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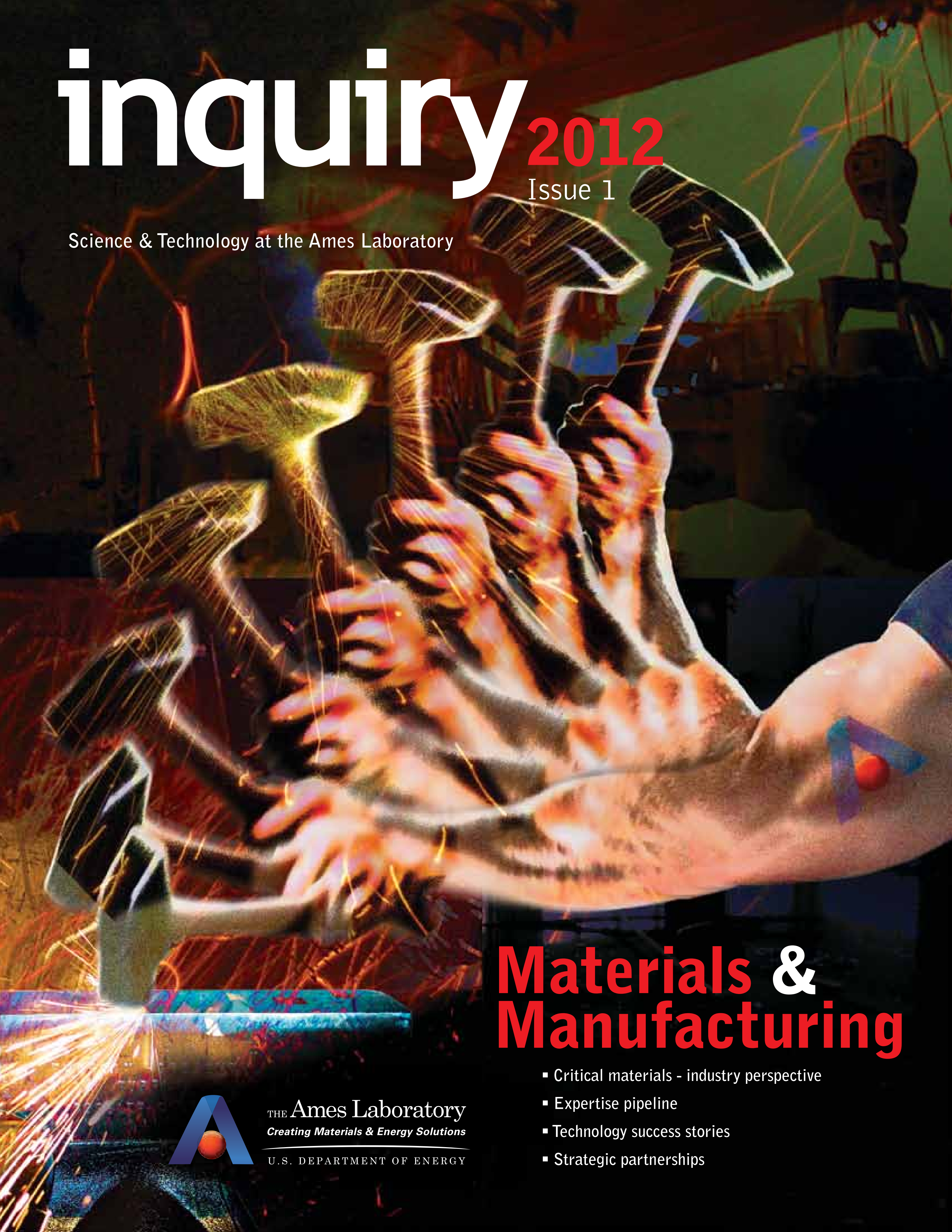
Science & Technology at the Ames Laboratory



Materials & Manufacturing

- Critical materials - industry perspective
- Expertise pipeline
- Technology success stories
- Strategic partnerships

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

Materials and Manufacturing

Manufacturing, we are told, is the key to a robust economy. It adds value and it creates jobs. But if you are going to manufacture a magnet, a motor, a car, a computer or an airplane, one of the first things you need to do is figure out what materials you're going to make it from.

Materials are selected for their properties (e.g. whether they are magnetic, transparent, electrically conductive, etc.); for performance factors, such as their strength-to-weight ratio; for their availability and cost; or even for purely esthetic reasons. Whatever drives the selection of a particular material, though, manufacturing cannot occur without the existence of an assured supply-chain for it. The Ames Laboratory is among the research centers that are the most consistently successful in the world at bringing advanced basic science together with manufacturing applications in the realm of materials. This kind of success in technology transfer requires many skills and capabilities, but the first of these is world-leading fundamental research.

The Ames Laboratory has a proud history of inventing materials.

Our work addresses the invention of new materials, the manufacture of materials, and the processes for manufacturing with these materials.

The Ames Laboratory has a proud history of inventing materials. Binary quasicrystals, magnetic zinc alloys, optical metamaterials, magnetocaloric compounds, high-temperature superconductors and topological insulators have all been invented and made in Ames Lab research projects. Perhaps our biggest hit, however, has been the invention of the lead-free solder alloy that is now the standard for the manufacture of all consumer electronic products in the world.

The Lab has an even longer history of influencing the manufacture of materials, starting out in the 1940s with our very first project – purifying uranium. We have developed the basic processing methods used to make industrial quantities of the magnetostrictive material Terfenol-D, and to make superconducting wires out of magnesium diboride. We continue this excellence in processing in our Materials Preparation Center, which is the world's preferred provider of pure rare earths, among many other things.

Recent successes have included novel approaches to the processing of materials that will enable manufacturing of titanium parts with enormously reduced waste. Since titanium can be very expensive, and traditional manufacturing methods can result in less than 10 percent of the original material being utilized in the final product, this is an important advance. It was recently recognized with an "America's Next Top Energy Innovator" award from the Department of Energy, and is being commercialized through a new start-up company, Iowa Powder Atomization Technologies.

Read on to find out how Ames Lab research is providing the materials for a resurgence in manufacturing.

Alex King, Director

Awards

Canfield selected for E.O. Lawrence Award

Ames Laboratory physicist Paul Canfield has won a 2011 Ernest Orlando Lawrence Award in recognition of his outstanding work in synthesizing and characterizing materials in single crystal form. Canfield is the first Ames Laboratory scientist to win a Lawrence Award.

Canfield, who is also a Distinguished Professor and the Robert Allen Wright Professor of physics and astronomy at Iowa State University, accepted the award at a ceremony in Washington, D.C., May 21, 2012. He is one of only nine winners named for 2011.

The Lawrence Award citation reads, "Paul C. Canfield will be honored for innovative syntheses and high-quality single crystal solution growth of novel new materials and the collaborative consummate elucidation of their fundamental properties using a range of techniques."

The latter part of the citation is exceptionally appropriate according to Canfield.

"I have been truly fortunate to enjoy a host of friends, colleagues and collaborators over the past 20 years at Ames Lab," says Canfield. "We can, and have repeatedly, formed groups and teams to tackle problems that would be too large for a single researcher or group. This is not only efficient, but also fun, like sharing an intense obsession or hobby with friends."

Paul Canfield

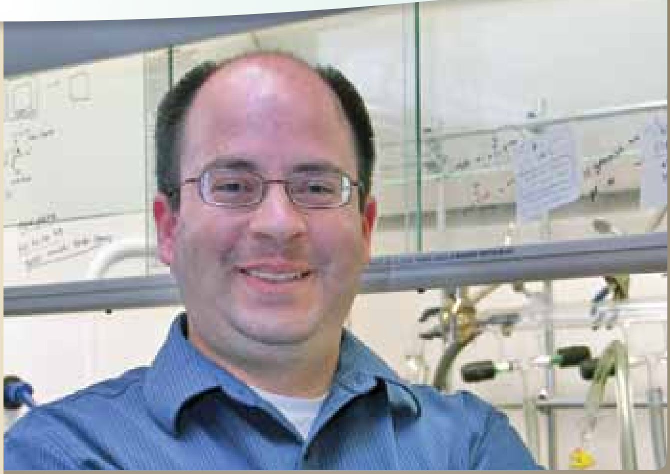
The Department of Energy's Lawrence Award recognizes contributions in research and development supporting the DOE. The Lawrence Award was established in 1959 to honor the memory of Dr. Ernest Orlando Lawrence, who invented the cyclotron, a particle accelerator. The award includes a gold medal and an honorarium.

Jenks named AAAS Fellow

Ames Laboratory's Cynthia Jenks, assistant director for scientific planning and division director of chemical and biological sciences, has been elected as a 2011 Fellow of the American Association for the Advancement of Science. Jenks was elected a AAAS Fellow for her "scientifically or socially distinguished efforts to advance science or its applications."

Cynthia Jenks

Jenks was cited for "major discoveries about surfaces of aluminum-rich quasicrystals, for sustained scientific outreach, and for leadership in scientific planning within the Ames Laboratory of the U.S. Department of Energy."



Javier Vela-Becerra

Vela makes Hispanic Engineer's "Top 40"

Javier Vela-Becerra, Ames Laboratory chemist, has made Hispanic Engineer magazine's "40 under 40" list of top young engineers. Vela was featured in the fall issue of the magazine, and his research is focused on photoactive nanomaterials for applications in biology, catalysis and energy. To see the article, go to **http://content.yudu.com/Library/A1u77k/HispanicEngineerandI/resources/index.htm**

Joel Rieken and Andy Heidloff

IPAT one of "America's Next Top Energy Innovators"

Iowa Powder Atomization Technologies, founded by Ames Lab research assistants Joel Rieken and Andy Heidloff, was one of the top three startup companies selected in the Department of Energy's "America's Next Top Energy Innovator" challenge. The contest, which included 14 startup companies from around the country, was based on a public vote and an expert review.

IPAT is using gas atomization technology developed at Ames Laboratory to make titanium powder. Powdered titanium is easier to work with than casting the metal, particularly given titanium's tendency to react with the mold material. Titanium's strength, light weight, biocompatibility and resistance to corrosion make it ideal for use in artificial limbs, military-vehicle components, biomedical implants, aerospace fasteners and chemical plant valves.

As part of America's Next Top Energy Innovator, the DOE reduces both the cost and paperwork requirements for startup companies to obtain option agreements to license some of the 15,000 patents and patent applications held by its 17 national laboratories.

Pat Thiel

Thiel named MRS Fellow

Ames Laboratory chemist Pat Thiel has been named a Fellow of the Materials Research Society for 2012. Thiel was chosen for her "seminal contributions to understanding the structure, reactivity, and tribology of quasicrystal surfaces, and to understanding growth and stability of metal nanostructures and metal thin films."

Thiel, who is also an Iowa State University Distinguished Professor of chemistry, has been an active member of MRS for many years and has served as co-chair for two different MRS symposia in the past. She is the third Ames Laboratory researcher to be named MRS Fellow, joining Ames Lab Director Alex King (2009) and metallurgist Karl Gschneidner (2011).

The honor is just the latest in a long list of achievements for Thiel. She is also a Fellow of the American Vacuum Society, the American Physical Society and the Institute of Physics.

Ho awarded APS 2012 Aneesur Rahman Prize

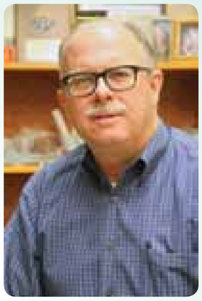
Ames Laboratory physicist Kai-Ming Ho has been selected by the American Physical Society to receive the 2012 Aneesur Rahman Prize for Computational Physics sponsored by International Business Machines. Ho was selected for the prize for "his pioneering work in the development of computational physics for photonic crystal and atomic cluster structures calculations."

The Rahman Prize, established in 1992 with support from the IBM Corporation, recognizes and encourages outstanding achievement in computational physics research. It consists of an honorarium and a certificate.

Kai-Ming Ho

Houk receives ACS Spectrochemical Analysis Award

Ames Laboratory researcher and Iowa State University chemistry professor Robert S. (Sam) Houk has been honored with the 2012 Award in Spectrochemical Analysis, presented by the Analytical Division of American Chemical Society. Houk will receive the award at the ACS national meeting in Philadelphia in August.



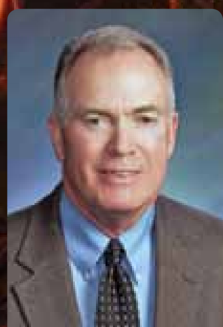
Robert S. Houk

Houk is the 26th recipient of the award since its inception in 1987 and joins his Ames Lab colleague and mentor, the late Velmer Fassel (1988), in being so honored.

According to Houk, his nomination was based on a number of improvements he has made to inductively coupled plasma mass spectroscopy, or ICP-MS, a technique that converts compounds into their atomic components. The highly sensitive equipment is capable of detecting extremely small concentrations of these atomic components, as low as parts per trillion.

Productive Partnerships

BY BREEHAN GERLEMAN LUCCHESI



Jason Goldsmith | George Byers | Joel Rieken | Andy Heidloff | Jon Snodgrass | Eric Summers

One of Ames Laboratory's missions is to transfer technologies to the private sector and to other federal agencies. The Ames Laboratory has a long tradition of moving technologies into the economy and in working with partners to help solve materials issues. Ames Lab does this by licensing intellectual property developed with DOE funds, educating tomorrow's scientific workforce, publishing research findings, and entering into research or technical assistance agreements.

Research agreements with non-DOE entities advance or tailor Ames Lab-developed technologies, or create new materials with specific properties. All work for non-DOE organizations must meet the missions of DOE and the Ames Laboratory, must not compete with U.S. private industry, must be fully funded, and is performed on a best effort basis.

Read on for several industrial partners' perspectives on the benefits of the unique expertise available at the Ames Laboratory.

What are the nation's most critical manufacturing challenges?

Joel Rieken, co-founder, Iowa Powder Atomization Technologies: When we look to the future, whether it's in the aerospace, automotive, military or energy sectors, everything is moving toward advanced materials. In many cases, those will be advanced metals.

Andy Heidloff, co-founder, Iowa Powder Atomization Technologies: We'll need to make these metals with two things in mind. They'll need higher performance, and we'll need to do that more economically.

Jason Goldsmith, materials research scientist, Greenleaf: Industry is always striving for the competitive edge, and that means in price, but also in performance and quality. That's true for cutting tools and fine ceramic products like those made by Greenleaf. Demands for finish machined goods are rising along with globally competitive operating and energy costs. One way to counter this is to increase productivity using the same given equipment and resources. Often the limitation of machining is with the tools. The ability to operate faster or cut deeper results in more components produced per given time using the same resources. With a better performing tool, this output demand can be satisfied in the long term.

Heidloff: And many, many tools or components that are needed for advanced manufacturing are made from metals. Metals processing is so important for improving materials, whether that means making them work at higher temperatures or for longer durations.

George Byers, vice president for government and community relations, Rare Element Resources Inc.: And part of the challenge of making better materials is convincing policy makers of the fast-growing needs in manufacturing that materials science can help address, and that the regrowth of the United States' intellectual infrastructure is too slow to catch up to other countries. We need policy makers to act to encourage materials research at universities, national laboratories and corporations that already have the capabilities to do this work.

So, how does materials research at Ames Laboratory help address these challenges?

Jon Snodgrass, president and chief operating officer, Etrema Products Inc.: In the case of rebuilding certain key areas of materials research, the people and experience at Ames Lab will help solve that challenge. Scientists at Ames Laboratory have decades of experience in a vast array of areas. We like to say that Ames Lab materials scientists have forgotten more about materials science than most people would ever hope to know!

Rieken: And, in particular, the areas of rare earths and powder metallurgy are incredibly important to the future of American manufacturing. Rare earths are required for so many electronics and green products, and powder metallurgy can be used to reduce waste and improve importance in aerospace components, among others. Both of those fields are Ames Laboratory's strong suits.

Ames Lab is a multifaceted lab, so you can get a lot of bang for your buck when it comes to solving materials challenges. If you have a materials problem for a part you're making, you can come to Ames Laboratory and you'll not only come up with an alloy to solve that problem, but you can also come up with a process to make that alloy and a process to make the part. The scientists can help put together the entire "supply chain" to help meet your overall goals.

Heidloff: From idea to part to everything in between, Ames Lab has the capabilities. And that's pretty unique.

Goldsmith: In our case at Greenleaf, innovative materials research concepts and developments by Ames Laboratory scientists advanced our understanding of fundamental issues with cutting tools in aerospace applications. This, in turn, led to successful developments in high-temperature, metal-alloy machining.

Eric Summers: vice president and chief materials engineer, Etrema Products Inc: At Etrema, we feel fortunate that we're only across town from Ames Laboratory so we can really take advantage of all it has to offer: skill sets, people, and equipment. Ames Lab has researchers who have so much experience, and Ames Lab's equipment is on the scale that it's large enough to get meaningful work done and at a price that's accessible for small businesses. You don't see a lot of other facilities like Ames Lab.

Snodgrass: I don't think we've ever come across a materials research challenge that Ames Lab hasn't been able to do. If we need to process a material for experimentation, there's a pretty good shot someone at Ames Lab has done it before or is willing to try to figure out how to do it.

Rieken: It's no secret that industry is driven by revenue and profit, and that's something Ames Laboratory takes very seriously. Ames Lab scientists know they have to show the clear cost benefit of the research when collaborating with business partners. And Ames Lab scientists excel at that, doing advanced metal research and applying that research to the marketplace through licensing patents. And Ames Lab doesn't just hand over a patent, it also has the capability to actually teach industry collaborators, students and other scientists how to use the patented technology.

How do you think Ames Laboratory can help train the next generation of materials scientists and advanced manufacturing workers?

Heidloff: Finding trained metals processing engineers and scientists is a real problem, from what we hear from our industrial collaborators, and what's advantageous about Ames Laboratory is that it's colocated with Iowa State University so there's a steady supply of potential workforce. Those students can be trained at Ames Lab in cutting-edge materials science and technologies and then be placed in industry to help solve the expertise gap.

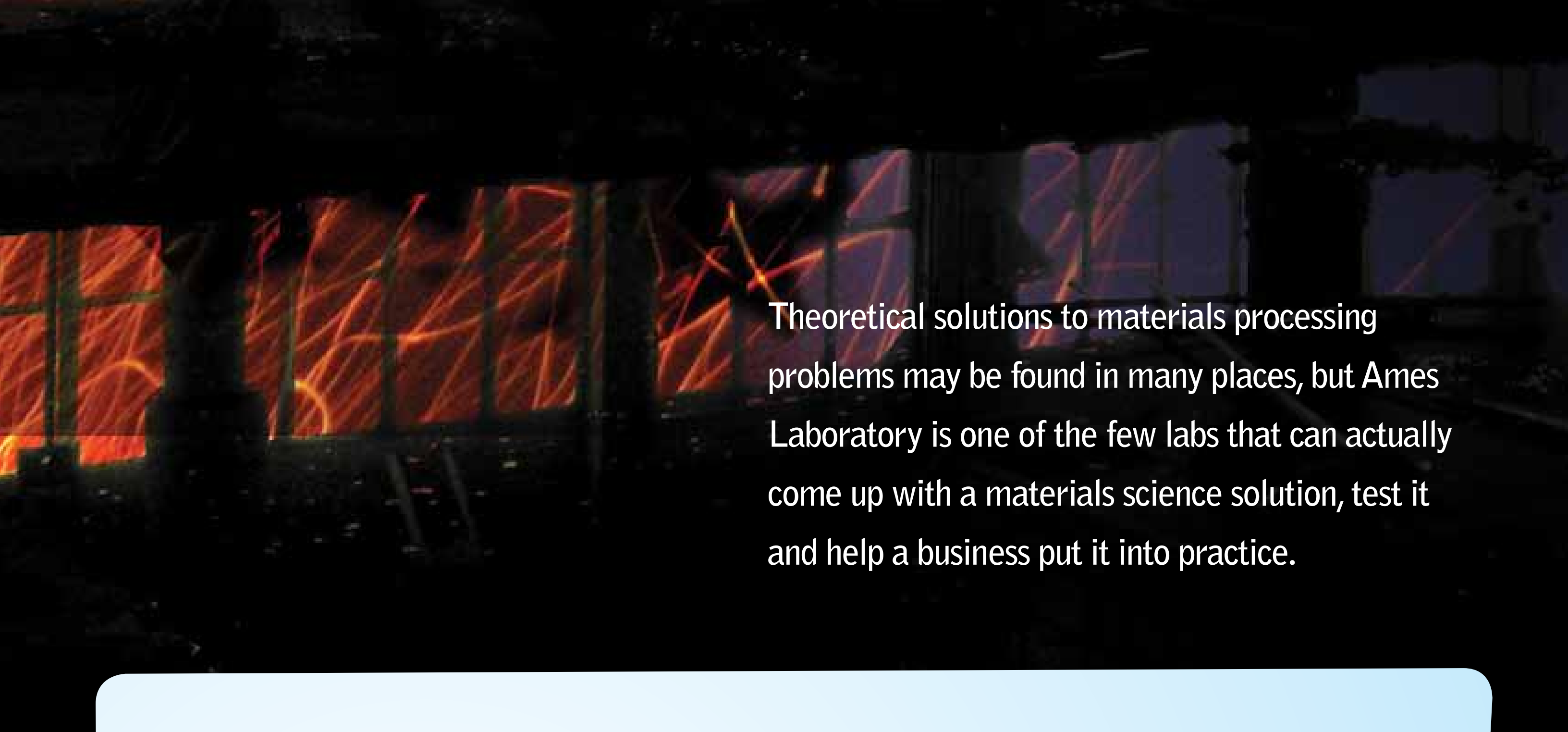
Rieken: Ames Laboratory, with its partnership with ISU, is a great place to "seed" technology in students, our potential workforce, so they can see the potential of advanced research and technology. And they may just be encouraged enough to even start their own technology companies. That's where Andy and I got our start with IPAT. We saw the work being done at Ames Lab and decided to take it a step further ourselves. Since Ames Laboratory's work is scalable, we could turn it into a business.

Ames Lab already helps train many materials science engineers, and it's ready to take on a bigger role, where it both develops new technology – like advances in metal injection molding with metal powders, for example – and trains student engineers in the skills it takes to further improve designs and processes, and trains technicians to run the equipment.

Summers: Ames Lab already has great, experienced technicians and there's a lot of hands-on knowledge there that can be shared with students.

Snodgrass: And it's hard to find qualified technicians. It's highly skilled work, and Ames Lab is in a unique position to give the next generation of technicians experience working in their labs, since Ames Lab has such a wide range of equipment and projects.

Byers: I agree. Our company and others can really benefit from the research talent being developed at Ames Laboratory. We'll need people to meet our research needs at our mine sites and metallurgy plant.



Theoretical solutions to materials processing problems may be found in many places, but Ames Laboratory is one of the few labs that can actually come up with a materials science solution, test it and help a business put it into practice.

What other unique capabilities come to mind when you think of Ames Laboratory?

Goldsmith: I think of Ames Laboratory's understanding of manufacturing needs and their innovative materials solutions to problems. Greenleaf's cutting tool material properties have to meet high demands since the high-temperature wear properties and chemical resistance is more demanding than other components. And Ames Lab is able to help us solve those challenging materials problems that lead to better machining performance, saving both time and energy.

Heidloff: Ames Lab is unique because of the large number of different capabilities they have right here. They're rolling, extruding, casting and forming. It's all the equipment that's necessary to make metal-based parts. I don't know of many other labs that have the suite of technologies and facilities for advanced metals processing, from milling all the way to powder metal processing. And what's better is that Ames Lab actually has commercially viable-scale manufacturing equipment that you can use to scale up new processes and technologies.

Rieken: Theoretical solutions to materials processing problems may be found in many places, but Ames Laboratory is one of the few labs that can actually come up with a materials-science solution and test it and help a business put it into practice. All the equipment at Ames Lab is built to be scalable. So, for example, if Ames Lab helps you solve a powder-metallurgy problem, you can extrapolate that easily to the commercial scale.

Byers: What comes to mind for me is that Ames Lab has a high level of understanding of the capabilities of rare-earth materials and a real awareness of the exponential growth in the application of rare earths into technologies, from use in agriculture, to stealth technology and magnetic refrigeration.

Rieken: In addition to rare earths, Ames Lab has really unique expertise in powder-metal processing. IPAT is given a lot of credit for developing our titanium powder atomizer, but the nuts and bolts of the atomizer were really designed at Ames Laboratory. So, that's the technology we're bringing to industry. And if we have a problem with our atomizer, Ames Laboratory would be the first place we would come for help because of Ames Lab scientists' expertise, experience and knowledge.

Joel Rieken and **Andy Heidloff** are cofounders of Iowa Powder Atomization Technologies, a startup company that uses gas atomization technology developed at Ames Laboratory to make titanium powder with processes that will significantly reduce the cost to manufacturers. Rieken and Heidloff earned Ph.D.s in materials science and engineering from Iowa State University and are postdoctoral researchers at Ames Laboratory.

Jason Goldsmith is a materials research scientist at Greenleaf, a leading developer of cutting tool technology. Greenleaf worked with Ames Laboratory on improved materials for cutting tools.

George Byers is vice president for government and community relations for Rare Element Resources Inc., which is exploring rare-earth deposits in its Bear Lodge Project in northeast Wyoming.

Jon Snodgrass is president and chief operating officer at Etrema Products Inc, and **Eric Summers** is vice president and chief materials engineer at Etrema Products Inc. Etrema makes Terfenol-D, a product based on processing technology developed at Ames Laboratory.

Rare-earth Recycling

BY BREEHAN GERLEMAN LUCCHESI

Recycling keeps paper, plastics and even jeans out of landfills. Could recycling rare-earth magnets do the same?

Ames Laboratory scientists are recycling rare earths from magnets, and the recycled materials maintain the properties that make rare-earth magnets useful.

The current rare-earth recycling research builds on Ames Laboratory's decades of rare-earth processing experience. In the 1990s, Ames Lab scientists developed a process that uses molten magnesium to remove rare earths from neodymium-iron-boron magnet scrap. At the time, rare earth costs were low. Back then, the goal was to produce a mixture of magnesium and neodymium because the neodymium added important strength to the alloy, rather than separate out high-purity rare earths.

But rare earth prices are rising and supplies are in question. Therefore, the goal of today's rare-earth recycling research takes the process one step farther.

"Now the goal is to make new magnet alloys from recycled rare earths. And we want those new alloys to be similar to alloys made from unprocessed rare-earth materials," says Ryan Ott, the Ames Laboratory scientist leading the research. "It appears that the processing technique works well. It effectively removes rare earths from commercial magnets."

Ott's research team includes Ames Laboratory scientist Larry Jones and scientists from the Korea Institute of Industrial Technology. They are developing and testing the technique in Ames Lab's Materials Preparation Center.

"We start with sintered, uncoated magnets that contain three rare earths: neodymium, praseodymium and dysprosium," says Ott. "Then we break up the magnets in a mill until the pieces are 2–4 millimeters long."

Next, the tiny magnet pieces go into a mesh screen box, which is placed in a stainless-steel crucible. Technicians then add chunks of solid magnesium.

A radio frequency furnace heats the material. The magnesium begins to melt, while the magnet chunks remain solid.

"What happens then is that all three rare earths leave the magnetic material by diffusion and enter the molten magnesium," says Ott. "The iron and boron that made up the original magnet are left behind."

The molten magnesium and rare-earth mixture is cast into an ingot and cooled. Then they boil off the magnesium, leaving just the rare earth materials behind.

"We've found that the properties of the recycled rare earths compare very favorably to ones from unprocessed materials," says Ott. "We're continuing to identify the ideal processing conditions."

The next step is optimizing the extraction process. Then the team plans to demonstrate it on a larger scale.

"We want to help bridge the gap between the fundamental science and using this science in manufacturing," says Ott. "And Ames Lab can process big enough amounts of material to show that our rare-earth recycling process works on a large scale."

Rare-earth magnet scraps are melted in a furnace with magnesium in a process to reclaim the rare-earth metals.

Success STORIES

BY KERRY GIBSON

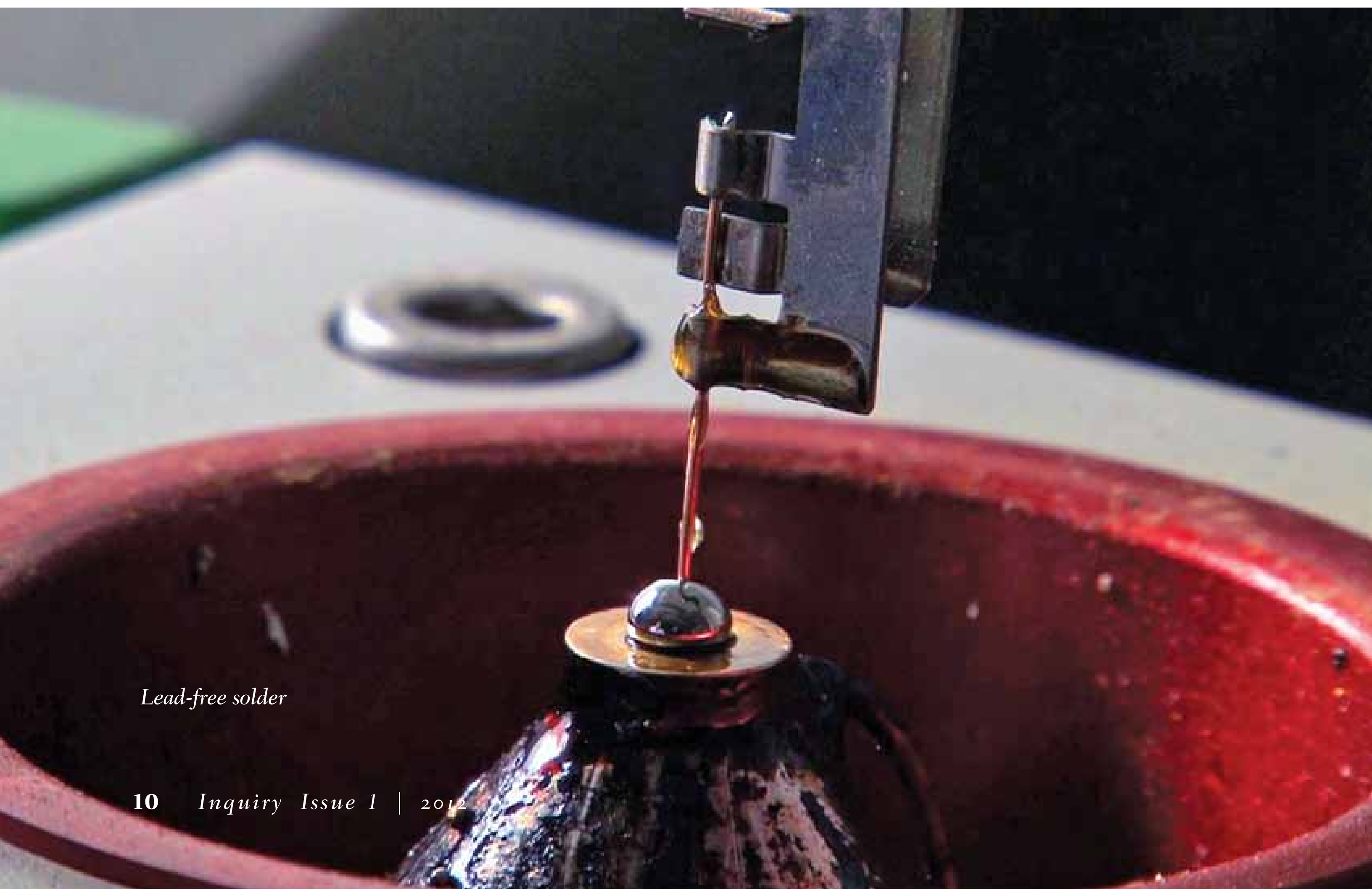
When it comes to successfully moving inventions from the laboratory bench to the commercial marketplace, Ames Laboratory has an excellent track record. Among the Department of Energy's 17 national laboratories, Ames Laboratory has historically ranked at or near the top in royalty income generated by inventions, despite the fact that it's the smallest lab with the smallest budget.

For example, in fiscal year 2011, Ames Laboratory inventions generated approximately $9.2 million in royalty income on $767 million in sales. That total sales amount represents over $22 of economic activity for every dollar of Ames Lab's $35 million annual budget. And of those total sales, more than $110 million were generated by Iowa-based companies, supporting more than 540 manufacturing jobs in the state.

Since record keeping began in 1980, Ames Lab researchers have been issued a total of 224 patents for 159 different technologies. A number of these patents have been licensed and developed commercially, and we highlight some of those success stories here.

Lead-free Solder

Ames Laboratory's most successful invention to date has been the development of a tin-silver-copper alloy to replace traditional lead-based solder. Licensed by more than 50 companies worldwide, Ames Lab's lead-free solder has generated nearly $39 million in royalty income since it was patented in 1996.



Lead-free solder

The Ames Laboratory in Fiscal 2011

$9.2 million in royalty income on **$767 million** in sales. **$22** of economic activity for every dollar of Ames Lab's $35 million annual budget. **$110 million** were generated by Iowa-based companies, supporting more than **540 manufacturing jobs** in the state.

A technician at Advanced Analytical Technologies Inc tests a Fragment Analyzer prior to shipping it to Texas Tech.

Developed by a team of researchers led by Ames Laboratory senior metallurgist Iver Anderson, lead-free solder was a necessary development to help eliminate toxic lead from landfills caused by the disposal of an ever-growing amount of electronic waste. Solder is the shiny metal "glue" used to attach components to circuit boards in all types of electronics from cellphones and computers to televisions and kitchen appliances.

"Solder has been around for 5,000 years and the basic formula of 63 percent tin and 37 percent lead was unchanged," Anderson says. "It was used because it was a eutectic alloy – it acts likes a pure metal with a single melting (and solidification) point."

It was this eutectic property that made finding a non-lead substitute difficult. Anderson's team experimented with various combinations until they found a mixture of tin, silver and copper that offered a lower melting point and greater strength than other alloys being considered.

The driving force behind a lead-free alternative to traditional solder was a ban on the use of lead and other hazardous materials in all electronics that was imposed by the European Union in 2006. Given the global nature of electronics manufacturing and distribution, the EU's ban was essentially international in scope.

Tests show the Ames Lab solder exhibits higher strength than the original lead-based predecessor. Its 217° C melting point makes it a viable choice for the increasing number of electronic components in automotive applications. Temperatures there can easily reach 150° C, causing typical lead solder, with a 183° C melting point, to become pliant and subject to failure.

Multiplexed Capillary Electrophoresis

This R&D 100 Award-winning analytical technology was developed by Ames Lab senior chemist Ed Yeung as a breakthrough in quickly and inexpensively analyzing the chemical composition of multiple samples at once. The technology uses hair-fine glass capillary tubes, typically arranged in eight groups of 12 – 96 total, to draw in the solution to be analyzed.

High voltage and the capillary action of the tubes are used to separate the component molecules in the sample mixture. The capillaries are exposed to ultraviolet light and depending on the speed at which the material passes through the tubes and the amount of UV light it absorbs, the chemical make-up of the material is detected. Another variation uses a laser or LED light source and measures the amount that the component molecules fluoresce to determine chemical makeup.

Industrial cutting tools sit atop a disk of the boron-aluminum-magnesium alloy. Even a microns-thin coating of BAM greatly increases the useful life of cutting tools.

Yeung's technology was used extensively to help map the human genome and is a vital tool in genetic research labs around the world.

The technology was commercialized by an Ames-based startup company called Combisep that in 2006 merged with another Ames company, Advanced Analytical Technologies Inc. AATI had specialized in microbial detection, but the acquisition of Combisep opened the door to allow further development of Yeung's technology.

"It gave us a platform and a tool that you can use in a variety of ways and fields," says Steve Siembieda, AATI's chief operating officer, "including pharmaceuticals, biotech, biofuels, and medical research. One of the great things is we can identify many different segments within those fields, such as children's genetics or autism research and work to customize the technology for that specific need."

The company currently offers five different analyzers based on Yeung's technology. The most popular is a compact machine called the Fragment Analyzer used in genetic research to separate and analyze DNA and RNA fragments. In fact, AATI can't build the machines fast enough.

"We've built 75 instruments since the beginning of the year and we still have a backlog of orders," Siembieda says. "We're adding production staff, growing and working hard to have a major presence in life science instrumentation to help researchers get work done quicker and better."

And while the company has a growing international reputation, it will likely stay in Ames.

"We have access to a high-quality workforce, the engineers and scientists, right here in our own backyard," Siembieda says, adding that several AATI staff formerly worked with Ed Yeung at Ames Lab and Iowa State University. "Ames is a good place to find people who want to work and work hard and the State, through various incentives, has been instrumental in keeping biotech companies in Iowa."

BAM (Boron-Aluminum-Magnesium)

This super-tough ceramic alloy with a very low coefficient of friction was discovered somewhat by accident as Ames Laboratory researchers Bruce Cook and Joel Harringa were looking at the thermoelectric properties of intermetallic materials. The samples of the boron-aluminum-magnesium were so hard, the Lab's diamond saws could barely cut them.

According to Ames Lab associate Alan Russell, BAM isn't like most superhard materials, such as diamond, that have a simple, regular and symmetrical crystalline structure. Instead, BAM's structure is complex, has low symmetry, and often has a few atoms missing. As for its slipperiness, Cook speculates that boron oxidation takes place on the surface, and this thin film of boron oxide reacts with the water vapor in the air to make the coating slippery.

"It's almost as if it's a self-lubricating surface," he says. "It's inherently slippery so you don't have to add oil or other lubricants."

Like most intermetallics, the material is brittle, which means that for some uses it's better to apply it as a thin coating on metal rather than as a solid piece. Early trials showed such promise that Cook's group was awarded a four-year, $3 million grant through the DOE's Office of Energy Efficiency and Renewable Energy to study it further for use in boosting energy efficiency in pumps and industrial cutting tools.

Applying a micron-thick coating of BAM + titanium boride to the blades of a pump turbine reduces friction within the pump, allows the pump to run more efficiently, and also boosts wear resistance and pump life. Eaton Corporation, a leading manufacturer of fluid power equipment, partnered with Ames Lab to test the coating on pump components.

Similarly, applying BAM + titanium boride coatings on industrial cutting tools also reduces the amount of friction between the tool and the metal workpiece, so less applied force is needed, which directly translates to a reduction in the energy required for the machining operation. Greenleaf Corporation, a leading industrial cutting tool maker, also partnered on the project to investigate BAM's use on cutting tools.

Recently, Cook and Russell began working with ISU materials science and engineering researcher Kaitlin Bratlie to investigate the bio-compatibility of BAM as a preliminary test toward possibly using the material as a wear-resistant coating on medical implants such as artificial knee and hip replacement joints. The work is being funded by a grant from the Iowa State University Research Foundation.

BAM was patented and licensed to New Tech Ceramics, an Iowa-based startup located in Boone. According to New Tech's chief operations officer Peter Hong, the company has been in discussions with 60 different companies about the product and is close to signing agreements with six of them.

Hong says there are four main branches in the potential use of BAM – as a powdered alloy, as a thin (less than five microns) coating, as a thick coating (thousandths of an inch thick), and as a solid. Potential uses depend on the branch being considered.

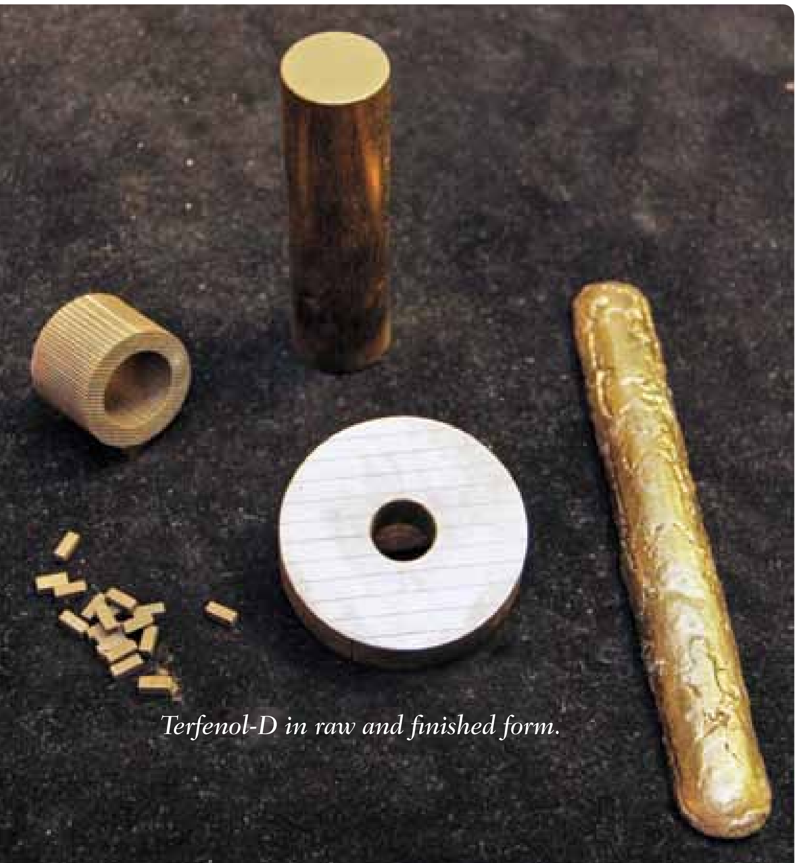
"The powder itself can be used as an additive to improve lubricity or hardness of other materials such as polymers," Hong says. "As a thin film, there's a wide range of potential uses from consumer products to aerospace and defense applications. It improves wear resistance so it's a substitute for heat treating, hard anodizing, or chroming, with applications for engine parts, rifle barrels and munitions, a non-metallic interface for hip and knee joints or even in helping keep the dentist's drill sharper so vibration is reduced."

As a "thick" film, the material could be sprayed in an open atmosphere to coat larger surfaces, similar to spray painting, for parts like grader or snowplow blades, agricultural implements like plows and discs, and surfaces of jet engine turbines. It would also replace heat treating these larger parts, which would also reduce the producer's carbon footprint by eliminating the heat source.

Solid parts would be molded and sintered from powders to produce wear-resistant products such as spray nozzles used in cutting tools and as potential armor plate for military vehicles as well as body armor. It could even be used for making jewelry.

TERFENOL-D

Terfenol-D is an alloy of terbium, iron and dysprosium that exhibits giant magnetostriction – it changes shape when subjected to a magnetic field. Originally conceived by the Naval Ordinance Laboratory in the 1970s for high-powered sonar, the metallurgy to produce Terfenol-D was developed by Ames Laboratory researcher Dale McMasters and others, who partnered with NOL to produce Terfenol-D in research quantities.



Terfenol-D in raw and finished form.

"Since record keeping began in 1980, Ames Lab researchers have been issued a total of 224 patents for 159 different technologies."

As a so-called "smart material," Terfenol-D has a variety of uses that take advantage of its ability to convert electrical energy (magnetic field) into mechanical energy (linear expansion).

ETREMA Products Inc. (EPI) is the sole U.S. supplier of Terfenol-D and was established in 1987 to commercialize Terfenol-D and transition the technology from laboratory discovery to industry. The technology for producing Terfenol-D was fully transferred from Ames Laboratory to EPI, granting it the technique to start small-scale production of the material.

In 1993, EPI expanded to a new facility in Ames, Iowa with the ability to house, develop and manufacture Terfenol-D and products based on that core technology. EPI has created three key business areas: Terfenol-D material sales, manufacture of devices powered by Terfenol-D and engineering services to assist customers in the development of new products based on Terfenol-D.

"About 80 percent of our business is engineering services," says Jon Snodgrass, EPI president and chief operating officer. "We produce Terfenol-D, but the actual quantities used in most products are relatively small. Our bread and butter is providing engineering expertise to help take advantage of Terfenol-D's properties."

One area where Terfenol-D touches everyday life is the lawnmower, string trimmer or chain saw sitting in your garage. The smart material is used in the precision machining of pistons in small engines to improve their fuel efficiency and reduce pollution.

The pistons are turned in an oval shape so that as they heat and expand, their shape becomes round and better fits in the engine's cylinder bore. To turn the oval shape, EPI developed its Active Machining System that uses Terfenol-D to precisely move the cutting tool in and out as the piston blank turns on a machining lathe. This back and forth movement happens twice for each time the lathe spins the piston one full rotation. The AMS is synchronized with the speed of the lathe to deliver precision results with no degradation in control over time.

"We're just preparing to ship our 14th AMS," Snodgrass says, "so it's an important product for us. If you buy a Briggs and Stratton engine or Stihl gas-powered product, it's highly likely the pistons were produced by our AMS."

M S E 557X.

Chemical and Physical Metallurgy of Rare Earth Metals. (3-0) Cr. 3. F. Dual-listed with Mat E 457X Prereqs: Mat E 311 or (Chem 325 and Chem 324 or Phys 322). Electronic configuration, valence states, minerals, ores, beneficiation, extraction, separation, metal preparation and purification. Crystal structures, phase transformations and polymorphism, and thermochemical properties of rare earth metals. Chemical properties: inorganic and organometallic compounds, alloy chemistry, nature of the chemical bonding. Physical properties: mechanical and elastic properties, resistivity, and superconductivity.

Nonmajor graduate credit.

BY STEVE KARSJEN

Rare Earths
Make a "Class" Comeback

Not since Mr. Rare Earth himself, Karl Gschneidner, gave up teaching a class on rare-earth materials at Iowa State University back in 1994 in order to devote his full time to research, have college students been able to get any serious, comprehensive education on rare earths. But the hiatus is now over. Rare-earths education is back in vogue.

A new course, MSE 457/557X, the Chemical and Physical Metallurgy of Rare Earths, began being offered at Iowa State during the 2012 spring semester. The three-credit, experimental class is taught twice weekly by Vitalij Pecharsky, Ames Laboratory senior metallurgist and ISU Distinguished Professor in materials science and engineering. The course covers the basics of rare earths, such as where rare earths are found in nature, how they're extracted from the earth's crust, how they're made into metals and how the metals can be made into products.

Pecharsky, who is actively involved in rare-earth research at the Ames Laboratory, also lectures on the physical and chemical properties of rare earths and their compounds.

"This is the only course of this scope and magnitude offered in this country and offered on a regular basis to both undergraduate and graduate students as well as distance-education students," says Pecharsky.

The timing of the class coincides directly with renewed worldwide interest in rare-earth materials and the restart of the mining and processing industry in this country, Canada and Europe, and, of course, the ability of Ames Laboratory scientists to teach the course.

Megan Meyer, a graduate student in materials science and engineering (MSE) at ISU, signed up for the course because "it was something I knew little about, and it was an opportunity to learn from a leading expert." Meyer adds, "Rare earths are part of our everyday lives in every aspect, and with the increase in demand of rare earths and the economics that affect importing rare earths, it will be an important industry in the United States."

Meyer's reasons for participating in the class also ring true for other participants, such as Weijie Wang, a graduate student in MSE at ISU. But whereas Meyer discovered the course on her own, Wang's graduate advisor, Mufit Akinc, Ames Laboratory research associate and ISU MSE professor, suggested

Megan Meyer, MSE457/557X student

Ames Lab senior metallurgist Vitalij Pecharsky lectures on rare-earth magnetism and microstructure to both in-house and distance-education students at ISU.

he take the course. "He just thought the course would be beneficial to my research, and I wanted to have more knowledge about the rare-earth industry, which may help me in finding a job in the near future," Wang says.

Altogether, there are 19 students in this semester's class, a very strong showing for an experimental class, which is indicative of its timeliness, says Pecharsky. Adding to its relevance is its makeup: five of the class participants work in industry and are taking the course via distance ed. Pecharsky attributes this to the class' emphasis on the properties of rare-earth compounds that have "industrial importance" and are also important for basic science.

Weijie Wang, MSE457/557X student

Terry Gatchell is one of the class' distance ed students. She's also a researcher and industry consultant for the Anchor House, a U.S. company that concentrates primarily on "understanding the economics and viability of rare-earth resources worldwide." She's found the class' topics to be directly related to her work. "We deal strictly with rare earths, so this class has been fantastic," she says.

Distance ed student Mallory Dalsin is a graduate student at the University of British Columbia completing her Master's in a rare-earth related field, but she also works for Mackevoy Geosciences Ltd., a Canadian company that "specializes in working on deposits with unique mineralogy, including rare earths." She says her company has worked on rare-earth deposits in British Columbia, the Yukon and Ontario in Canada. "A course with this kind of detail on rare earths is not offered where I live, and it makes learning the information more accessible," Dalsin says, "The class is giving me further knowledge of how rare earths behave and the extractive process, which assists determining the economic potential of an exploration project. I feel the more you know about the commodity you're looking for, the more beneficial it will be to the overall evaluation of the project."

If the class remains popular, Pecharsky believes it will likely be expanded to being offered every spring semester. And that would seem the likely scenario if comments made by students like Terry Gatchell have any bearing. Her tongue-in-cheek advice to those, whether in academia or industry, who are taking or may take the class in the future: "It's [rare earths] an exciting place to be right now, and young, bright scientists who are willing to work on problems in mining, metallurgy and materials science will be worth their weight in dysprosium."

Rare Earth Industry and Technology Association

REITA, a consortium of global industry, government and academic partners, of which Iowa State is a member, is working to provide other course offerings on rare earths. REITA's goal is to facilitate the development and commercialization of rare-earth technologies critical to the economic and national security interests of developed nations. According to Keith Delaney, REITA executive director, "Creating the intellectual infrastructure for rare-earths is vital for the commercial sustainability of the industry."

REITA supported another of its members, the Colorado School of Mines, when it provided a three-day short course on rare-earth resource recovery in the summer of 2011. The short course was sold out with over 100 participants and will be repeated in summer 2012. CSM's course focuses on mining, beneficiation, purification, reduction and making metals. CSM is also looking to expand its rare-earth course offerings via distance education in the near future.

The University of Nevada at Reno will be offering a course in rare-earth spectroscopy via distance learning in fall 2012. Details will be provided on the REITA website at: www.reitaglobal.org.

New Kid on the Block

BY STEVE KARSJEN

Cerium. Chances are when you think of the elements in the international spotlight right now for use in rare-earth magnets, the rare-earth element cerium doesn't come to mind. But in the future, cerium may occupy a rather large seat at the rare-earth magnet table as a substitute for its more famous cousin, neodymium.

Rare earths are of high interest because they are key components, of among other things, the lightweight, permanent magnets that are used in nearly every modern-day electronic device from televisions to cell phones and computer hard drives to electric and hybrid automobile drivetrains to generators in wind turbines. Neodymium is so significant to our nation's energy future that it is one of five rare earths identified in the Department of Energy's "Critical Materials Strategy" report as being vital to the nation's "clean energy economy."

So you might ask what this has to do with cerium. It turns out that cerium has the potential to be a substitute for neodymium in today's permanent magnets. This is big not because cerium is a better rare-earth material than neodymium for making permanent magnets, but simply because there's more of it. Cerium, it seems, is four times more abundant in the earth's crust than neodymium. Imagine the potential then for cerium, particularly in light of our nation's growing quest to become energy independent.

In an effort to further rare-earth research in many areas, including cerium as a replacement for neodynium, the federal government last fall introduced the Rare Earth Alternatives in Critical Technologies (REACT) program through the DOE's Advanced Research Projects Agency-Energy's (ARPA-E). One of the projects takes advantage of the Ames Laboratory's scientific expertise in rare earths. As part of a $2.2 million, potentially three-year project (the program is renewed after 18 months) Bill McCallum, an Ames Laboratory metallurgist, has been leading a project researching the use of cerium as a replacement for neodymium in magnets.

The Ames Lab research will look at combining other metallic elements with cerium to create a new powerful magnet with high-temperature stability for electric vehicle motors. Partners in the project are General Motors, NovaTorque and Molycorp Minerals – a "dream team" of worldwide leaders, says McCallum. General Motors will take an active role in alloy development, and along with NovaTorque, will provide the evaluation of the material for traction motors in vehicles. Molycorp, the only U.S. producer of rare-earth materials, will provide the important supply chain and development path for commercialization of these materials.

Ames Laboratory scientist Bill McCallum will lead research to develop high-strength permanent magnets using the rare-earth element cerium. Cerium is four times more abundant than neodymium, which is the critical element used in today's permanent magnets.

During the past three months, McCallum has been ramping up the Ames Laboratory project by hiring additional scientists and staff.

"We've mostly been doing baseline experiments and theoretical calculations," says McCallum, who adds the current work is helping scientists better understand challenges like the role of the hybridization of cerium electrons, crystal structure, and the symmetry of neighboring atoms. The result, he says, should be a better understanding of the best crystalographic environment for having cerium behave the way in which scientists want it to. In layman's terms, McCallum says, "We first have to determine what's wrong with cerium before we can find out how to make it behave."

To learn more about Ames Laboratory's work, check out this video:

U.S. DEPARTMENT OF ENERGY

Short Circuiting the "Edisonian" Approach

By Steve Karsjen

Manganese, a non-rare-earth material, is the focus of another Ames Laboratory research project.

Matthew Kramer, materials scientist, is teaming with scientists at Pacific Northwest National Laboratory (PNNL) to develop a new material based on manganese as a rare-earth-free alternative to permanent magnets that contain neodymium and dysprosium. These manganese composite magnets hold the potential to double magnetic strength relative to current magnets while using raw materials, such as iron, cobalt, chrome and nickel that are abundant and less expensive than current permanent-magnet materials.

Kramer says Ames Lab's part of the project will take advantage of the Lab's expertise in computational materials science. As he explains it, one of the major obstacles to coming up with any new alloy is finding a faster approach to looking at new materials. Kramer hopes to speed up the process of developing new alloys by using computational tools to guide materials selection. He says the current suite of computational tools allow scientists to begin doing "what if" scenarios much more effectively than in the past, both in terms of accuracy and the complexity of the materials being analyzed.

"By using computers to do materials research, we hope to short-circuit the traditional Edisonian process, which consists of going into the lab, trying a couple of ideas, measuring a few things and, if finding that doesn't work, going back and doing it again," he says.

In addition to Kramer, two other Ames Lab scientists, Duane Johnson, chief research officer, and Vladimir Antropov, physicist, will be investigating "density function theory codes," which will allow them to quickly assess the key chemistries and structures in the new alloys. These computer codes will allow scientists to make different substitutions within the element's structures. By understanding this, Kramer says "scientists can focus on improvements that can be made to the alloy's composition that will provide the biggest boost to its magnetic properties, which is critical to the success of the project."

Other partners in the ARPA-E project include Electron Energy Corp, United Technologies Research Center, the University of Maryland and the University of Texas at Arlington. The partners will be doing things like materials synthesis, combinatorial synthesis and materials processing. The Ames Laboratory portion of the overall $2.3 million project will be approximately $500,000.

If successful, the manganese composite magnets could reduce U.S. dependence on expensive rare-earth material imports and reduce the cost and improve the efficiency of green-energy applications, such as wind turbines and electric vehicles.

Ames Lab scientist Matt Kramer operates the Lab's transmission electron microscope. Various equipment options allow scientists to probe different aspects of a material. In scanning mode, or scanning transmission electron microscopy (STEM), the electron beam is scanned back and forth across the sample.

In 2011, the Department of Energy awarded $156 million to ARPA-E for 60 different high-risk/high-reward research projects related to renewable power, energy efficiency and national energy security. The projects focus on acceleration of innovations in clean technology, while increasing competitiveness in areas such as rare-earth alternatives and breakthroughs in biofuels, thermal storage, electric-grid control and solar-power electronics. Projects selected were in 25 states.

Collaboration with sister labs on upswing

Partnering for Progress

BY KERRY GIBSON

Ames Laboratory has a long history of collaborating with other DOE national laboratories. From its start in developing the technique for refining uranium for the Manhattan Project, Ames Laboratory has provided the raw materials and materials characterization expertise in a variety of projects. Those partnerships are on the upswing today as the national labs work together to help keep U.S. manufacturing at the forefront in both product and process innovation.

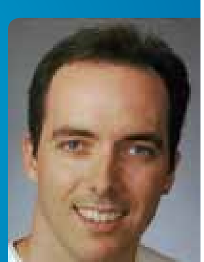
There's probably no better example of this than the advanced manufacturing initiative taking place at the DOE's Oak Ridge National Laboratory. According to Ames Laboratory Chief Research Officer Duane Johnson, teams of researchers are looking at a number of new technologies from three-dimensional printing to magnetic field annealing as well as developing new materials to help give U.S. manufacturers a leg up on the international competition.

"Ames Lab is involved in developing and supplying some of the new materials being studied," Johnson says, "such as metal powders or single crystals. There's a good synergy that exists as we work together on trying to break through these manufacturing barriers."

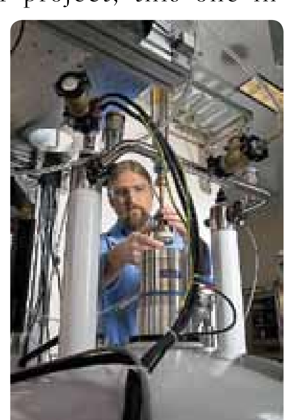
But that's not the only collaboration between Ames Lab and Oak Ridge. Bruce Moyer and ORNL's chemical separations group is in the planning stage with Ames Lab researchers and the Materials Preparation Center to develop designer reagents to do separations for rare-earth oxides. Ames Lab's computational materials group is logging time on ORNL's supercomputing center through an INCITE grant.

Ames Lab's neutron and X-ray scattering group regularly works at ORNL's Spallation Neutron Source and High-Flux Isotope Reactor, as well as the Advanced Photon Source at Argonne National Laboratory. As evidence of Ames Lab's strength in this area, physicist Rob McQueeney was recently tapped to serve as an expert detailee at DOE Headquarters to help oversee review of the complex's neutron scattering facilities.

Johnson points to another project, this one in conjunction with DOE's Pacific Northwest National Laboratory, where Ames Laboratory expertise in solid-state nuclear magnetic resonance is helping develop the next generation of NMR



Rob McQueeney



Pacific Northwest National Laboratory

Spallation Neutron Source, Oak Ridge National Lab

Advanced Photon Source, Argonne National Lab

technology. This characterization technology is vital to understanding the molecular structure of materials, especially in catalysis where we can "watch a reaction" happen.

"Last December, the Ames Laboratory and PNNL co-organized a workshop entitled 'Science Drivers and Technical Challenges for Advanced Magnetic Resonance,' " Johnson said. "Leaders in solid-state NMR from throughout the world outlined the scientific drivers and instrument demands for advanced NMR techniques, especially a technique called Dynamic Nuclear Polarization (DNP) that provides remarkable enhancement of signal-to-noise ratio of the NMR data – offering a faster and better view of chemistry."

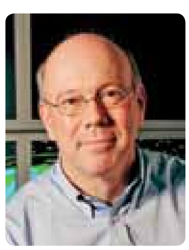
Marek Pruski

According to Johnson, Ames Lab's Marek Pruski has been working with PNNL's Karl Mueller to advance DNP techniques that integrate high-field, electron spin-polarization resonance (EPR) that uses electron spin polarization to give higher signal to noise than NMR, which is based on nuclear spin polarization.

"By combining the two within DNP-based NMR, you get increased signal to noise along with chemical sensitivity," Johnson says, "which will provide unique capabilities in the United States for studies of catalysts, biomolecular materials and inorganic materials relevant to the DOE mission."

Also of note, in conjunction with Agilent Technologies, Ames Laboratory has moved new fast NMR probes into the marketplace.

Mark Bryden, head of Ames Lab's Simulation, Modeling and Decision Sciences program, is working with Idaho National Lab on extraction and separation technology and with the National Energy Technology Laboratory on virtual design of power plants.



Mark Bryden

At Argonne, Ames Laboratory is supplying materials being studied for innovative new batteries and helping develop new characterization techniques at the Advance Photon Source.

Also, Argonne and Ames labs are developing a joint *materials discovery, design and synthesis* effort that leverages expertise at both labs, especially in computational materials science and scientific computing, to accelerate materials development toward useful technologies, a partnership to address part of the White House "Materials Genome Initiative" promoting materials development to manufacturing in half the time.

Those are just a few examples of the collaborative work Ames Lab researchers are doing with DOE sister labs in the last year and a half. In fiscal 2011, for example, Ames Lab researchers co-authored 24 papers that were the result of collaborative work with colleagues at other labs, with another 17 papers thus far in fiscal 2012.

"Ames Laboratory's excellence in designing and synthesizing the materials for study and its vast expertise in a variety of characterization techniques makes it a valuable partner," Johnson says. "And we're also able to take advantage of facilities and equipment beyond our capabilities. It's a win-win situation."

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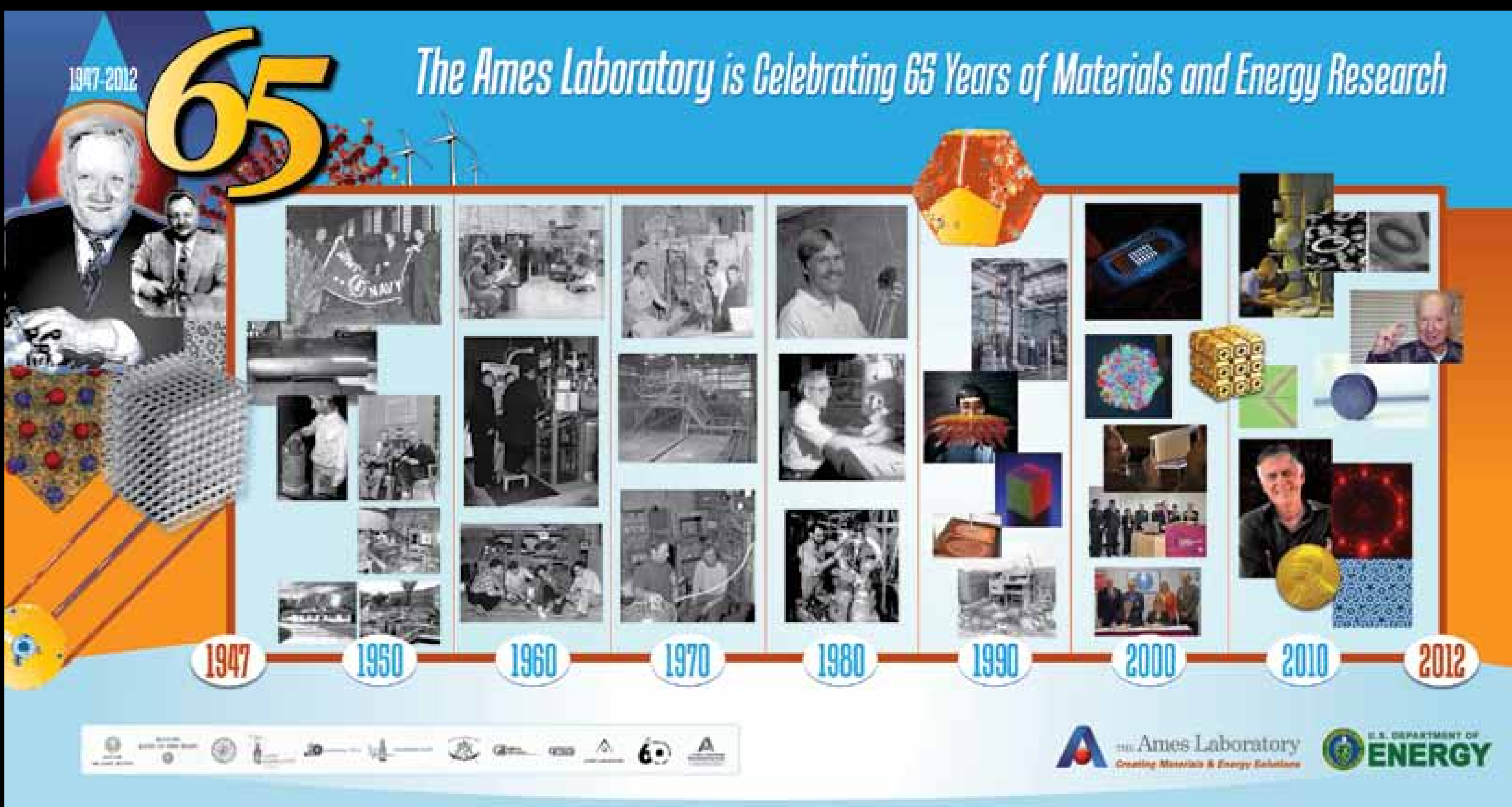

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