Science & Technology at the Ames Laboratory

inquiry

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Issue 2

NEW MATERIALS VIA 3D PRINTING

Boosting NMR sensitivity with microwaves

Ionic liquids for rare-earth recovery

Shielding sensitive instruments

LASER-FOCUSED SCIENCE

THE Ames Laboratory
Creating Materials & Energy Solutions
U.S. DEPARTMENT OF ENERGY

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

Building our Future

It seems like everywhere you turn at the Ames Laboratory, there's something new. We're in the process of constructing our first new research facility in more than 50 years to house electron microscopes and other sensitive instruments. The $10 million Sensitive Instrument Facility, scheduled to open by the summer of 2015, will provide a real boost in our ability to probe materials at the atomic level, free from outside influences such as vibration and electro-magnetic interference. You can take a peek at the building as it takes shape on *pages* 6 and 7.

This past summer, we installed state-of-the art solid-state dynamic nuclear polarization nuclear magnetic resonance equipment, or DNP-NMR. The technology uses microwaves to polarize electrons, then transfers that polarization to the nuclei of the sample being studied. The result is a huge leap in the sensitivity of the spectral signal acquired.

We've also begun using 3D printing in a number of ways—to prototype materials rapidly or "print" organic and inorganic materials, such as ceramics and metals. The Ames Laboratory-led Critical Materials Institute, a U.S. Department of Energy Innovation Hub, is using its LENS (laser engineered netshaping) MR-7 system to combine up to four different metal powders in a nearly infinite variety of alloy compositions and gradients. The system, shown on the cover and on *page 16*, uses a laser to melt the powders as they are deposited onto a substrate. For catalysis, Ames Laboratory scientists Igor Slowing and Aaron Sadow are using different types of 3D printers to develop processes for creating unique materials and structures (see the story on *pages 16-18*).

Yet another CMI-funded research group, led by Anja Mudring, is working to develop ionic liquids for use in improving the rare-earth separation process, either for use extracting rare earths from ore or recycling rare earths from discarded magnets. You can read more about this work on *page 14*.

Even the CMI itself is still relatively new, having just celebrated its first official birthday this fall. Despite its "youth," CMI has been exceedingly busy, and successful, during its inaugural year with research by its various partners resulting in more than a dozen invention disclosures. You can find out more about CMI's progress on *page 8*.

Another research group, this one led by Marit Nilsen-Hamilton, is on the brink of creating a technology that would allow a clearer look at the complex interchange between the microorganisms in soils and the cellular activities of plants' root systems, what scientists call the rhizosphere. The researchers are using aptamers, short strands of genetic material that bind to a specific target molecule, a sort of non-destructive imaging, extended to biological systems. Read about this work on *page 12*,

I was impressed with the Laboratory and its people even before I took on my new role, but have come to appreciate this organization in a whole new light in my brief tenure. The commitment to excellence here is very strong and the examples we're highlighting in this issue are proof positive that we're moving forward on multiple fronts to create materials and energy solutions!

There's even a new face —mine— in the Director's Office. I took over as Director of the Ames Laboratory effective June 1, replacing Alex King who stepped down to lead the Critical Materials Institute. I was impressed with the Laboratory and its people even before I took on my new role, but have come to appreciate this organization in a whole new light in my brief tenure. The commitment to excellence here is very strong, and the examples we're highlighting in this issue are proof positive that we're moving forward on multiple fronts to create materials and energy solutions!

Adam Schwartz, Director

Paul Canfield

Sergey Bud'ko

Costas Soukoulis

Ames Lab scientists named Most Influential Scientific Minds

Three Ames Laboratory physicists, **Paul Canfield**, **Sergey Bud'ko**, and **Costas Soukoulis**, were recently named to Thomson Reuters' World's Most Influential Scientific Minds 2014.

Researchers earned inclusion on the list by writing the greatest number of highly cited papers, ranking among the top one percent for their subject field and year of publication between 2002 and 2012. According to Thomson Reuters, the work of the scientists ranked has "consistently been judged by peers to be of particular significance and utility." The three were named highly cited researchers in a list compiled by Thomson Reuters of more than 3,000 scientists in 21 fields of research.

All three conduct research in the Ames Laboratory's Division of Materials Sciences and Engineering. Canfield and Bud'ko study the design, discovery, growth and characterization of novel electronic and magnetic compounds and their interesting physical properties. Soukoulis researches the properties of disordered systems with an emphasis on electron and photon localization, photonic crystals, random lasers, metamaterials, left-handed materials, random magnetic systems, nonlinear systems, and amorphous semiconductors. Canfield and Soukoulis are both distinguished professors in the Department of Physics and Astronomy at Iowa State University. Bud'ko is an adjunct associate physics professor, also at Iowa State.

"This honor is gratifying, but not surprising," said Ames Laboratory Director Adam Schwartz. "Our scientists have earned the respect of their peers internationally, and that is based not on reputation alone but on solid and measurable contributions to their fields. We at the Lab congratulate Paul, Sergey, and Costas on their recognition."

Thiel wins 2014 Welch Award

Pat Thiel has been named the 2014 winner of the AVS Medard W. Welch Award, which recognizes outstanding research in the fields of materials, interfaces and processing. Thiel, who is a faculty scientist at the U.S. Department of Energy's Ames Laboratory and a Distinguished Professor of chemistry at Iowa State University, is recognized for her "seminal contributions to the understanding of quasicrystalline surfaces and thin-film nucleation and growth."

"We congratulate Pat on the Welch Award and for her outstanding contributions to the field of surface chemistry. Pat's work in understanding the surface structures of complex materials has advanced the understanding of quasicrystals and nanoparticles on metal and semiconductor surfaces," said Adam Schwartz, director of the Ames Laboratory.

The Welch Award was established in 1969 and Thiel is the first woman to win the Welch Award in its 44-year history.

"This award is defined by the people who won it before me. They have been the giants in the field of surface science. I am humbled and honored to be joining their ranks. The award really recognizes much more than me. It recognizes my many talented coworkers and the agencies that have enabled our work, especially the Department of Energy and the National Science Foundation," said Thiel.

Pat Thiel

Former interns win scholarships

Two participants in the U.S. Department of Energy Office of Science's Science Undergraduate Laboratory Internship (SULI) research program at the Ames Laboratory have been awarded prestigious scholarships, one from the Barry M. Goldwater Scholarship and Excellence in Education Program and the other from the National Science Foundation Graduate Research Fellowship program.

William Robin Lindemann a participant in the Ames Laboratory's 2014 spring semester SULI program has been awarded a Goldwater Scholarship, the nation's premier undergraduate scholarship in mathematics, natural sciences and engineering. Out of over 1,100 students who applied for the scholarship, which is based on academic merit, 283 were selected and awarded a scholarship that will cover the cost of tuition fees, books, and room and board up to a maximum of $7,500 per year. Lindemann applied the award to his senior year at Iowa State, where he was an undergraduate in materials science and engineering. He plans to pursue a Ph.D. in materials science and conduct research in and teach advanced ceramics.

William Robin Lindemann

Lindemann worked with mentor David Vaknin, Ames Laboratory physicist and Iowa State University adjunct physics professor. Lindemann has participated in hands-on x-ray reflectivity and fluorescence research. Lindemann is a two-time participant in the SULI program, having also participated in the summer 2013 SULI program, also with Vaknin as his mentor.

Javier Grajeda has been awarded a highly competitive fellowship through the National Science Foundation Graduate Research Fellowship Program (GRFP). Grajeda received his undergraduate degree in chemistry from the University of Texas at El Paso and will use his three-year fellowship at the University of North Carolina at Chapel Hill, where he recently enrolled as a graduate student.

Javier Grajeda

The GRFP recognizes and supports outstanding graduate students in science, technology, engineering and mathematics disciplines who are pursuing research-based master's and doctoral degrees. Fellows benefit from a three-year annual stipend of $32,000 along with a $12,000 cost of education allowance for tuition and fees, and opportunities for international research and professional development.

Grajeda participated in the SULI program at the Ames Laboratory in summer 2011 under the mentorship of Javier Vela, Ames Laboratory faculty scientist and Iowa State University assistant professor of chemistry.

Vela receives award for advancing diversity

Javier Vela, Ames Laboratory scientist and an assistant professor in chemistry at Iowa State University, has been selected as a 2014 recipient of the Stanley C. Israel Regional Award for Advancing Diversity in Chemical Sciences. The award is given by the American Chemical Society (ACS) and is sponsored by the ACS Committee on Minority Affairs. The award honors nominees who have created and fostered ongoing programs or activities that result in increased numbers of persons from diverse and underrepresented minority groups, persons with disabilities, or women who participate in the chemical enterprise. Vela received the award at the ACS Midwest Regional Meeting in Columbia, Missouri, November 12-15, 2014.

Javier Vela

Award winners receive a medal and $1,000 grant to support and further the activities for which the award was made.

David Johnston

Outstanding APS Referee

Ames Laboratory scientist and Iowa State University Distinguished Professor of Physics, **David Johnston** was named a 2014 American Physical Society Outstanding Referee. The award recognizes scientists for their exceptional quality, number and timeliness of their work assessing manuscripts for publication in APS scientific journals.

SIF Nearing Completion

BY KERRY GIBSON

A. *Groundbreaking for the new building was held June 6, 2014, making it the first new research facility at Ames Laboratory in more than 50 years.* **B.** *This photo, taken Aug. 27, shows the footings for the building ready to be poured. Wet weather slowed construction in the summer and fall.* **C.** *Precast wall panels are set in place in this photo taken Sept. 25. The panels were built elsewhere and trucked to the site.*

After years in the works, Ames Laboratory's new Sensitive Instrument Facility has taken shape and is on track to open in 2015. The state-of-the-art facility will be the new home of Ames Laboratory's existing scanning transmission electron microscope and some new highly sensitive equipment, providing an environment isolated from vibration, electro-magnetic and other types of interference that can obscure atomic-scale details from clear view.

The photos on these pages show the building from inception on the architect's drawing board through groundbreaking in June and construction through summer until mid-November. As this issue was being finalized, construction crews were installing the aluminum lining on the instrument bays that will shield the equipment from electro-magnetic interference (as shown in photo F *below*).

As the building nears completion, work is also progressing on obtaining several additional pieces of equipment, including a focused ion-beam instrument, an aberration-corrected scanning transmission electron microscope and a field-emission electron scanning microscope. Ames Laboratory administration has been working closely with Iowa State University and the DOE to secure funding to purchase the equipment, hopefully within a year's time.

D. *A crane lifts precast roof panels into place on Oct. 20. Much of the concrete used in the building contains non-steel reinforcing material to limit electro-magnetic interference.* **E.** *The exterior is enclosed, including windows, and the sidewalk poured in this photo from Nov. 10. The sidewalk connects the building with the existing Applied Sciences II building.* **F.** *Work on the building's interior was also progressing in November, as shown in this photo of aluminum plate being installed in one of the six instrument bays. The aluminum lining creates an electro-magnetic barrier.*

Critical Materials Institute
AN ENERGY INNOVATION HUB

CMI, YEAR ONE:

Listening to Industry

BY LAURA MILLSAPS

One might think Critical Materials Institute Director Alex King would lead off the first-anniversary meeting of the Critical Materials Institute, held in September, with some big numbers, or some big papers. Scientists can be like that.

Instead, he led with those far-harder-to-quantify human values, ones like respect, collaboration, and agility. And he'd been consciously keeping track of them in meetings throughout the year.

THE KEY VALUE? LISTENING.

"Listening is the most important thing we do," said King to the assembly of 150 scientists, most of them visiting from CMI's partner labs and institutions. "Our best successes in our first year come from the fact that we listened to our industrial partners and acted on the advice we heard."

It will be that value, King said, that will carry CMI through its upcoming second year, and beyond.

Launched in 2013 as the newest of the U.S. Department of Energy's four Innovation Hubs, the Critical Materials Institute was tasked with the goal of finding and commercializing ways to reduce reliance on the critical materials essential for American competitiveness in clean energy technologies.

CMI Director Alex King (back left) talks with advisory board members John Poate, Colorado School of Mines, (right) and Tom Graedel of Yale.

Alex King

To date, the Critical Materials Institute has generated 20 invention disclosures, a number that has garnered favorable attention from the DOE and legislators in Washington.

"It's quite an achievement," said King in the plenary session. "We have companies interested in the inventions already and they are moving forward toward commercialization." King noted that the list of inventions garnered positive attention from Congress, "so, we deliver."

The Critical Materials Institute has delivered some promising discoveries in substitute materials, especially in the area of efficient lighting.

In addition, it has developed processes for reducing the cost of mining and separating rare-earth materials.

"If you consider that you're looking at technology that's been around 50 or 100 years or more—to be able to go in and say, here's a significant improvement—that's a big deal," said King in a post-event interview.

FINE-TUNING RESEARCH GOALS

King said the institute would be carrying that listening value into the second year, since it has served CMI so well in the first; one of the hub's second-year goals is doubling the number of industrial partners.

Initial research efforts, while targeted at practical solutions from the beginning, were fine-tuned or even changed direction as industry partners weighed in on what were likely to be the most promising outcomes for manufacturing. King said there would continue to be a shifting of resources and focusing of individual projects as CMI evolved.

"Learning where all those go/no-go decisions are from an industry perspective, and then focusing all our efforts on reaching them, that's been really important. And the more people we listen to, the better," said King.

REACHING OUT TO INTERNATIONAL PARTNERS

CMI's hosting of the fourth annual EU-US-Japan Trilateral working group meeting on Critical Materials added an international dimension to the first year gathering, one that will continue to grow according to King.

The hub hosted delegates from the European Union, Japan and other countries in collaborative sessions covering topics in the rare-earth industry, source discovery, new materials research and deployment, and processing and recycling technologies.

King said this trilateral meeting started out four years ago as a venue to talk about policy and general approaches, and has moved on to planning scientific collaborations. As international concern grows over the demand for rare-earth and other critical materials, King expects CMI to play a vital role as a source of scientific expertise.

"We are by far the largest investment the U.S. government has made in this area," said King. "Other players in the group recognize that and while they look to Washington for matters of policy, more and more we're becoming the technical point of contact."

King believes CMI is well-positioned for that role in the coming year and beyond, and the first-anniversary meeting, a planning and working event rather than a celebration, helped frame that future.

"The meeting itself was a success, and the Ames Laboratory made a tremendous impression on our visitors. Looking over CMI's first year broadly, we've achieved a fantastic amount in a pretty short time."

Above: *Ames Lab researcher Matt Besser, right, explains the CMI's 3D metal printer to Japanese visitors.* ***Below:*** *CMI Director Alex King addresses scientists at the plenary session of the Critical Material Institute's annual meeting in September.*

Schwartz Reflects on Time at Ames Laboratory Helm

Adam Schwartz officially took over as Director of Ames Laboratory on June 2, 2014. Prior to coming to Ames, he served as division leader of the Condensed Matter and Materials Division at Lawrence Livermore National Laboratory, and also coordinated LLNL's projects for the Critical Materials Institute, a $120 million DOE Energy Innovation Hub led by the Ames Laboratory.

Schwartz sat down in late October with Inquiry editor Kerry Gibson to reflect on his first few months on the job, to share his insights on a variety of topics, and offer his vision for the coming months and years.

1. You've been on the job for roughly five months (six by the time this comes out). What's your impression of the Ames Laboratory now and has it changed in that time?

I'm more impressed than ever with Ames Laboratory as well as the Iowa State University. When I came out here to work with Ames Laboratory on the proposal preparation for the Critical Materials Institute and then as part of the CMI leadership team, I got to know a relatively small subset of the Lab staff well. Since coming here, I've been getting out and about meeting with people, particularly the FWP (field work proposal) leads, in order to get a much better understanding of the science they're doing and direction they're headed. I've also met with many operations and scientific teams, seen equipment, done safety walk-throughs, and represented the Lab in Washington, D.C. The Ames Laboratory leaves a positive impression in the science we do, how we conduct operations, and in the direction we are headed.

The interface and extent of focused interaction with ISU also gives a good impression. With a focus on physics, chemistry, materials science and engineering, some chemical engineering, and some biology, tremendous collaborative opportunities exist to continue building upon our strengths.

2. Is there anything about the Lab, the DOE or the job that's been a total surprise or something you didn't expect?

Absolutely! There have been surprises everywhere. Most at the Laboratory have been pleasant surprises and some of them have been more, "Oh, I hadn't thought of it that way" revelations. I've worked in the National Nuclear Security Administration (NNSA) system for 20 some years and this is different. More than anything, Ames Laboratory has its way of doing business and doing science, and in some cases, it's just new. And many times that difference is better and other times, it's just as good as what I'm used to, merely different. Coupling that NNSA experience with the Lab's very successful 67-year history invites opportunities for continued progress. The Ames Laboratory does so many things right, and we definitely don't need to change just for the sake of change in leadership.

On the DOE side, coming from NNSA, I'm aware of their method of doing business and general budget challenges. The Office of Science has similar operational and budget challenges. Overall, the Ames Laboratory is in solid shape. We've done extremely well with both equipment procurement and the CMI. I do worry some about our core research budgets and am putting much attention into that.

3. Are there any particular areas that are a priority, either near-term or long-range?

That's something that the Executive Council and I have been spending a good deal of time on. Our top priority is safety as it always has been and as it always will be. The Laboratory has a wonderful safety record, but we've had a few chinks in that armor recently – seven incidents over a period of months – some of them very serious. I've instituted safety awareness discussions and I think it's a timely reminder to everyone working here that safety is our highest priority. It's always a good time to 'Stop, Think and Check Your Equipment' and to rethink what you're doing and why you're doing it.

Our next priority is setting our priorities. There are so many options out there in science. Ames Laboratory is positioned to contribute in so many different areas of basic science and applied science or technology development and choosing which areas to focus on is really hard. Funding, of course, is limited. We received important feedback from the Lab Plan review in June and need to include that in our preparation for the triennial review of all Division of Materials Sciences and Engineering FWPs and a number of Chemical and Biological Sciences FWPs next summer. It's a critical juncture for the DMSE and CBS programs. Successful reviews position the Laboratory to continue on

its successful path. If some FWPs do not review well, that's certainly an issue for us.

So we're having discussions on what our core capabilities are and what areas we would like to strengthen if there is the budget. Money is tight, and we can't do everything we want to do or think we need to do. None of the national Labs can do everything they want to do. So we have to be selective, focus on our strengths and clearly articulate where the Lab is now and where we need to go to address scientific challenges that are part of DOE's mission. That's our short, intermediate and long-term priority.

Another near-term priority is that the Sensitive Instrument Facility be built on time and on budget. After a rainy spring and summer, things are going great. The walls are up, the roof is on, work is progressing well and it's all very exciting.

An intermediate priority associated with this is populating the SIF with state-of–the-art equipment. We're making progress on that, and I'm optimistic. We've had discussions with Iowa State administration and a number of the department chairs and we are building a coalition with the intent of purchasing a focused-ion-beam (FIB) instrument and an aberration-corrected scanning transmission electron microscope (STEM).

We recently had discussions in Washington, D.C. with both Linda Horton (Materials Sciences and Engineering Division Director) and Harriet Kung (Associate Director of Science for Basic Energy Sciences) where we laid out our plan to build this coalition, and those meetings were both positive. We will be requesting mid-year funds to help fund those instruments, and while I don't have a definitive "yes" in my pocket, I'm optimistic we'll be able to order that equipment within the year.

Another intermediate term priority is working on our computational-science capabilities. We are basically maxed out on power and HVAC to house computer clusters in our existing research buildings. The Laboratory has presented a proposal for a new computational science facility to DOE for the last two years, and we've been encouraged to come up with alternatives.

After the Lab Plan review this summer, we came back to Ames and evaluated some of our other buildings, and we're looking closely at the paint and air conditioning shop. We've had a pair of architectural firms evaluate whether we can convert that well-built building into a good, intermediate solution for our computational facility. DOE is receptive to the idea of repurposing existing space. We might be a little out of sync with the budget cycle, but we have a good plan and a good building. It would serve our needs on an intermediate basis, and we'll work with DOE on acquiring funding to accomplish that.

4. How much have you traveled so far? How many trips have you made to D.C.? Is it what you expected?

I'm not sure I want to know. I have a feeling it's been eight or so trips to D.C. There was the Lab Plan in week number two, a couple of trips for the National Laboratory Directors Council, and National Lab Day, which was an outstanding opportunity to highlight the work we do at Ames Laboratory. In addition, I've been to Oak Ridge National Laboratory for a meeting with the Secretary of Energy's Advisory Board. The travel schedule has been seemingly every other week, pretty much what I expected.

The meetings with the national laboratory directors are very important, interesting, and productive because we're trying to tackle some longstanding problems within the national laboratory complex. The Secretary of Energy, Ernest Moniz, is very interested in our input and in working together to improve DOE and the national lab complex. We've been picking important problems and making some progress.

The Ames Laboratory is well-known within DOE, but not necessarily within other parts of Washington so I believe it's important to get out and meet with Iowa's Congressional delegation. I've had the chance to visit all but one of the offices so far. I'll be back out to D.C. in December to receive our laboratory grades, and hope to take some extra time to once again meet with our representatives. It's important to let them know what great science we're doing, to show them the importance of the national laboratories and how we are contributing to the nation, as well as Iowa and the local economy.

5. Any other opportunities for improvement/ changes that you've identified so far?

The Laboratory has been very successful in securing the funding for state-of-the-art equipment. The CMI has two signature pieces of instrumentation – the laser engineered net shaping (LENS) for additive manufacturing—as well as the robotic system for synthesizing catalysts. Those two systems are the envy of many laboratories and position us very well. Additionally, both the Chemical and Biological Sciences and Materials Sciences and Engineering divisions have done well in recent years. We are in the process of procuring a field-emission electron scanning microscope that will go into the SIF and, as I mentioned earlier, we are optimistic about getting the other two pieces—the STEM and FIB—as well.

On the operations side, one area where we experienced an early success was the roll out of the new website. We still have work to do on that, but things are moving in the right direction. As far as operational efficiency, I'm amazed at what we get done for the budget we have. Things run very smoothly, and I'm impressed across the board, from accounting to finance to budget to procurement. I'm always looking for ways to improve efficiency, but I'm not sure there are any big ones to be had. We're bringing in a new manager for Facilities and Engineering Services so we will see new leadership in that area.

BY LAURA MILLSAPS

Learning the Language of Cell Life:

Ames Laboratory Scientists Use Genetic Markers to Discover the Rhizosphere

It's a science lesson so fundamental that we teach it to small children, planting bean seeds in Styrofoam cups: plants take nutrients from the soil to grow.

It is surprising then, that the complex interchange between the microorganisms in soils and the cellular activities of plants' root systems, what scientists call the rhizosphere, remains one of science's great mysteries.

"We want to know how plants and microbes in the soil talk to each other," said Marit Nilsen-Hamilton, an Ames Laboratory scientist and professor in the Roy J. Carver Department of Biochemistry, Biophysics and Molecular Biology at Iowa State University. "We know they're communicating with each other, but how? Multicellular communities are vastly more complex than we currently understand. How do we go about finding out?"

Nilsen-Hamilton said that traditional scientific methodology, taking samples from the environment back to the lab for genetic analysis, gives only part of the total picture of this vital ecological system.

"It can tell us the population of microbes, the various components of the rhizosphere, and then what the end products are. It's basically telling us who's there and how many, but who is doing what? How are they doing it? Do we even know where they're doing it? We may think we know, but we really don't, not for sure."

The impact of environmental changes on these systems is another question. Variations in temperature, atmosphere, and chemical composition of the soil force plant systems to adapt. Current science, Nilsen-Hamilton says, can only observe changes in the plant-soil system through analysis of the end-products.

"Right now the science is like a person who isn't a mechanic looking at an operating machine. We can bash it with our fist and observe that it runs faster or slower; but unlike a mechanic, we really don't understand what we did or why it changed."

Ames Laboratory scientists George Kraus and Marit Nilsen-Hamilton.

Nilsen-Hamilton, working in partnership with Ames Laboratory, Lawrence Berkeley National Laboratory, Ames Laboratory researcher George Kraus and Iowa State University associate professor of plant pathology and microbiology, Larry Halverson, is on the brink of creating a technology that would allow a clearer look at the entire rhizosphere system through the use of aptamers, short strands of genetic material that bind to a specific target molecule.

"It's really a type of non-destructive imaging, extended to biological systems," said Nilsen-Hamilton. "There is a little extra portion of genetic material that we place on the gene, and if we do it properly, it doesn't affect how the gene functions. On the right gene, it will report on a response to a change in the cell's environment such as a signal from another cell or more nutrients. We'll know when that gene is turned on."

These "reporters," called IMAGEtags (Intracellular MultiAptamer GEnetic Tags), are established into a particular species of microbe, or in a particular type of plant cell such as in a root hair, and will allow scientists to track cellular activity when they are in their normal environment. The reporters allow live-cell imaging with fluorescence microscopy methods and are now being expanded to use with radioactive imaging to "see" through soil.

Nilsen-Hamilton said the IMAGEtags have been developed and proven to work in the lab. The next step is establishing them in soil microbes and plant material and in a controlled soil environment that replicates conditions found in nature.

"These are more defined conditions that are closer to what you would observe in the field than a cell in a dish," said Nilsen-Hamilton, "and practical application could allow us to understand much more specifically, in real time, how these microbes and plant cells interact."

The technology could be applied to a number of uses, including agricultural research, environmental monitoring, medical diagnosis and treatment, or anything involving a biological system.

Graduate assistant Judhajeet Ray works as part of Marit Nilsen-Hamilton's research project to develop methods of non-destructive imaging of biological systems.

Ionic Liquids, High Hopes

BY BREEHAN GERLEMAN LUCCHESI

Safer. Sustainable. Customizable. Multi-functional. Ames Laboratory and Critical Materials Institute materials chemist Anja Mudring is harnessing these promising qualities of ionic liquids, salts in a liquid state, to optimize processes for critical materials.

"Ionic liquids have a lot of useful qualities, but most useful for materials processing is that ionic liquids are made up of two parts: the cation and the anion. We can play around with the chemical identities of each of those components and that opens the doors to huge amount of options," says Mudring. "That means we can really engineer ionic liquids with specific functions in mind."

One such function is improving the rare-earth separation process, either for use extracting rare earths from ore or recycling rare earths from discarded magnets.

"We are tuning the ionic liquids in such a way that they dissolve rare-earth oxides, and then we're using electrodeposition, where electricity is run through a liquid to create a chemical change to get the rare earth in metal form," says Mudring, who is also a professor of materials science and engineering at Iowa State University.

Traditionally, electrodeposition processes are extremely high temperature and often require corrosive chemicals. But Mudring's process requires much lower temperatures and ionic liquids are less hazardous, so less energy is needed and the process is safer and greener.

Mudring's group is also using ionic liquids to create phosphors for compact fluorescent light bulbs.

"We're using ionic liquids, putting them in a microwave, energizing them, and creating a phosphors material. The phosphors particles are less than 10 nanometers, which means they do not scatter light, key for optical applications like for compact fluorescent light bulbs," says Mudring.

Better yet, Mudring's process also reduces the amount of rare-earth materials required in the process, and may someday make it possible to replace mercury vapor with less-hazardous noble gases in CFLs. And looking farther down the road, the new phosphors could also be used in LEDs as they continue to replace CFLs.

"Ionic liquids are the key to the improvements in this material synthesis," says Mudring. "They function as the solvent, a safer one than an alcohol or other combustible solvent. And they are also the reaction partner. Here, the ionic liquid is the fluoride source, so we can omit hazardous hydrofluoric acid from the process. Again, that makes the process safer and cleaner. And they even function to stabilize the nanoparticles created in the process, eliminating the need for an additional stabilizer. Three functions in one! Add to that how efficiently ionic liquids take up microwave energy and there's just huge potential there for improving materials synthesis."

Anja Mudring's research group is working to optimize critical materials processing using ionic liquids. To fully understand the processes, Mudring and her colleagues must grow crystal samples, as seen here, and characterize the materials.

Reactions in ionic liquids can be done by microwave synthesis in just a few minutes.

Anja Mudring is new to the Ames Laboratory as a full-time scientist, but her ties to the Lab date back to 1997 when she first came for a two-week fellowship trip as a graduate student.

"I read in my chemistry text book about molten salts and ionic liquids, and I thought it was so interesting. And a name kept popping up: John Corbett, here at Ames Laboratory. So, I wrote to John and he invited me to come here to Ames for my fellowship trip."

Mudring returned as a postdoctoral research associate from 2001-2003, and even after she returned to Germany to start her own research group, she continued to visit Ames Laboratory for about a month each year.

"Always in the winter. I've always liked the quietness in Ames in the winter. The summer feels too hot to me, so I vowed to always only come in winter."

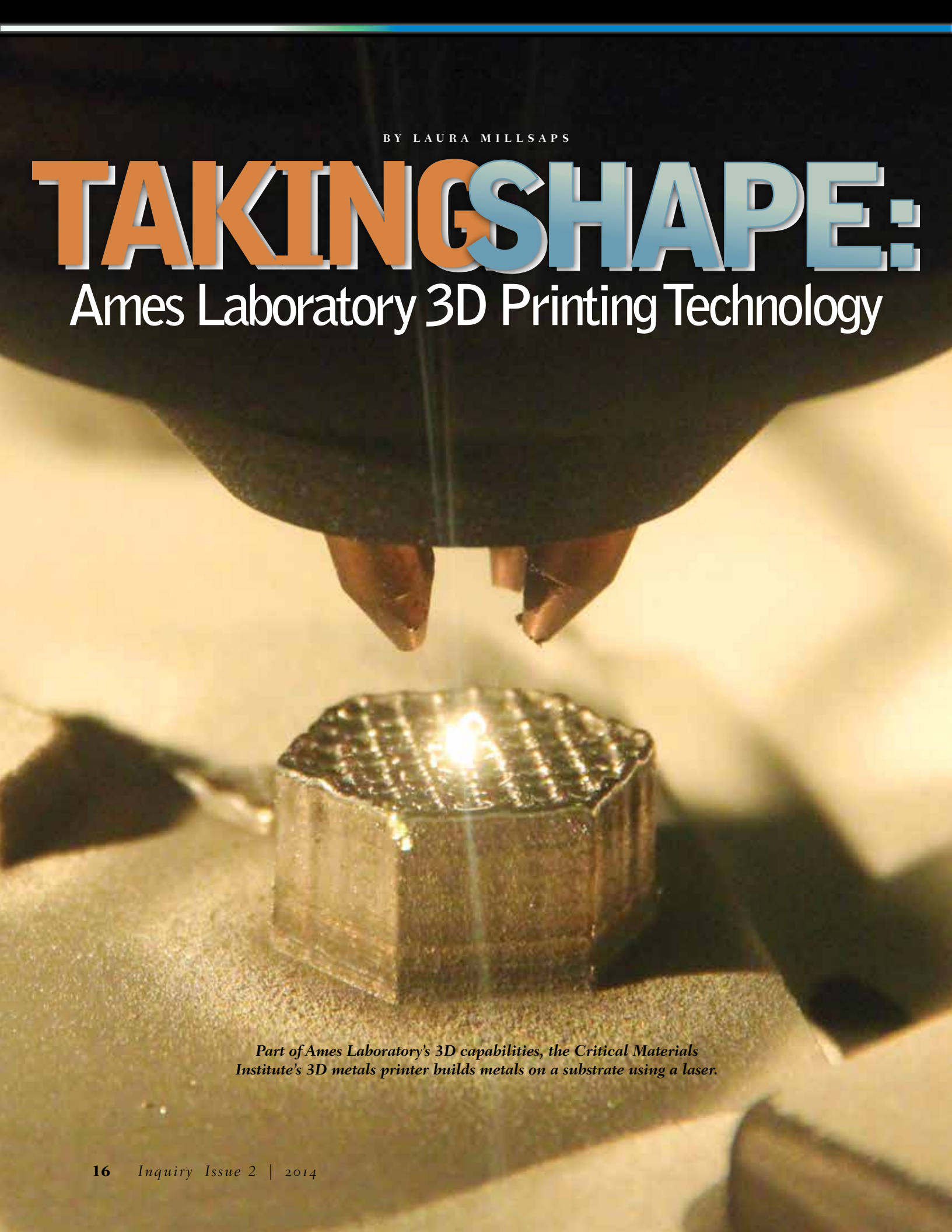
But then the opportunity came to join Ames Laboratory—all four seasons of the year.

"When the Critical Materials Institute started at Ames Laboratory, I learned of the openings and I applied. I already knew I loved Ames and the people here. And the research opportunities provided by the CMI were excellent," says Mudring. "So here I am. Happy to be here all year long!"

BY LAURA MILLSAPS

TAKING SHAPE:

Ames Laboratory 3D Printing Technology



Part of Ames Laboratory's 3D capabilities, the Critical Materials Institute's 3D metals printer builds metals on a substrate using a laser.

> "... the goal of the research is to develop processes that will create unique materials and structures during the printing process, rather than printing pre-existing materials."

The market for 3D printing products grew to just over $3 billion in 2013 according to Forbes, and technology analysts don't see any sign of it slowing as manufacturers, researchers, businesses and the public explore applications for the technology.

Scientists at Ames Laboratory are enthusiastic too, seeing amazing potential in 3D printing and additive manufacturing, and they are focusing research toward further advances.

Ames Laboratory researchers have at their command four experimental 3D printers that cover a range of unique capabilities.

"The possibilities in 3D printing are growing," said Igor Slowing, Ames Laboratory scientist and adjunct professor of chemistry at Iowa State University. "And here at the Lab we have a lot of ideas about how to take this technology further. The world of 3D printing technology is full of amazing things right now. We want to be a part of that."

The Laboratory operates two filament extrusion printers and a syringe-based injection printer. This fall, the Laboratory also acquired a laser printer to use photochemical processes for producing three-dimensional objects. Slowing and his research partner, Ames Laboratory scientist and Iowa State associate chemistry professor Aaron Sadow, are also developing a printer capable of extruding metals with low energy input.

In addition, they expect to leverage the Critical Materials Institute's 3D metals printer, which builds alloys on a substrate via metal powders that are melted by a laser. Slowing and Sadow also conduct research for the Critical Materials Institute, an Ames Laboratory-led U.S. Department of Energy Innovation Hub.

The range of equipment gives Ames Laboratory scientists the capability to print organic materials as well as inorganics, such as ceramics and metals.

Slowing said the goal of the research is to develop processes that will create unique materials and structures during the printing process, rather than printing pre-existing materials.

"For instance, currently you can print with plastics, but depending on the type of printer there are only two or three options you can use," said Slowing. "By being able

Igor Slowing

Aaron Sadow

Ames Laboratory scientist Igor Slowing demonstrates the use of a syringe-based injection printer.

to mix the components during the printing process itself, we can create as many different polymers as we want."

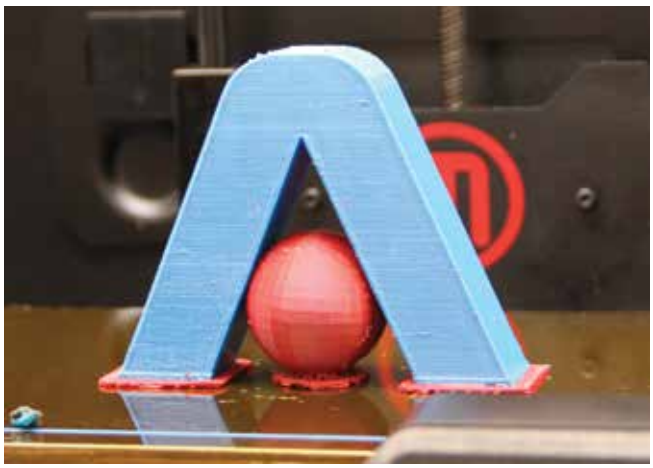
The approach can also be applied to catalysis research, by manufacturing entire functional pieces at once, said Slowing.

"A catalytic device can be constructed—the support, the reactors, the catalysts—all in a single unit. For researchers, the advantage is that modifications to the reactor design can happen quickly, in-house, without having to wait for customization from an outside source."

These catalytic devices could be used for sensing, purifying, refining "almost any application you could think of," said Slowing.

Another objective for research in 3D printing at Ames Laboratory is addressing the need for high resolution in additive manufacturing. Slowing believes that expertise in chemistry can bridge the gap between the nano- and macro-scale.

"If on one hand we are able to produce macroscopic solids with a 3D printer with a resolution down to a couple of microns, and on the other hand we can use the self-assembly methods of chemistry to organize groups of molecules into nanoparticles that can be organized up to a couple of microns, then we can control the manufacturing of matter in the whole range from the nano- up to the macro-scale," said Slowing.



A demonstration 3D model of Ames Laboratory's logo.

"The transformative potential of this research is very large and it is expected to create avenues for partnerships with other research facilities and industry."

Andrew Fidler on a hike in the mountains around Los Alamos.

Former SULI Student Chalks up Another Success

BY STEVE KARSJEN

The awards for research excellence just keep stacking up for Andrew Fidler, former Science Undergraduate Laboratory Internship (SULI) program intern at Ames Laboratory.

Fidler's latest award comes from Los Alamos National Laboratory (LANL), the Department of Energy national laboratory where he's currently serving as a postdoctoral fellow. Fidler was named one of LANL's Director's Fellows in 2014. Director's Fellows collaborate with LANL scientists and engineers on staff-initiated research. Award selections are made based on academic and research accomplishments and the strength and potential impact of the proposed research.

But this is not the first time Fidler has been recognized for excellence in his short career. In 2007, he was awarded a 10-week SULI internship at the Ames Laboratory. For 10 weeks, he was mentored in the lab with by Ames Laboratory physicist Ruslan Prozorov. During that short internship experience, Fidler co-authored the paper, "Suprafroth in type-1 superconductors," which was published in the journal Nature Physics.

Following his internship at Ames Laboratory, Fidler returned to Albion College to finish his Bachelor's degree and enrolled in graduate school at the University of Chicago, where in 2009, he was awarded a DOE Office of Science Graduate Fellowship. The prestigious fellowship provided Fidler financial support to apply toward his Ph.D. in physical chemistry.

Graduating with his Ph.D. in 2013, Fidler became a postdoctoral researcher at LANL, where he is currently a member of the Nanotechnology and Advanced Spectroscopy Team. The team's research focuses on synthesis, electronic and optical properties, as well as device applications of semiconductor nanocrystals and nanoscale assemblies built from these particles.

Upon hearing of Fidler winning the Director's Fellowship, Prozorov had this to say about his former student: "I am not surprised at his accomplishment, and I am very happy."

Ultimately, Fidler's success is a testament to the importance of science internship programs like SULI that provide opportunities for students to work in real-world research labs doing cutting-edge research alongside senior scientists.

"I have nothing but good memories of my summer at Ames," says Fidler. "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."

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