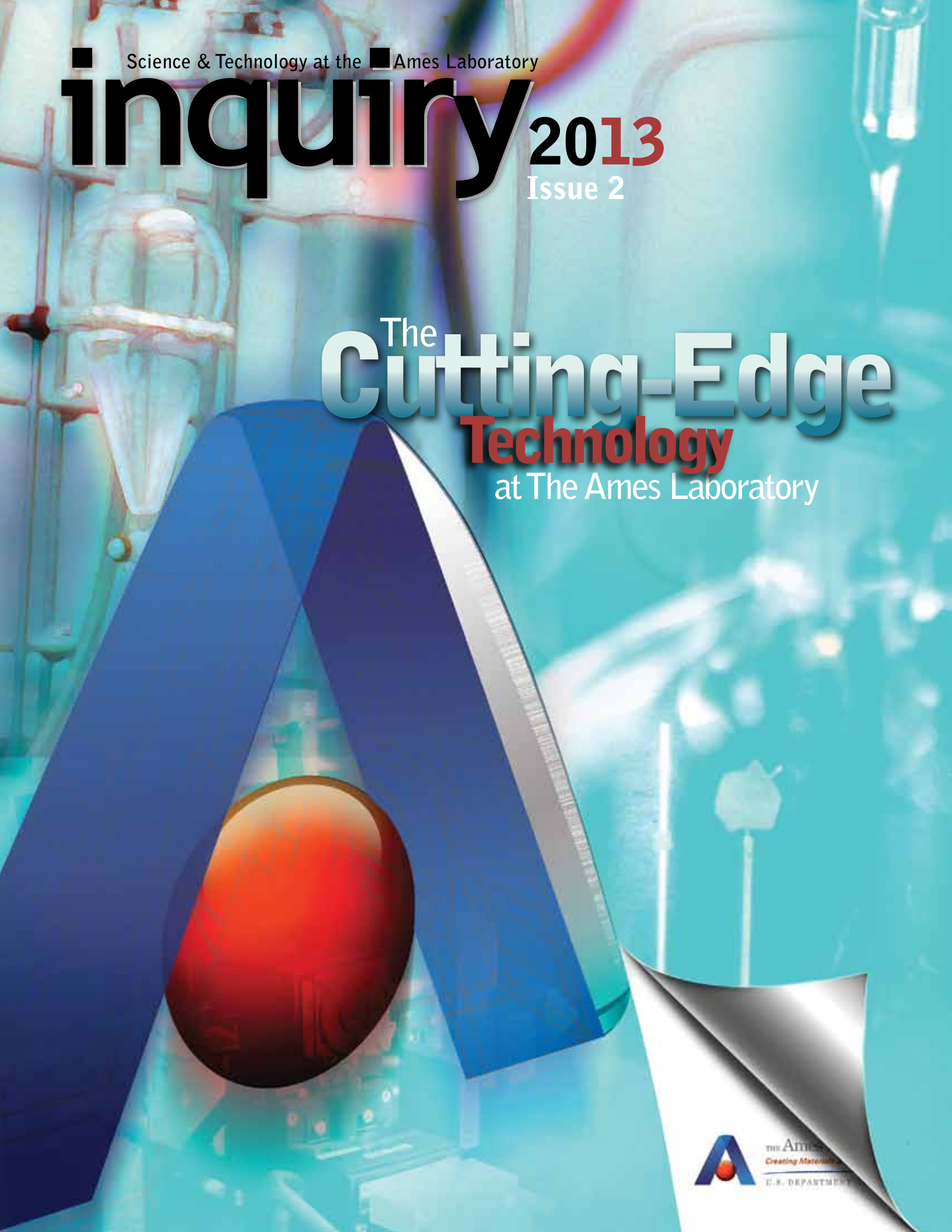
Science & Technology at the Ames Laboratory

inquiry

2013
Issue 2

The Cutting-Edge Technology at The Ames Laboratory



inquiry

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The Ames Laboratory is a U.S. Department of Energy national laboratory seeking solutions to energy-related problems through the exploration of chemical, engineering, materials and mathematical sciences, and physics. Established in the 1940s with the successful development of the most efficient process to produce high-purity uranium metal for atomic energy, Ames Lab now pursues much broader priorities than the materials research that has given the Lab international credibility. Responding to issues of national concern, Ames Laboratory scientists are actively involved in innovative research, science education programs, the development of applied technologies and the quick transfer of such technologies to industry. Uniquely integrated within a university environment, the Lab stimulates creative thought and encourages scientific discovery, providing solutions to complex problems and educating and training tomorrow's scientific talent.

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U.S. DEPARTMENT OF ENERGY | Office of Science

From the Director

Materials Characterization

Materials characterization has always been a hallmark of the Ames Laboratory. Determining a material's specific properties – its crystal structure, electrical and magnetic properties, how it moves through various phases – gives scientists a better understanding of why it performs or behaves in a certain way and allows them to predict how other materials may behave in similar or different manners.

Obviously, the better we're able to measure those characteristics, the more accurate and predictive our theoretical descriptions can be. And while Ames Lab scientists have excelled at characterizing new materials and developing new techniques, the Lab is on the verge of taking a giant step forward in its characterization capabilities.

One cutting-edge advancement will be the construction of the new Sensitive Instrument Facility. Scheduled to be built beginning the spring of 2014, the SIF will be a state-of-the-art building designed specifically to provide an isolated environment for atomic-scale electron microscopes so sensitive that the breathing or heartbeat of the operator can distort the image of the specimen under study. You can read about this unique facility on page 8 of this issue.

Ruslan Prozorov is spearheading an effort to enhance our capabilities for studying the magnetic properties of nanoscale materials. As you might imagine, as the sample size diminishes, greater sensitivity is required of the equipment used to characterize its properties. Prozorov is developing a new piece of equipment that utilizes a defect in the crystal structure of diamond to create a highly sensitive probe for measuring the magnetic field of nano-particles down to the level of a single electron. Find out more about this work on page 14.

Similarly, Marek Pruski is leading an effort to enhance the Lab's nuclear magnetic resonance (NMR) with the addition of a dynamic nuclear polarization-NMR spectrometer. DNP-NMR uses microwaves to polarize electrons, and then transfers that polarization from the electrons to the nuclei of the sample being analyzed, an enhancement of anywhere from eight to 30 times in signal sensitivity. Results that used to take a week to obtain will now take hours or minutes. Turn to page 16 to find out more about this effort.

The Lab has also excelled at producing some of the best single crystals, in part because the Materials Preparation Center provides the best raw materials. But the recent acquisition of a new crystal-growth furnace now allows us to grow crystals at elevated pressure, letting us incorporate materials that were too volatile for traditional methods. Take a closer look on page 12.

The Sensitive Instrument Facility will be a state-of-the-art building designed specifically to provide an isolated environment for atomic-scale electron microscopes so sensitive that the breathing or heartbeat of the operator can distort the image of the specimen under study.

Finally, we hosted the ribbon-cutting ceremony for the Critical Materials Institute in September. As one of DOE's Energy Innovation Hubs, the CMI marks a major effort to reduce or eliminate material criticality for our nation. By establishing a team comprised of top researchers from national labs, research universities and industry, the CMI hopes to focus the combined resources to quickly and efficiently solve the problem of potential shortages of the materials vital to high-tech, clean-energy technologies. We hope that our efforts will soon bear fruit as we strive to quickly move solutions from the lab bench to the marketplace.

Tom Lograsso, Interim Director

Awards

Canfield receives APS David Adler Lectureship Award

Paul Canfield, Ames Laboratory scientist, has been selected by the American Physical Society for the 2014 David Adler Lectureship Award in the Field of Materials Physics.

The award recognizes outstanding materials physicists who have made noted contributions through their research, review articles and lecturing.

Paul Canfield

2014 Acta Materialia Materials and Society Award to Gschneidner

Karl A. Gschneidner Jr., senior metallurgist at the Ames Laboratory, has been named the winner of the 2014 Acta Materialia Materials and Society Award. The award honors scientists who have made a major positive impact on society through materials science.

Karl A. Gschneidner Jr.

Ames Lab scientists receive Iowa State University honors

Ames Laboratory staff received the following awards during Iowa State University's fall convocation.

Award for Mid-Career Achievement in Research

The award recognizes a faculty member who has demonstrated exemplary research performance or scholarship accomplishments as documented by peers and experts in the field. A $1,500 award is granted.

Ruslan Prozorov

Award for Outstanding Achievement in Research

The award recognizes a faculty member who has a national or international reputation for contributions in research, and who has influenced the research activities of students. A $1,500 award is granted.

Mei Hong

Louis Thompson Distinguished Undergraduate Teaching Award

Established by the late Louis Thompson, emeritus associate dean of Agriculture and Life Sciences, the award recognizes an outstanding teacher who is dedicated to helping undergraduate students. A $1,500 award is granted.

Alan Russell

Pat Thiel

Professional and Scientific Research Award

The award recognizes excellence in research in a professional and scientific staff member who has been at Iowa State for at least five years. A $1,500 award is granted.

Marek Pruski

A celebratory handshake after Fumio Ueda (left), executive director of NEDO, and Thomas Lograsso (right), interim director of the Ames Laboratory, signed a memorandum of understanding to collaborate on rare-earth scientific efforts and to exchange information and scientists.

East meets Midwest

Ames Lab to collaborate with Japanese energy R&D organization

Scan to watch a video of the signing ceremony.

BY BREEHAN GERLEMAN LUCCHESI

Ames Laboratory and New Energy and Industrial Technology Development Organization (NEDO), a Japanese energy and industrial technology R&D organization, signed a memorandum of understanding on Sept. 10 to promote cooperation between the two agencies in rare-earth and critical-materials research.

The memorandum establishes a framework for Ames Laboratory and NEDO to collaborate on rare-earth scientific efforts and to exchange information and scientists.

"I'm very excited about the memorandum of understanding. This MOU will provide the foundation for the Ames Laboratory and NEDO to explore common interests in and share information on rare-earth research and other critical materials. The MOU will help both organizations with the global perspective on these materials," says Deb Covey, Ames Laboratory's director of technology transfer and commercialization.

Ames Laboratory and NEDO signed the MOU as part of inaugural events for the Critical Materials Institute, which is led by the Ames Laboratory. The NEDO delegation members were special guests at the CMI opening ceremony and attended the CMI overview presentations.

"I'm very happy to have this MOU event because this MOU will pave the way for reinforcement in the field of critical materials, such as rare earths, in the pivotal bilateral relationship between the United States and Japan," says Tohru Nakamura, NEDO's director of electronic, materials technology and nanotechnology department.

David Danielson

Tom Lograsso

Alex King

Steven Leath

Ames Laboratory begins new era in research with Critical Materials Institute

BY LAURA MILLSAPS

It was a past-meets-future moment when Karl "Mr. Rare Earth" Gschneidner Jr. cut the ribbon at opening ceremonies for the U.S. Department of Energy's Critical Materials Institute in September.

Gschneidner, a rare-earths materials expert and scientist at the Ames Laboratory since 1952, was the natural choice to grace the Critical Materials Institute's official launch.

"The Ames Laboratory has been laying the groundwork for this moment ever since the Lab first opened," said CMI director Alex King. "It seemed particularly appropriate for Karl to cut the ribbon, since he built so much of the foundation that made this possible."

It is that research heritage that makes the Ames Laboratory such a good fit with the mission of the new institute, said interim director Tom Lograsso during speeches made that day.

"Drawing from our historical strength in rare-earth chemistry, metallurgical expertise, and analytical capabilities, the Critical Materials Institute will carry on the research tradition that has been the hallmark of the Ames Laboratory," he said.

The opening event also included remarks from King, Iowa State University President Steven Leath, and David Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy.

With the Critical Materials Institute, its fifth Energy Innovation Hub, the DOE launched a concentrated effort to develop solutions to domestic shortages of rare-earth metals and other materials vital to U.S. energy security. These materials are essential in many modern clean-energy technologies – such as wind turbines, solar panels, electric vehicles, and energy-efficient lighting.

Ames Laboratory senior metallurgist Karl Gschneidner Jr. receives applause after cutting the ribbon to mark the opening of the Critical Materials Institute.

"A robust and innovative clean-energy sector creates new jobs, helps strengthen our economy, and ensures a cleaner and safer planet for our children..."

"A robust and innovative clean-energy sector creates new jobs, helps strengthen our economy, and ensures a cleaner and safer planet for our children," said Danielson. "The global clean-energy race is not something we can afford to lose. America must continue to make significant investments in clean-energy technologies and the Department of Energy is leaving no stone unturned in our all-of-the-above approach to solving the nation's energy challenges."

Leath said the university and federal partnership has historically led to "incredible advancements" in fuels, new materials, and environmental sustainability, and would continue to do so.

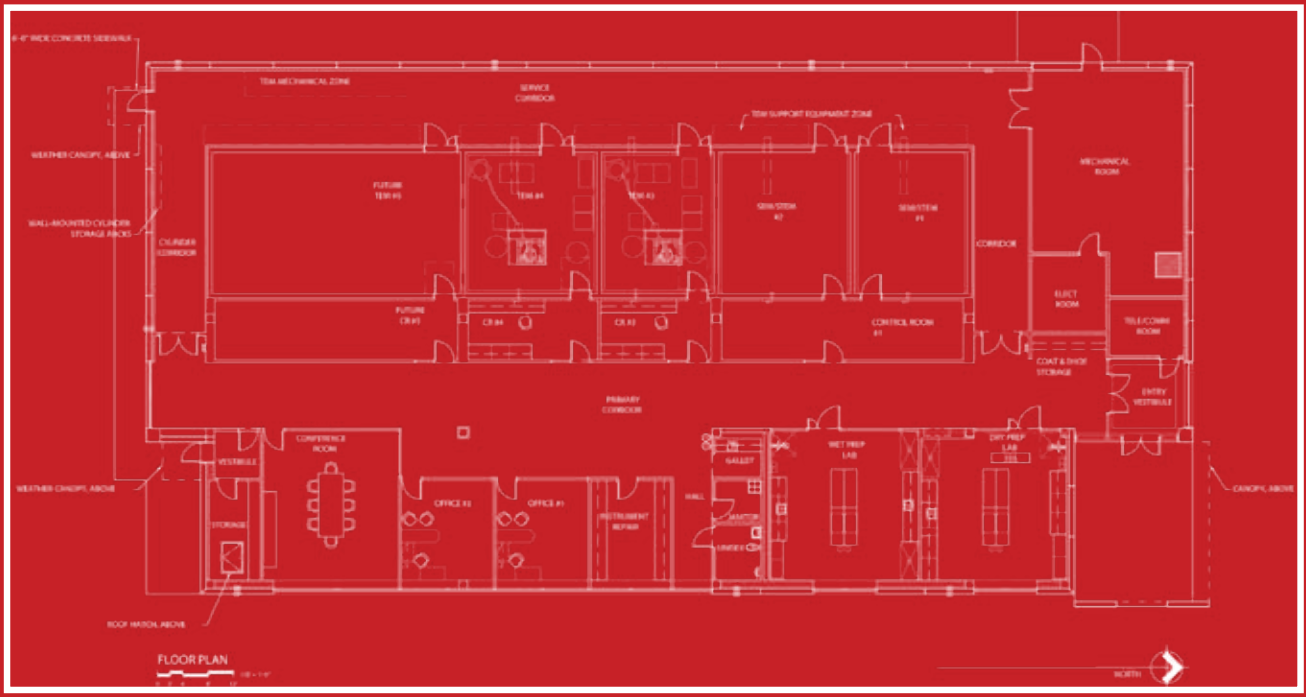
"We're extremely proud that the Ames Laboratory and Iowa State University were selected by the Department of Energy to lead its newest hub here," said Leath. "We're ready to tackle the challenges in ensuring that this nation, its industries and government, have a safe, stable and reliable supply of critical materials."

DOE announced in January that the Ames Laboratory had been selected to lead the Critical Materials Institute with federal funding of up to $120 million over five years. The hub is a collaboration of leading researchers from universities, four DOE national laboratories, and members of industry. Energy Innovation Hubs are major integrated research centers with researchers from many different institutions and technical backgrounds, combining basic and applied research with engineering to accelerate scientific discovery in critical energy areas.

On the same day as the ribbon-cutting, scientists and representatives from partner institutions convened at the new research hub to chart a path for future research.

"We began building this team in 2010," said King. "Opening the Institute is really just a milestone on our way to meeting the real goal—innovative solutions to avoid critical material shortages."

Shhhh!


TEM MECHANICAL ZONE
SERVICE CORRIDOR
TEM SUPPORT EQUIPMENT ZONE
WEATHER CANOPY, ABOVE
WALL-MOUNTED CYLINDER STORAGE RACKS
CYLINDER CORRIDOR
FUTURE TEM #5
TEM #4
TEM #3
SEM/STEM #2
SEM/STEM #1
CORRIDOR
MECHANICAL ROOM
ELECT ROOM
TELE/COMM ROOM
FUTURE CR #5
CR #4
CR #3
CONTROL ROOM #1
COAT & SHOE STORAGE
ENTRY VESTIBULE
PRIMARY CORRIDOR
VESTIBULE
CONFERENCE ROOM
STORAGE
OFFICE #2
OFFICE #1
INSTRUMENT REPAIR
GALLEY
WALL
MASTER
UNISEX
WET PREP LAB
DRY PREP LAB
CANOPY, ABOVE
ROOF HATCH, ABOVE
FLOOR PLAN
NORTH

New facility to shelter delicate instruments from **outside interference**

BY KERRY GIBSON

Plans are being finalized for construction of a new Ames Laboratory research facility that will house current and next-generation sensitive instruments, such as electron and scanning probe microscopes. These instruments allow for detailed description of materials at the atomic level to aid in the discovery and design of novel materials. The nearly $10 million project is being funded through the DOE's Office of Science.

"This state-of-the-art facility will greatly enhance our capability to study and characterize materials at the atomic scale and in turn improve how we are able to support the DOE's mission," says Interim Ames Laboratory Director Tom Lograsso. "The quality and impact of Ames Laboratory scientific research has increased our visibility within the DOE and around the world. We see support for this facility as recognition of that hard work."

Planning for the Sensitive Instrument Facility (SIF) has been in the works for about three years and included an in-depth site survey of five possible locations. The SIF will be built at the Applied Science Complex northwest of the main Iowa State University campus because this site offers "the lowest site vibration levels ever measured" by the consulting firm reviewing the sites. According to Ames Laboratory facilities engineer Steve Carter, the plans should be finalized this fall, which will allow the project to be bid in early winter with construction tentatively slated to begin in April or May 2014. Construction is expected to take 12-15 months to complete.

The 13,300 square-foot facility will be a straight-forward, rectangular-shaped building, but its rather plain exterior

An architect's view of the Sensitive Instrument Facility.

Access corridors along the outside of the building will help minimize the impact of foot traffic on the sensitive instruments that will be housed in isolated instrument bays. The building will have its own wet and dry labs for sample preparation. It will be located in relatively close proximity to the existing Applied Science 2 building (center).

design belies the complexity of creating interior space isolated from vibration or electrical interference. It will have six bays to house sensitive instruments, such as electron microscopes used to reveal atoms and atomic structures. Working at such a small scale, even the slightest disturbance from vibration or electro-magnetic interference will blur the image.

"Isolation is key and we've tried to design it to accommodate the next generation of instruments," Carter says. "We're talking about instruments so sensitive that the operator will work from a separate control room because the beating of their heart or breathing will cause excess vibration. It's a very unique and complex building."

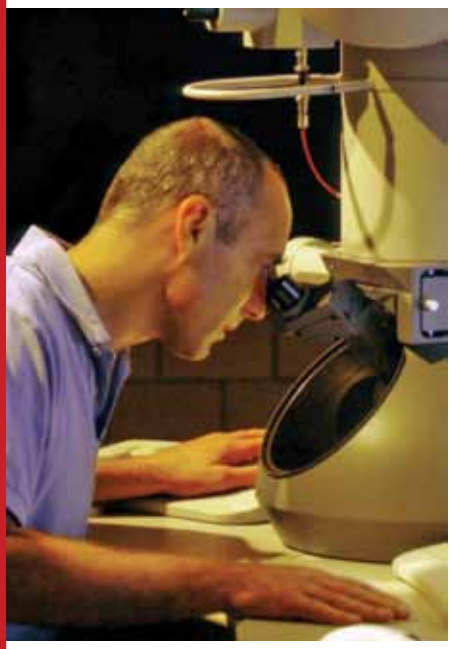
For example, the concrete floors will be approximately two feet thick with vibration dampening layers built in. Similarly, the walls and ceilings will be thick concrete and the instrument bays will be lined with quarter-inch-thick aluminum plate to help create an electro-magnetic barrier. Reinforcing bars in the concrete must be fiberglass, not steel. Likewise, the electrical conduit and even the fasteners used must be non-magnetic (non-ferrous). And the heating and ventilation system must keep the temperature and humidity constant without creating vibration or interference.

"There's been good input from a lot of players, including the Lab's microscopy group and ISU Facilities Planning and Management staff," Carter says. "And (facilities manager) Mark Grootveld deserves a lot of credit for guiding the overall project."

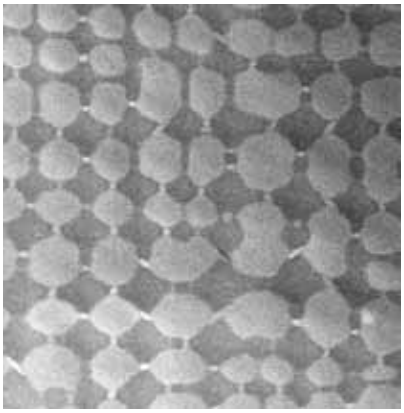
The Sensitive Instrument Facility is the first new research facility to be built by the Ames Laboratory in more than 50 years. The last new construction was the Lab's Technical and Administrative Services Facility, which was completed in 1993.

"We're talking about instruments so sensitive that the operator will work from a separate control room because the beating of their heart or breathing will cause excess vibration. It's a very unique and complex building."

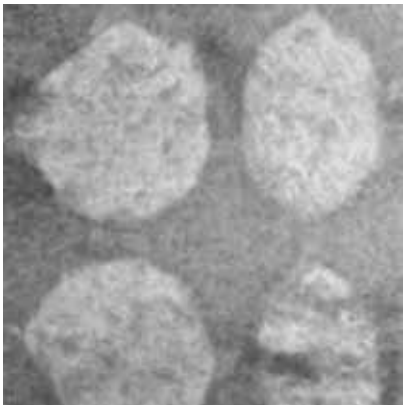
An inside look at the SIF



Matt Kramer



Resolution of the current equipment



Resolution of proposed equipment

The Sensitive Instrument Facility grew from Ames Laboratory's historic role in characterizing materials and the need for ever-more sophisticated and sensitive equipment required to carry out that investigative work.

"We planned this facility in particular to take advantage of the next generation of electron microscopes," says Matt Kramer, interim Materials Science and Engineering division director and leader of the Lab's microscopy group. "The equipment has gotten so much better there's been an increase in resolution of roughly a magnitude factor of 4 … we've gone from about 2 angstroms down to 0.6 angstroms, or less than the diameter of an atom in the past decade."

While the existing Tecnai transmission electron microscope, now located in Willhelm Hall, will be moving to the new facility, the Lab is pulling together a list of new equipment to enhance and expand the Lab's characterization capabilities. The list includes a field emission scanning electron microscope ($555,000); a focused ion beam microscope ($1.2 million) and an aberration-corrected scanning transmission electron microscope ($4.2 million).

"The field emission SEM would replace two existing microscopes," Kramer says, "which are becoming obsolete. The focused ion beam (FIB) microscope will bring a whole new capability sorely needed at the lab. While it can be used as a microscope in its own right, the FIB provides a new tool for sample preparation."

Acquiring the aberration-corrected scanning transmission electron microscope will be a more daunting task.

"Due to its cost, the scanning transmission microscope may take a few years to acquire because DOE requires that capital equipment expenditures over $2 million must be a line item in the federal budget, and as you might imagine, that process is very involved."

For now, Ames Lab researchers have been using new-generation equipment at other DOE user facilities, but the situation is less than ideal. Besides having to travel and schedule limited availability on the equipment, preparation of the samples is also problematic. Some materials being studied degrade rapidly so they need to be prepared on site.

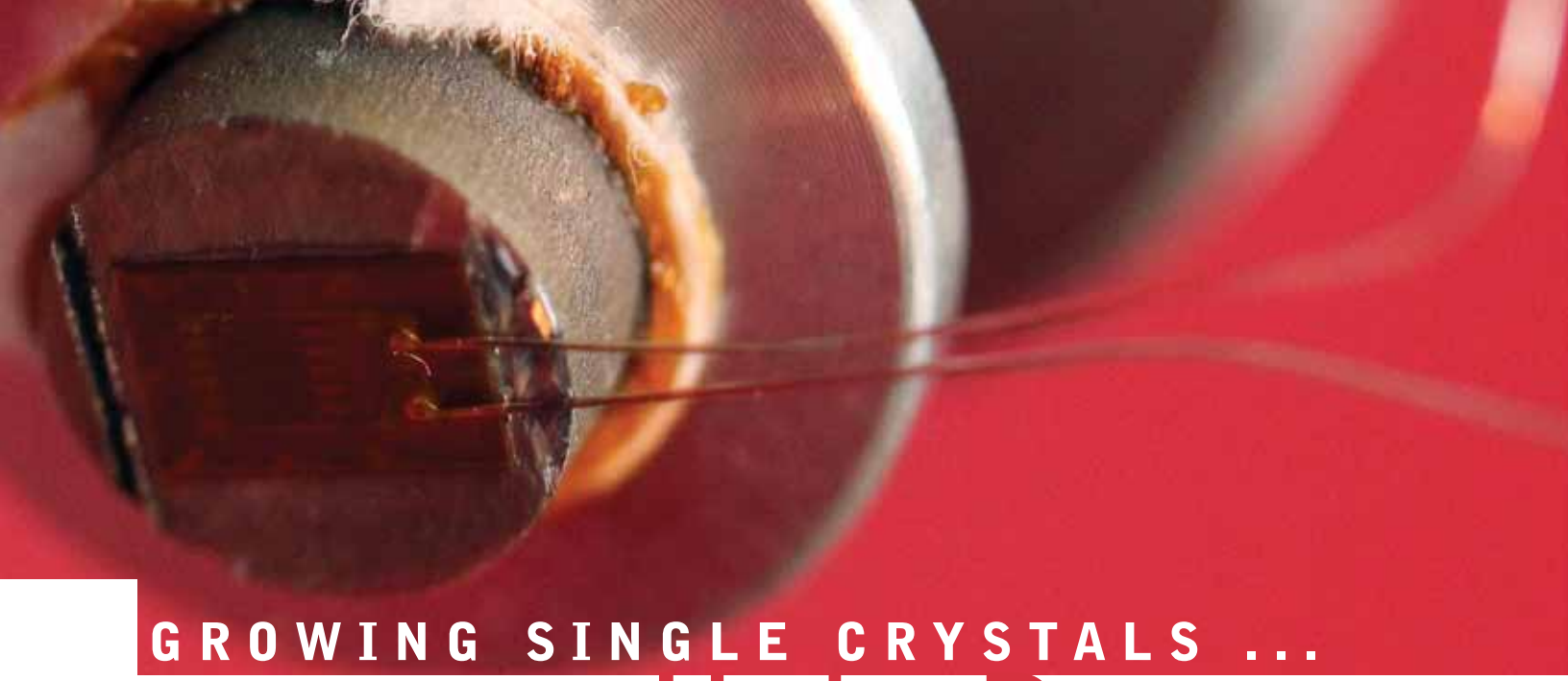
That will be one other advantage of the new facility. It features both dry and wet labs for material preparation. The dry lab will handle the cutting, grinding and polishing of metallographic materials. The wet lab will allow preparation of bio-inspired materials, such as those being studied by Ames Lab scientist Tanya Prozorov.

The location of the facility near the Applied Science Complex about two miles northwest of the ISU campus will present a minor challenge.

"We'll need to get our user base used to traveling," Kramer says, "because unfortunately, none of the sites in closer proximity to our existing buildings were suitable. However, the sophistication of the equipment will allow some activity to be viewed remotely on line, saving physical travel."

While computerized controls will allow many users to get up to speed quickly, it will require extensive training to get the most out of the equipment. That is particularly true for some types of sample preparation.

"There will be a fairly steep learning curve on some aspects," Kramer says, "but it's what we'll need to do in order to get the most out of the equipment. But we're excited about the possibilities and it will be worth the investment."



GROWING SINGLE CRYSTALS ...

Under Pressure

BY KERRY GIBSON

The Materials Preparation Center has long had the reputation for producing some of the highest quality and largest single-crystal materials available. But with the addition of a new piece of equipment, those capabilities have increased dramatically.

A new Cyberstar crystal-growth furnace, installed about a year ago gives Ames Lab's crystal-growth experts Tom Lograsso and Deborah Schlagel capabilities to grow both larger crystals using the Bridgman technique as well as the ability to work with a wider variety of materials, including those too volatile to tackle with the existing equipment.

"We're able to greatly increase the pressure within the furnace so that we can work with and grow crystals from volatile materials," Schlagel says. "The new furnace is capable of 15 bar, which is just over two times more pressure than our previous equipment allowed. The increased pressure will allow us to better suppress the evolution of vapors from volatile alloy components.

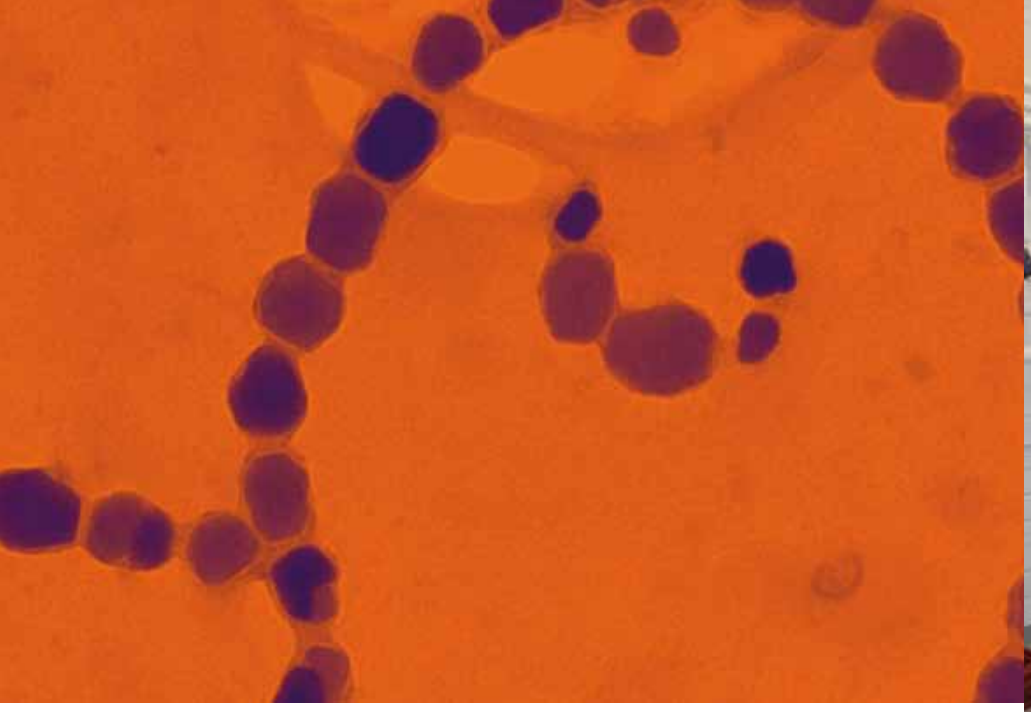
"For example, if we have an alloy of manganese and iron, we worry about manganese volatilizing off, which will change the composition of the remaining liquid, resulting in the first part of the ingot to solidify being richer in manganese than the last part to solidify," Schlagel explains. "Ideally we want the grown crystal to be the same composition as the material we started with and homogenous along its entire length. Also the vapors can make a mess of the chamber walls."

This feature has already paid dividends by allowing Schlagel to produce a sample of galfenol, a magnetostrictive — it changes shape in response to a magnetic field — alloy of iron and gallium, that for the first time also contains zinc. Over the past 15 years, Schlagel has tried unsuccessfully to introduce zinc into the alloy, but the volatile metal flashes off before the crystal forms.

"We've produced a polycrystalline sample for the Naval Surface Warfare Center (NSWC) Carderock division that appears to contain eight atomic percent," Schlagel says. "The composition will vary along the length of the crystal but that's the highest percentage we've been able to achieve so far."

The equipment also allows MPC staff to grow much larger crystals. The furnace, which stands well above normal ceiling height, also extends below floor level. This provides added travel length for the crucible on which the crystals form.

"It gives us the ability to grow samples up to 2.5 times bigger in diameter and 5.25 times longer than our previous capabilities," Schlagel says. That gives researchers more latitude in the types and range of characterization that can



(opposite page) Testing the resistance of a sample. (above) This single crystal of copper, approximately an inch in diameter and 11 inches long, shows off the capabilities of the furnace; (right) Deborah Schlagel with the crystal- growth furnace; (below) The induction coils in the furnace used to heat the furnace during crystal growth.

> "... but the fact that we can develop techniques to work with volatile and reactive materials will help set us apart from other labs."

be done with a specific sample."

The other benefit of the new equipment is that it uses induction heating as opposed to resistance heating in the existing furnace. Think of it in terms of the new style of stove top that uses magnetic field induction coils to heat the pan instead of the glowing red heating elements.

"Induction heating allows us to produce steeper temperature gradients, which are more ideal for crystal growth," Schlagel says, adding that the new furnace's maximum temperature is 2000 C, which is slightly lower than the existing Bridgman equipment.

"The higher temperature gradients allow faster growth which further minimizes evaporation and reactions with crucibles," says Lograsso, who is also the Lab's interim director. "This gives us a capability of working with reactive materials like the rare earths where crucible choices are limited."

The French-made Cyberstar furnace was supported with funds from the Department of Energy's Basic Energy Sciences Materials Sciences and Engineering Division.

"This equipment vastly improves our previous capabilities," Schlagel says, "but the fact that we can develop techniques to work with volatile and reactive materials will help set us apart from other labs."

Using Defects in Diamond to Probe Magnetic Properties at the Nanoscale

BY KERRY GIBSON

Diamonds have the reputation as flawless, sparkling gems. In scientific applications, their hardness is used to test the highest pressure levels. But researchers at the Ames Laboratory plan to exploit defects in diamond's crystal structure, known as nitrogen vacancy centers, to build a device that will give them the ability to visualize magnetic fields produced by magnetic nanostructures.

While the technology is relatively new, the physics behind the phenomena is fairly well-established. In fact, some major contributions in this area have come from Ames Lab theorist, Viatcheslav Dobrovitski and his colleagues.

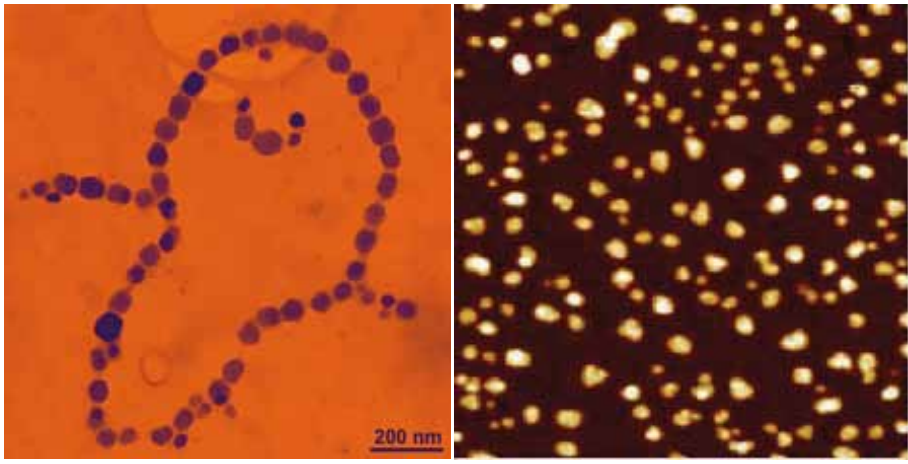
"The nitrogen-vacancy centers in diamond are quite unique, combining long quantum spin lifetimes with unusual coupling between spin state and the optical properties of the center," Dobrovitski says. "This opens the way to using them as very sensitive and efficient detectors of classical magnetic field and surrounding quantum spins, as well as detectors for electric field, temperature, etc. Nowadays, many groups are pursuing the possible application of the NV centers for nanoscale magnetometry."

According to Dobrovitski, researchers at several institutions, such as Harvard, Berkeley, and Delft, have this technology, but are taking different approaches. Ames Lab's Ruslan Prozorov, an experimentalist and leader of Ames Lab's nanoscale efforts, plans to create another group here by building a magnetic nanoscope to study magnetic materials at the nanoscale.

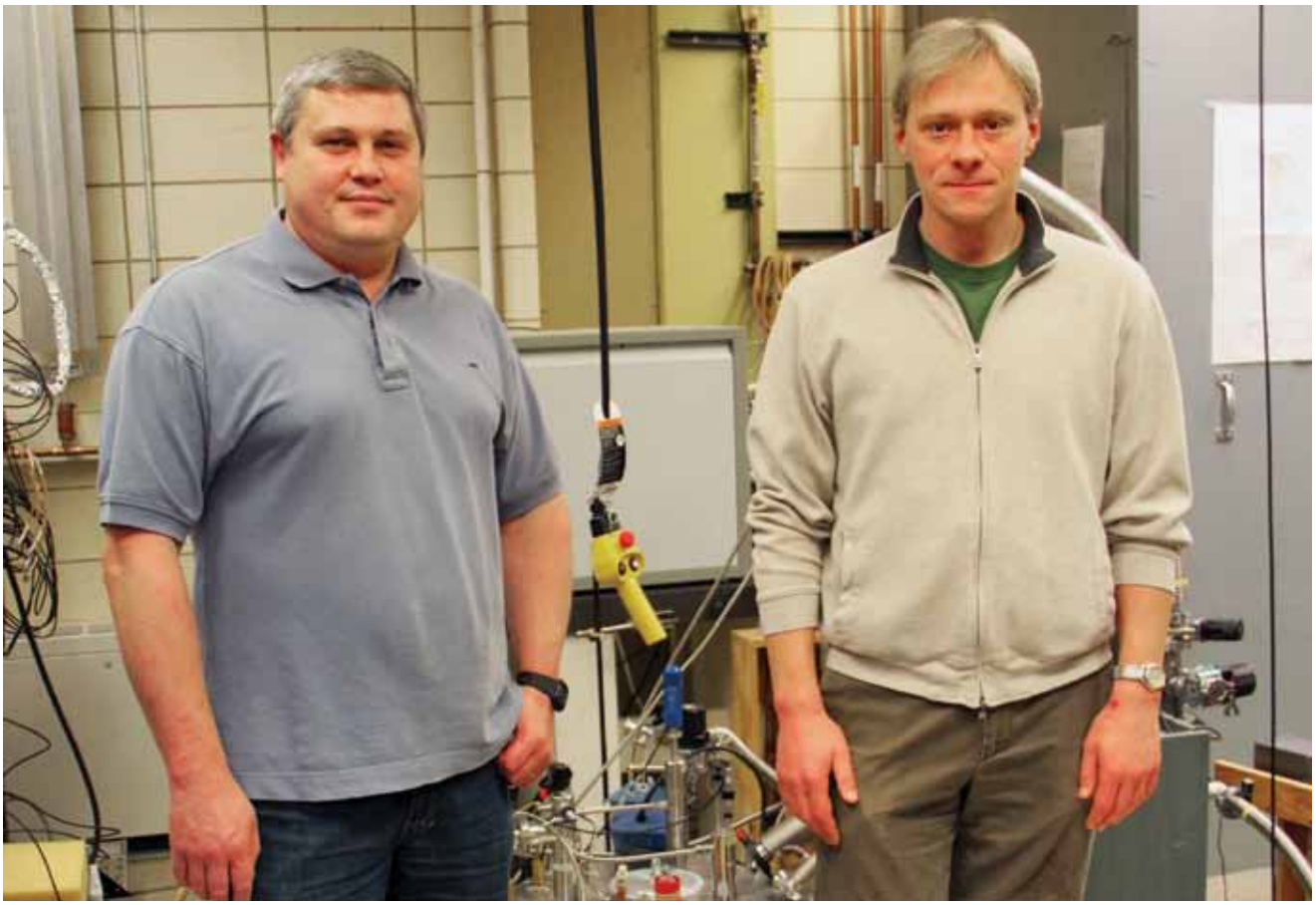
"The fundamental physics is the same, but there's no single recipe for how to do it," Prozorov says. "So it comes down to an actual task at hand and the scientific goals. Most groups are interested in pushing the technology to the limit for the sake of engineering progress."

"Our goal is different – we need a versatile instrument to study various magnetic nano- and meso-structures produced at the Ames Lab and by our collaborators elsewhere," Prozorov explains. "In particular, we plan to

In simple terms, if you shine a laser light on a NV center defect, it will induce photoluminescence whose intensity depends on the magnetic field at the location of the defect.



Measuring the magnetic field of nanoparticles produced by magnetotatic bacteria (left) and dysprosium nanoislands (right) are just two potential uses for new equipment that Ames Lab physicist Ruslan Prozorov plans to build.



Ames Lab physicists Ruslan Prozorov (left) and Viatcheslav Dobrovitski are involved in developing new, sensitive instrumentation that will allow the visualization of magnetic fields produced by nano-scale particles. Dobrovitski has been involved in the theoretical work behind nitrogen-vacancy centers, a defect in the crystal structure of diamond that Prozorov hopes to be able to use to measure minute magnetic fields of nanomaterials.

study magnetic 'nanoislands' that fellow Ames Lab physicist Michael Tringides has grown on graphene as well as bio-inspired magnetic nanoparticles similar to those grown in vivo by magnetotatic bacteria that are being studied and grown *in vitro* by Ames Lab scientist Surya Mallapragada's research group."

"In simple terms, if you shine a laser light on a NV-center defect, it will induce photoluminescence whose intensity depends on the magnetic field at the location of the defect," says Prozorov. "The defects are very small – just a few angstroms across and are extremely sensitive to the magnitude of the magnetic field. It is possible to detect signals at the levels of a single electron."

While other techniques have yielded many important results, the sensitivity of the new equipment would provide a much better look at what's taking place. Dobrovitski's theoretical expertise will prove very useful in designing Ames Lab's new equipment.

"During the last few years, I have been working on controlling the dynamics of the NV centers, and harnessing them for quantum spin detection," Dobrovitski says. "Some of my previous results, and the work planned in the future, will be useful for designing different modes of operation of the NV microscope. When the microscope is built, this theoretical work will provide guidance for Ruslan, and supply him with the tools for the planned future work."

Ultimately, Prozorov hopes to develop a dedicated nano- and meso-scale magnetic imaging research facility that combines existing capabilities, such as magneto-optics and magnetic-force microscopy with this new state-of-the-art nitrogen-vacancy magnetoscope and other techniques, such as magnetic-force resonant imaging.

"Ultimately, we want to be able to probe very small magnetic fields at the length scales from nanometers to millimeters," Prozorov says. "It won't happen overnight, but our goal is to have first data to show by the next DOE (program) review."

"The critical element will be to find good postdocs to carry out the work," Prozorov concludes. "Currently, we're looking for one experimentalist and one theorist to make it happen and Ames Lab has already allocated space and resources to build the device."

Ames Laboratory leads with new cutting edge NMR technology

BY LAURA MILLSAPS

The Ames Laboratory will take a giant step forward in world-class solid-state nuclear magnetic resonance capabilities with its new equipment acquisition, a Dynamic Nuclear Polarization-NMR spectrometer. The instrument will be the first of its kind to be focused on materials and materials chemistry in the United States.

The acquisition was announced in August, and is funded by the U.S. Department of Energy's Office of Science.

Using NMR technology, researchers are able to discover physical, chemical, electronic, and structural information about materials, based on the way atomic nuclei in the sample absorb electromagnetic radiation in a strong magnetic field. NMR technology is similar to that used for magnetic resonance imaging in medicine.

Dynamic Nuclear Polarization (DNP)-NMR uses microwaves to polarize electrons, and then transfer that polarization from the electrons to the nuclei of the sample being analyzed.

The concept of DNP-NMR was first theorized and demonstrated in the 1950s at the University of Illinois, but it took decades of progress in microwave and NMR technology, mainly at MIT, to make a commercially produced instrument possible, only in the last three years.

"It's essentially a combination of two techniques, electron paramagnetic resonance (EPR) spectroscopy and NMR, which yields an amazing increase in sensitivity," says Cynthia Jenks, assistant director for scientific planning at Ames Laboratory and director of the Lab's Chemical and Biological Sciences division. "In the types of materials we study, we've been able to

(Opposite) *A manufacturer's image of the new DNP NMR equipment that's headed to Ames.* (Right) *Ames Lab has a reputation for leadership in NMR technology, thanks to researchers Klaus Schmidt-Rohr* (left), *Marek Pruski (center) who is heavily involved in the DNP NMR project, and Yuji Furukawa* (right).

> "Our acquisition of this instrument is creating a buzz in the scientific community. Already we are receiving inquiries about potential collaborations from researchers world-wide. This adds to the unique set of material characterization capabilities available at the Ames Laboratory."

demonstrate an enhancement of anywhere from eight to 30 times in signal sensitivity. Results that used to take a week to obtain will now take hours or minutes."

The increased capabilities of the DNP-NMR instrument will be in the hands of the Lab's six world-leading solid-state NMR scientists, and opens up possibilities for research that didn't previously exist.

"Needless to say, we are all very pleased with this acquisition," says Marek Pruski, the principal investigator of the research team. "The Ames Laboratory has an elite group of scientists specializing in the development and applications of solid-state NMR techniques. During the last two years we have conducted exploratory studies to demonstrate the critical importance of DNP-NMR to our materials chemistry research, using the existing instrument in Lausanne, Switzerland, and at the Bruker facility in Billerica, Massachusetts. All these factors, and the critical support from the Ames Laboratory leadership made this outcome possible."

The instrument will be installed next summer in Spedding Hall.

Laboratory scientists expect the instrument to greatly expand and accelerate the progress of research efforts in many areas, including catalysis, nanocomposites, fuel cell membrane materials, soil organic matter, carbon electrode materials, plant cell walls, hydrogen storage materials, and other complex materials.

"Our acquisition of this instrument is creating a buzz in the scientific community. Already we are receiving inquiries about potential collaborations from researchers worldwide. This adds to the unique set of material characterization capabilities available at the Ames Laboratory," says Cynthia Jenks.

Ames Lab Interns Make Their Research Mark

Program Results

SULI, CCI, VFP

- **76%** - Motivated by their Ames Lab experience to pursue an advanced degree
- **84%** - Ames Lab experience influenced their career decisions
- **29%** - Received or are pursuing a Ph.D.
- **27%** - Received or are pursuing a master's degree
- **34%** - Published articles or presentations based on research performed at the Ames Laboratory
- **45%** - Conduct research or teach at universities
- **19%** - Work in industry
- **11%** - Work for the DOE at national laboratories
- **92%** - Conducted further research supported by U.S. government funds

Ames Laboratory's internship programs include the Science Undergraduate Laboratory Internship **(SULI)**, Visiting Faculty Program **(VFP)** and Community College Internship **(CCI)**. Since 2005, approximately 200 students/faculty from over 100 colleges and universities nationwide have participated in Ames Lab internships, having been mentored by approximately 85 scientists and engineers.

Kevin Yang, **Science Undergraduate Laboratory Internship – 2008**

B.S., Electrical and Computer Engineering, Cornell University – 2011

Amazon.com, software development engineer

"From my experience at Ames Laboratory, I learned many invaluable skills that have helped me a great deal with my research and academic endeavors. I feel no hesitation in asserting that SULI is an invaluable program that fosters America's future scientific researchers."

Ryan Glamm, **Science Undergraduate Laboratory Internship –2006**

Ph.D., Materials Science and Engineering, Northwestern University – 2011

The Boeing Company, metallic materials and process engineer

Serves Boeing's Research and Technology division developing advanced aerospace alloys through applied systems design.

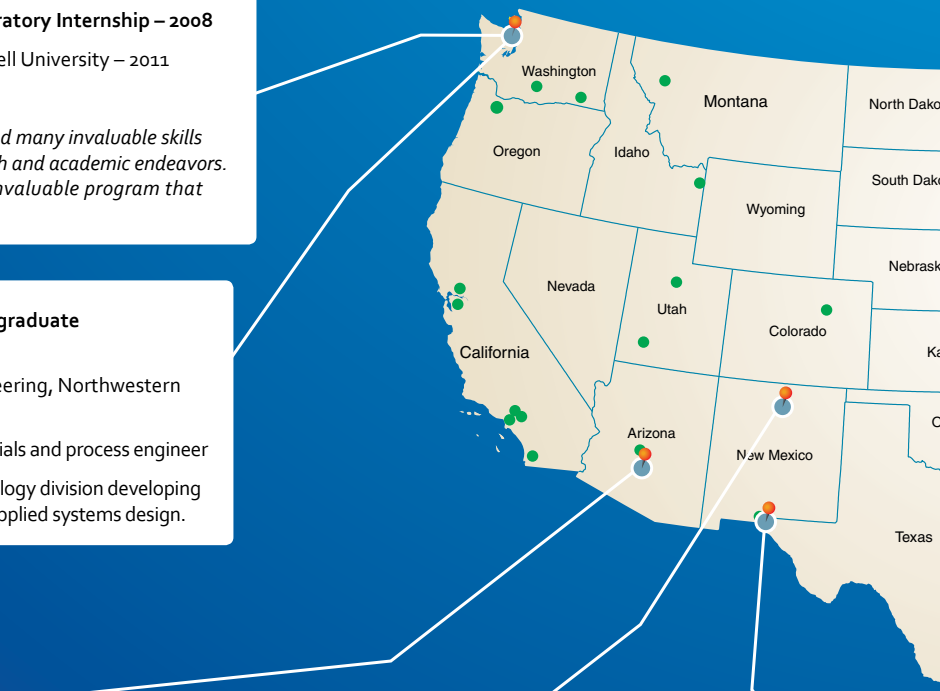
Nikki Wearth, **Science Undergraduate Laboratory Internship – 2009**

M.S., Civil Engineering, Arizona State University – 2013

Kroger Co., civil engineering project management intern

Optimizes efficiency to relieve sustainability problems that civil engineers may face in the future. Specializes in fluid mechanics, hydrology and urban water systems design.

"I can say I gained more from the SULI experience than any single college course. In addition to preparing me for a future career, the SULI program changed my mind about graduate school and allowed me to focus on what I really wanted to be involved in."



Andrew Fidler, **Science Undergraduate Laboratory Internship – 2007**

Ph.D., Physical Chemistry, University of Chicago – 2013
Department of Energy Office of Science Graduate Fellow 2010 – 2013
Los Alamos National Laboratory, postdoctoral researcher

Studied time resolved spectroscopic studies of energy transfer events in photosynthetic antenna complexes.

"I have nothing but good memories of my summer at Ames. The research opportunities continue to be of a high caliber and offer a great opportunity for undergraduates to see what a career in science is like."

in Industry, Academia and at DOE National Labs

Magdalena Furczon-Tylka, **Science Undergraduate Laboratory Internship – 2006**

Ph.D., Chemical Engineering, Illinois Institute of Technology – 2010
Argonne National Laboratory, engineering assistant

Working with pyroprocess development in the Nuclear and Environmental Processes department studying and developing innovative electrochemical processes for nuclear separations.

Lam Nguyen, **Community College Internship – 2012**

A.D., Electronics, Lansing Community College – 2012

Preparing to begin coursework to complete his bachelor's degree

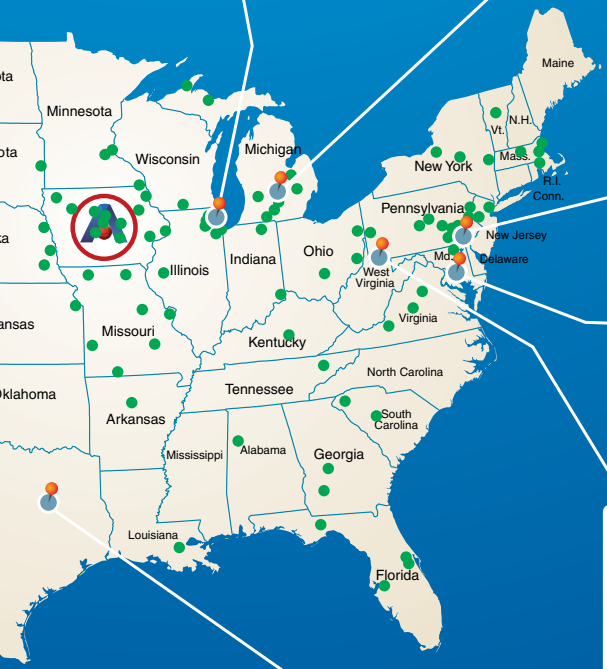
"My mentor at Ames Lab taught me interesting ideas that I wouldn't have learned in college classes alone. The internship was a great opportunity to become familiar with the working world."

Trishelle Copeland-Johnson, **Community College Internship – 2009, Science Undergraduate Laboratory Internship – 2010**

Ph.D., Chemical Engineering (in progress), University of Delaware, graduate student and researcher

Recipient of a 2013 NASA Space Technology Research Fellowship (NSTRF) seeking to improve materials that absorb electromagnetic radiation in II-VI thin-film cells.

"My experience at Ames National Laboratory helped me develop confidence as both a research scientist and an engineer. The technical skills I gained during my appointment have, on a number of occasions, distinguished me and provided me with further research opportunities."



George Scott, **Science Undergraduate Laboratory Internship – 2007**

M.S., Mechanical and Nuclear Engineering, Virginia Commonwealth University – 2011

Booz Allen Hamilton Inc., senior consultant

Supported the refueling of U.S.S. Theodore Roosevelt and U.S.S. Abraham Lincoln aircraft carriers as a nuclear engineer with the Naval Nuclear Propulsion program. Currently on the Cost Restructuring team in Decision Analytics for a leading security and defense contractor.

Brandon Callis, **Visiting Faculty Program – 2010/2011**

B.S., Chemical Engineering (in progress), Prairie View A&M University
National Energy Technology Laboratory (NETL), research assistant

Developing various high- and low-temperature ceramic oxide materials for multifunctional energy storage applications, such as battery materials, thermoelectric materials, and ultra-capacitor materials.

"The Ames Lab internship is a wonderful program full of great opportunities to network and experience research at its finest. It prepares you for a career in science and helps you apply what you learn or will learn."

Joana Cisneros, **Visiting Faculty Program – 2010**

B.S., Chemical Engineering (in progress), Prairie View A&M University
Summer Medical and Research Training (SMART) Program at the Baylor College of Medicine, researcher

Studies molecular mechanisms of gene structure, function and regulation in plant transformation and regeneration.

Javier Grajeda, **Science Undergraduate Laboratory Internship – 2011**

B.S., Chemistry, University of Texas at El Paso – 2013

Villagrán Research Group, research assistant

Working with coordinatively unsaturated bimetallic systems to model catalytic activation, which has applications in energy conversion and environmental remediation.

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Issue 2

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THE Ames Laboratory
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