INQUIRY | 2009

ISSUE 1

SCIENCE & TECHNOLOGY AT THE AMES LABORATORY

A New Dawn

FOR ENERGY RESEARCH

| Improving Transmission Capabilities |

| Deriving Biofuels from New Sources |

| Boosting Energy Efficiencies |

| Building Better Batteries |

THE Ames Laboratory

Creating Materials & Energy Solutions

INQUIRY

Ames Laboratory is a U.S. Department of Energy 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 tomorrow's scientific talent.

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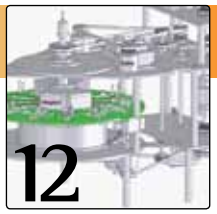

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Cover: *Iowa is second in the nation in wind-power generation. These wind turbines are part of a wind farm located near Colo in eastern Story County, about 25 miles from Ames and the Ames Laboratory.*

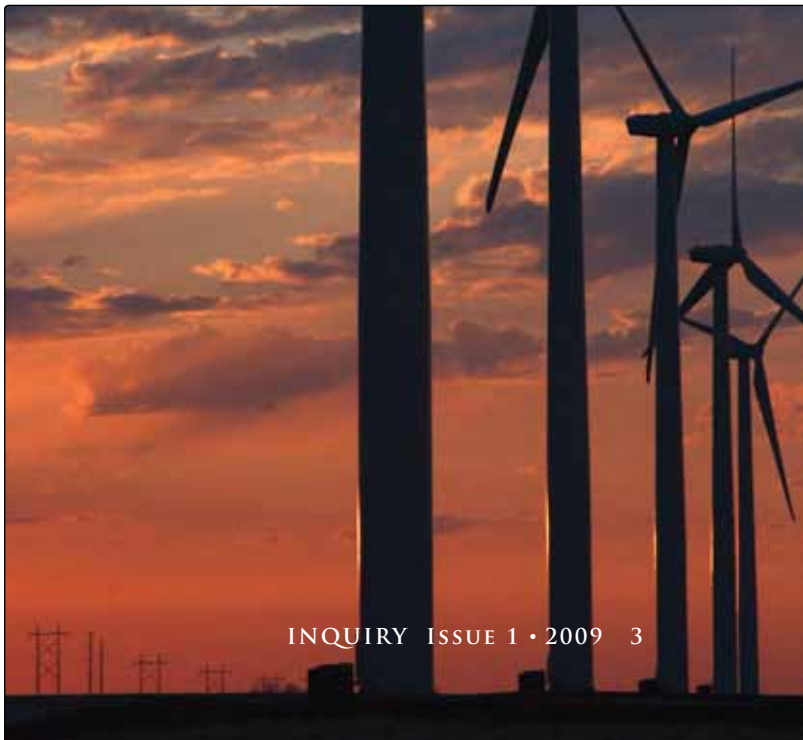
Beauty and Utility

The poet Robert Frost once remarked that Iowa's dark soil looks good enough to eat as it is, without going to the bother of putting it through vegetables; and if you look at some of the photographs in this issue of *Inquiry*, you will see that the Iowa skies can be stunningly beautiful, too. Robert Frost notwithstanding, the beautiful Iowa soil is really at its best when it is used to grow vegetables like corn and beans and that sky, while beautiful to look at, produces a wonderful crop of wind energy.

Like the soil and the Iowa sky at sunrise, great science often has a dual nature. It can be, and possibly even needs to be, beautiful in its own right, as noted by Marie Curie, Paul Dirac, and many others. Especially for the science that we do in Iowa at the Ames Laboratory, though, there is an aspect of usefulness that goes with the beauty. The Ames Laboratory has a consistently outstanding record of discovering new science and finding ways to apply it for the economic and ecological benefit of humankind.

In this issue, we highlight some Ames Laboratory projects that focus on applying world-class science to the problems of providing clean, plentiful and inexpensive energy to the world. The needs are great in every area of energy generation, storage, transmission and conversion. Read on to see a few of the things that are being done to address those issues here in the middle of Iowa.

Alex King, Director



Three Ames Laboratory Researchers Named AAAS Fellows

Surya Mallapragada

Klaus Schmidt-Rohr

George Kraus

Three Ames Laboratory researchers have been named AAAS Fellows by the American Association for the Advancement of Science for "their scientifically or socially distinguished efforts to advance science or its applications."

• Surya Mallapragada was honored for "research in the field of biomaterials and biomolecular engineering, particularly for important scientific advances in polymer design relevant to nerve cell regeneration and drug delivery."

• Klaus Schmidt-Rohr was honored for "using and developing solid-state nuclear magnetic resonance to answer important questions about diverse materials, including synthetic polymers, bone, soil and fuel-cell membranes."

• George Kraus was honored for "developing syntheses of natural products and other imaginative applications of organic chemistry and for promoting chemistry through visionary administrative leadership in the university environment."

"AAAS is the premier member-driven association serving the field of science," says Ames Laboratory Director Alex King. "It has incredible breadth, depth and impact, and the people who represent the association make significant contributions in an exceptionally wide range of ways."

"The recognition of Surya, Klaus and George with AAAS Fellowships is especially significant because AAAS crosses all fields of science, and standing out from the crowd is so much harder when the crowd is that large," King continues. "It's a real distinction, and we are very proud of the outstanding work that they are doing at the Ames Laboratory."

The new Fellows were presented with official certificates and pins on Feb. 14 in Chicago at the association's annual meeting. The Fellows honor is bestowed on association members by their scientific peers.

The three new Fellows join nine other Ames Laboratory researchers who are currently listed as AAAS Fellows: Andreja Bakac, John Corbett, John Hill, David Lynch, Gordon Miller, Marit Nilsen-Hamilton, Jacob Petrich, Klaus Ruedenberg and Costas Soukoulis.

Student Intern Wins DOE Poster Prize

Brita Kilburg

Brita Kilburg, a former Ames Laboratory intern, placed third in the environmental sciences division of the DOE Science and Energy Research Challenge competition. Kilburg, a student at Loras College who was mentored by ISU scientist Forrest Nutter, was a participant in the Lab's Science Undergraduate Laboratory Internship, or SULI, program.

SERCh is a poster competition that showcases the research projects of DOE-funded students and interns at the national laboratories. Students presented posters in Oak Ridge, Tenn. Cash prizes of $3,000, $1,500 and $1,000 were given for first, second and third place, respectively, in five categories.

Harmon, Finnemore Outstanding Referees

Three Ames Laboratory scientists were recognized for their exceptional efforts in assessing manuscripts for American Physical Society journals. Doug Finnemore, senior physicist; Bruce Harmon, deputy Lab director and senior physicist; and a third physicist who requested to remain anonymous were in the inaugural group of Outstanding Referee award winners.

APS initiated the Outstanding Referee award to express appreciation to all referees whose efforts in peer review both maintain the high standards of APS journals and help authors improve the quality and readability of their articles.

"Manuscript reviewers often operate in the background without much recognition, but their contributions to their fields of research are enormously important," says Alex King, Ames Laboratory director. "We are pleased that three Ames Laboratory scientists have been recognized for their service."

Ed Yeung

Yeung Receives ACS Analytical Chemistry Award

Ed Yeung, Ames Laboratory senior chemist, has been selected to receive the American Chemical Society's Division of Analytical Chemistry Award for Distinguished Service in the Advancement of Analytical Chemistry. The award, sponsored by Waters Corp., with its $2,500 cash prize, will be presented at the 238th ACS National Meeting to be held in Washington, D.C., Aug. 16-20, 2009.

Yeung, a longtime director of Ames Laboratory's Chemical and Biological Sciences Program, currently serves as the program's deputy director and is a Distinguished Professor in Liberal Arts and Sciences and holds the Robert Allen Wright Chair at Iowa State University. He has a distinguished career in the field of analytical chemistry. He pioneered separation analysis techniques, including multiplexed capillary electrophoresis, that won R&D 100 Awards in 1989, 1991, 1997 and 2001. He was also named a Fellow of the American Association for the Advancement of Science in 1992.

"In a stunningly productive career now exceeding three decades, Ed Yeung has time and again defined, then pushed beyond, the outer boundaries of chemical measurement science," says Paul Bohn, Arthur J. Schmitt Professor of Chemical and Biomolecular Engineering and Professor of Chemistry and Biochemistry at the University of Notre Dame and a longtime colleague of Yeung's. "From his early work mapping cutting edge laser spectroscopies onto molecular separations to a decade spent defining what can be learned from the study of single molecules, Ed has consistently moved into fruitful new areas and, by so doing, catalyzed enormously important developments by large numbers of researchers. I cannot think of a more deserving recipient of the Award for Distinguished Service in the Advancement of Analytical Chemistry."

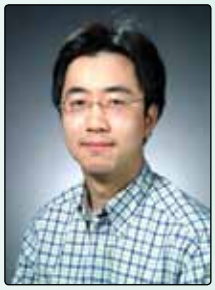
Fulbright Scholar

Mufit Akinc, an Ames Laboratory associate scientist and an ISU professor of materials science and engineering, was awarded a Fulbright Scholar grant. He will lecture on processing of advanced materials at Turkey's Koc University in Istanbul.

Mufit Akinc

NSF Career Award

Zhiqun Lin, associate scientist, received a National Science Foundation CAREER award, the organization's most prestigious award for junior researchers. The five-year, $400,000 award will support Lin's research in nanomaterials. Specifically, Lin plans to develop an evaporative self-assembly method for creating hierarchically ordered nanostructured materials.



Zhiqun Lin

ACS Computer Award

Mark Gordon, director of the Applied Mathematics and Computational Sciences program at Ames Laboratory and Iowa State's Frances M. Craig Distinguished Professor of Chemistry, has won the American Chemical Society's Award for Computers in Chemical and Pharmaceutical Research. The society called Gordon "a ubiquitous contributor to the field of computational chemistry."

Mark Gordon

Royal Society of Chemistry Fellow

John Corbett, a senior chemist, has been named a Fellow of the Royal Society of Chemistry. Fellowship is the RSC's most senior category of membership, and the Fellow award honors those who have made substantial contributions to advancing the wider application of chemical science.

John Corbett

A New Dawn for Energy Research

When it comes to renewable energy, Iowa is at the forefront. The leading corn producer in the country, Iowa has 35 ethanol plants with eight more under construction for a total capacity of 3.5 billion gallons a year – about one third of the overall U.S. capacity. The state also ranks near the top in biodiesel production.

Most industry sources also put Iowa near the top in wind energy production with more than 1,100 working turbines spread out among 47 wind farms. The state has roughly 2,800 megawatts of capacity with another 20 megawatts of capacity under construction. Yet this is only a fraction of Iowa's average potential output of 62,900 megawatts.

While these two energy sources are extremely important, they aren't without their problems. While corn is renewable, it requires significant inputs for the initial production and the distillation process. Some even argue that it is wrong to use food crops for fuel and that doing so unnecessarily raises not only the cost of your breakfast cornflakes, but the eggs and bacon on your plate (due to increased cost of livestock feed) and thousands of other products using corn-based sweeteners.

Kerry Gibson, Breehan Gerleman Lucchesi, and Mark Ingebretsen contributed to this series of stories

Iowa is a national leader on the sustainable energy frontier, and Ames Laboratory researchers are working to help clear the stumbling blocks that prevent wider adoption of these new technologies.

With wind, you can only produce energy when the wind blows, which typically isn't a problem in Iowa. The bigger problem is not being able to take full advantage of Iowa's windy days. Transmission lines from wind farms have a limited carrying capacity, and even if they could carry more electricity, there aren't enough homes, businesses, and industrial plants connected to the grid within a reasonable distance to consume all that power as it's being generated. And there's currently no way to store the excess, so that's why on windy days, you'll see only some of the turbines in a wind farm turning.

Fortunately for Iowa, and the rest of the country, researchers at the U.S. Department of Energy's Ames Laboratory are hard at work creating energy solutions right in our own backyard. Teaming up with crop scientists at Iowa State University, they are looking at using other crops and innovative methods to turn biomass into ethanol and biodiesel.

Our materials scientists are working to develop new materials, including superconductors, that can carry electricity more efficiently without significant losses. Others are looking to develop materials to store hydrogen, which could not only help put hydrogen-powered vehicles on the road, but could provide a method for storing up the energy produced on wind farms for use on days when the wind doesn't blow or when demand jumps.

But energy research at Ames Laboratory isn't limited to those areas. Our physicists are studying photonic crystals – lattice-packed devices – that could improve the efficiency of solar cells. Another group has developed a 3-D simulation of a power plant so engineers can explore its workings virtually to design plants that operate more efficiently and cleanly.

And our scientists are working to develop materials and technology that allow us to use energy more efficiently. This includes a magnetic alloy for use in electric-powered vehicles that retains its magnetic properties at high temperatures; a refrigerator that cools with a magnetic field and doesn't require a compressor or environmentally dangerous refrigerants; or an ultrathin, low friction coating that reduces friction so machinery operates more efficiently and parts last longer.

You'll find all these research efforts and more detailed in the following pages, examples of how Ames Laboratory is helping to solve the country's energy challenges.

Nanofarming oil from algae

ALGAE IS WIDELY TOUTED AS ONE OF THE NEXT BEST SOURCES FOR fueling the world's energy needs. But one of the greatest challenges in creating biofuels from algae is how to economically extract and isolate fuel-related chemicals from algae. Also, the current methods for extracting the oil from algae kill the organisms, dramatically raising production costs. Now researchers at Ames Laboratory and Iowa State University have developed groundbreaking "nanofarming" technology that safely harvests oil from the algae so the pond-based "crop" can keep on producing.

The so-called "nanofarming" technology uses sponge-like nanoparticles to extract oil from the algae. The process doesn't harm the algae like other methods being developed, which helps reduce both production costs and the production cycle. Once the algal oil is extracted, a separate and proven solid catalyst from Catilin, Inc., a nanotechnology-based company that specializes in biofuel production, will be used to produce certified biodiesel.

Victor Lin's research group is growing several strains of algae in the laboratory and testing how the organisms respond to introduction of the nanoparticles.

The three-year project is being funded with $885,000 from the DOE Office of Energy Efficiency and Renewable Energy's Industrial Technology Program as part of the 2008 Nanomanufacturing for Energy Efficiency program, $216,000 from Catilin and $16,000 from Iowa State University in matching funds. Phases one and two of the project will cover the culturing and selection of microalgae as well as the development of the specific nanoparticle-based extraction and catalyst technologies for the removal of algal oil and the production of biodiesel, respectively. Phase three will focus on scale-up of the catalyst and pilot plant testing on conversion to biodiesel.

The driving force behind this combination of nanotechnology and biofuels is Ames Laboratory Chemical and Biological Sciences Program Director Victor Lin. Since 2000, Lin, who is also a chemistry professor at Iowa State University, has been leading research on using nanotechnology to dramatically change the production process of biodiesel. This successful technology led Lin to found Catilin one and a half years ago.

Converting syngas to ethanol

ETHANOL PRODUCTION IN THIS COUNTRY IS EXPECTED TO EXCEED 10 billion gallons in 2009, representing about nine percent of the nation's gasoline supply. Nearly all of that fuel is produced through the fermentation of biomass, with corn a leading feedstock. But if grain could be replaced with more sustainable biomass like corn stover from the field, grass, wood pulp or even waste materials, ethanol could see even greater use as a green fuel.

Ames Laboratory chemist Victor Lin is working to do just that by pairing high-tech nanoscale porous catalysts with gasification, a technology that turns carbon-based feedstocks, under high temperature and pressure in an oxygen-controlled atmosphere, into synthesis gas. Lin's group is collaborating with engineers at Iowa State University's Center for Sustainable Environmental Technology, a leader in producing high-quality syngas from biomass.

Syngas is made up primarily of carbon monoxide and hydrogen (more than 85 percent by volume) and smaller quantities of carbon dioxide and methane. In studying the chemical reactions in syngas conversion, Lin found that the carbon monoxide molecules that yielded ethanol could be "activated" in the presence of a catalyst with a unique structural feature.

To maximize the surface area of this catalyst to promote the conversion reaction, Lin developed nanoscale catalyst particles dispersed widely within the structure of mesoporous nanospheres, tiny sponge-like balls with thousands of channels running through them. The total surface area of these dispersed catalyst nanoparticles is roughly 100 times greater than the surface area of the same quantity of catalyst material in larger, macro-scale particles.

Ground corn stover is one of the feedstocks being studied for conversion into syngas, which is then converted into ethanol with the use of nanoscale catalysts.

Visualizing tomorrow's power plants

If a picture is worth a thousand words, a 3-D virtual environment could equal a thousand blueprints. That's the hope of an Ames Lab research effort known as the Virtual Power Plant program. When completed, the project will allow planners to see a 3-D representation of every pipe, wire and bolt they design into a power-generating facility.

That kind of visualization is eons beyond computer-aided design, because instead of seeing their plans displayed on a computer screen, engineers can virtually walk through them,

Using 3-D visualization, engineers can walk inside a virtual power plant design and see and correct problems before the plans leave the drawing board.

simply by stepping inside a 3-D theater, such as the V6 Cube located inside Howe Hall at the Iowa State University College of Engineering. The Virtual Power Plant Program will let engineers spot problems simply by eyeing them. Does a pipe need to be rerouted? If so, engineers can quickly change it using a simple control interface.

Nearby, a supercomputer-like cluster of PCs will redraw the plans. Driving those computers is an open-source program called VE-Suite being developed by Ames Lab Program Director for Simulation, Modeling, and Decision Science Mark Bryden. VE-Suite is more than a rendering program. It can calculate the physics behind a power plant's operation. So when changes get made, engineers can assess how those changes will affect temperatures, pressures and other operational elements of the plant – a fact that meshes exactly with the Virtual Power Plant's overarching goal: building a platform to design the next generation of cleaner, safer and more efficient power plants that come on line faster and cost consumers less. But even that might be just for starters.

"We are working to create an interactive visual engineering environment that can be used to design new products, better power plants, new ships, new tractors, or any other engineered product. I believe this is how we will be doing engineering 10 years from now," Bryden says.

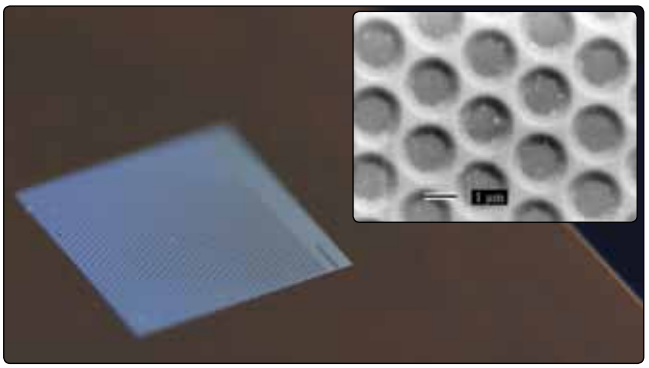
Seeking a brighter solar energy future

On paper, solar energy is a nearly perfect energy source: it's abundant, free, and produces no air or water pollutants. But in practice, solar energy conversion technologies still face cost and efficiency challenges that must be overcome before clean solar energy production can edge out fossil fuel use in the United States.

Ames Laboratory and Iowa State University researchers are collaborating to develop the next generation of solar energy technologies that are highly efficient and can be produced at a fraction of the cost of other solar conversion products on the market today. In the short term, the group plans to create thin-film solar cells from silicon alloys and to develop new solar cell structures using cutting-edge photonic technologies, an area where Ames Laboratory has world-leading expertise. Using such photonic crystal substrates enhances the absorption of red and near infrared photons and increases the current generated by the solar cell.

Theoretically, several photonic crystal designs with submicron periods have demonstrated a boost in solar cell performance. And, based on the designs, the group recently began fabricating amorphous silicon cells that show impressive performance improvements.

"These performance improvements are very cost effective and can be incorporated into manufacturing processes to boost solar cell performance," says Rana Biswas, an Ames Labora-



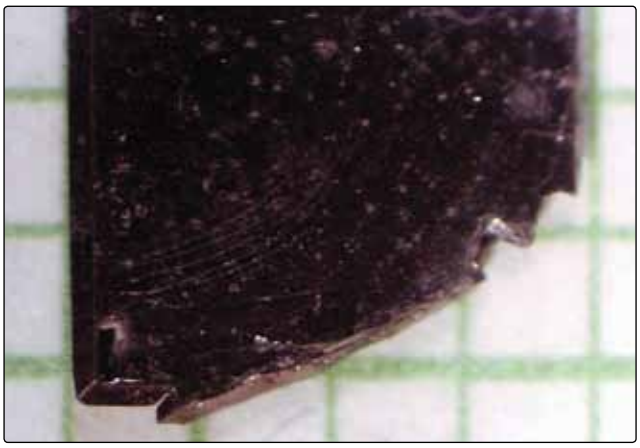
An amorphous silicon solar cell incorporating a photonic crystal lattice fabricated to reflect light back into solar cells is shown in the bright square area.

tory physicist. "Using alloys and nanocrystalline materials is an area where we can make progress that will help improve solar energy technologies."

The project brings together Ames Laboratory and ISU researchers in chemistry, physics, electrical and computer engineering and private industry leaders in thin-film solar cells. Ultimately, the research team hopes that their work will help make solar energy more cost-competitive with other forms of energy and help to spur Iowa's economic development in the solar energy sector.

Heating up the search for zero-resistance transmission

SUPERCONDUCTORS, MATERIALS THAT HAVE ZERO RESISTANCE AT low temperatures, have the potential to dramatically increase the energy efficiency of high-field magnets – like those in the MRI machines found in most hospitals – and to improve the power grid in surge protection and even, possibly, electrical transmission lines. But what is needed to make this happen is the design, discovery, and, ultimately, control over a superconducting material that carries a high current densities in high magnetic fields and requires little cost and cooling.



An iron-arsenic crystal grown by Ames Laboratory senior physicist Paul Canfield's crystal-growth group.

The 2008 discovery of a new type of superconductor based on iron and arsenic sparked a fast-paced, worldwide race to understand, modify and control iron-arsenic superconductors. Ames Laboratory scientists have been right in the thick of things, discovering new compounds and properties, and leading several parts of the effort to characterize and improve these complex compounds. Ames Laboratory scientists have racked up an impressive list of firsts including the first growth and characterization of single crystals of several classes of iron-arsenic compounds; the first discovery of pressure induced superconductivity; and the first experimental determinations of electronic structure and magnetic anisotropy, both of which indicate that these materials may well become practical superconductors.

Within the span of about a year, Ames Laboratory researchers have once again done that at which they excel: they have used the intellectual as well as material resources uniquely available within a national lab setting to assemble a focused, multidisciplinary team to address key problems associated with a new and vital material. Since 2008, nearly 70 scientific papers have been submitted to journals, with over half of them published, drawing over 1,000 citations.

Designing superconducting fault-current limiters

AS DEMAND FOR ELECTRICITY IN URBAN AREAS GROWS, POWER transmission lines are increasingly strained by growing currents. Fault-current limiters protect power grids from sudden spikes in power, much like household surge protectors save televisions and computers from damage during a lightning strike. Superconductors enable a novel and promising type of fault-current limiter — or "firewall" — that rapidly switches to a resistive state when the current exceeds the superconductor's critical current. At the same time, in normal operation, the superconductor's near-zero AC resistance minimizes power loss and makes the fault-current limiter effectively "invisible" in the electric grid.

Ames Laboratory physicist John Clem has developed a theory that identifies a design strategy to reduce costs and improve efficiency in bifilar fault-current limiters, a new and promising type of superconducting fault-current limiter being developed by Siemens and American Superconductor Corp. Clem's work, funded by the Department of Energy's Office of Science, Basic Energy Sciences Office, shows how to predict changes in AC losses in relationship to changes to components in fault-current limiters.

"My theoretical work shows that the AC losses in bifilar fault-current limiters could be reduced by using wider superconducting tapes," says Clem. "This may encourage American Superconductor to manufacture a new line of products."

Research by Ames Laboratory physicist John Clem will help protect power-grid transmission lines from sudden power spikes.

Boosting the power of lithium batteries

DRAMATIC BREAKTHROUGHS IN BATTERY TECHNOLOGY WILL BE needed to fully harness the potential of sun and wind energy sources, power the next generation of electric and hybrid cars, and enable future portable electronics. Lithium batteries are one promising type of storage technology, but as anyone with a cell phone knows, today's rechargeable lithium batteries are limited in capacity and charging lifetimes.

To help develop tomorrow's stronger, longer-lasting batteries, an Ames Laboratory and Iowa State University research team plans to prepare and characterize a new class of particulate anode alloys for lithium batteries. To date, most other anode materials have been developed by chemists, electrochemists, and ceramics specialists. But, current lithium battery material challenges call for a broader combination of expertise, especially in metallurgy. So, Ames Lab created a multidisciplinary team that brings together experts in metal alloy processing, materials characterization, and the electrochemistry of lithium batteries.

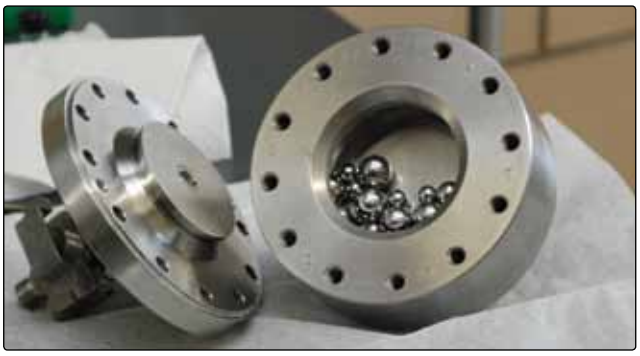
The group, with funding from Ames Laboratory's seed funding program, will use materials processing technologies at the Lab's Materials Preparation Center to create nanosized "core-shell" particles of metal alloys and carbon. The resulting materials may help not only to boost the capacity of lithium batteries, but to also increase the recharge cycle life as well.

"The race is on all across the world to develop new lithium battery technologies, and by combining expertise at the Ames Laboratory and ISU we think our new approaches may be very competitive," says ISU Anson Marston Distinguished Professor of Engineering and Ames Lab associate scientist Steve W. Martin, who leads the project.

Ames Laboratory scientist Steve Martin is working on improving lithium battery technology using nanosized particles to boost the storage capacity of all types of batteries.

Getting more hydrogen in and back out

ONE OF THE BIGGEST STUMBLING BLOCKS TO HYDROGEN FUEL technology is finding a way to store enough hydrogen on-board to make a hydrogen-powered vehicle viable. Storing hydrogen as a compressed gas or even a liquid would still require a prohibitively large tank to give a vehicle the driving range of a gasoline-powered car. It also requires considerable energy to either compress or liquefy hydrogen.



This specially constructed ball mill allows Ames Laboratory researcher Vitalij Pecharsky's group to mechanically combine metal hydrides under a high-pressure hydrogen environment to boost the amount of hydrogen the materials can store.

There are ways to store hydrogen in solid materials, such as complex metal hydrides, but because hydrogen forms such strong chemical bonds, it requires a high energy input to break those bonds to release the hydrogen. That problem can be overcome, but the net hydrogen yield isn't great. The ideal would be to find a way to "saturate" a material with hydrogen to boost the yield, but also make it easily "rechargeable."

Ames Laboratory senior scientist Vitalij Pecharsky and colleagues Marek Pruski, Scott Chumbley and Victor Lin have been working to solve those issues using a somewhat unorthodox method of forming those metal hydrides in the first place. Using a technique he calls "mechano-chemistry," Pecharsky and his research team form the complex hydride compounds without traditional solvents, opting to use high-energy ball milling to combine the materials.

To boost the hydrogen storage capacity, the team is forming the materials in specially designed equipment that allows the milling to be done in an extremely high-pressure (350 bar) hydrogen environment. The work is still in its early stages, but preliminary results show promise.

Reducing friction with nanocoatings

FRICTION IS THE BANE OF ANY MACHINE. WHEN MOVING PARTS are subject to friction, it takes more energy to move them. But if you could manufacture parts with tough, "slippery" surfaces, there'd be less friction, requiring less input energy and the parts would also last longer.

"When a hydraulic pump moves fluid, the friction between the turbine vanes and the housing translates into additional torque needed to operate the pump, particularly at start-up," says Bruce Cook, an Ames Laboratory scientist and co-principal investigator on the four-year, $3 million project. "It takes extra energy to get the pump started, and you can't run it at its optimum (higher speed) efficiency because it would wear out more quickly."

Coating the blades to reduce friction and increase wear resistance could have a significant effect in boosting the efficiency of all kinds of industrial and commercial pumps. According to Cook, a modest increase in pump efficiency could reduce U.S. industrial energy usage by 31 trillion BTUs annually by 2030, or a savings of $179 million a year.

Using a technique called pulsed laser deposition, Cook's team is depositing an ultrathin layer of a boron-aluminum-magnesium ceramic alloy, nicknamed BAM, on hydraulic pump vanes as well as tungsten carbide cutting tools. Eaton Corporation, a leading manufacturer of fluid power equipment, and Greenleaf Corporation, a leading industrial cutting-tool maker, are also involved in the project.

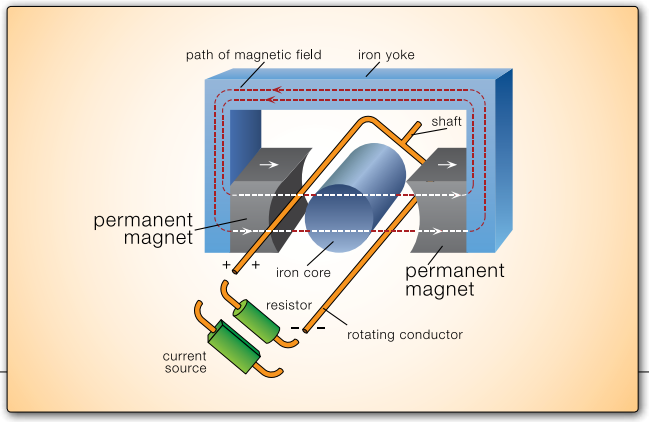
Ames Laboratory researchers Bruce Cook and Alan Russell are studying the use of a ultra-hard, low-friction nanocoating of boron-aluminum-magnesium (BAM) can extend the life of cutting tools and make pumps run more efficiently.

Initial tests at DOE's Oak Ridge National Laboratory, one of the nation's leading friction and wear research facilities, show a decrease in friction relative to an uncoated surface of at least an order of magnitude with the $AlMgB_{14}$-based coating. In preliminary tests, the coating also appears to outperform other coatings such as diamond-like carbon and titanium diboride. The project is funded by the DOE's Office of Energy Efficiency and Renewable Energy.

Boosting electric car's potential

THE SWITCH FROM GAS- TO ELECTRIC-POWERED VEHICLES WILL come about thanks to advancements in many fields, among them magnets. Electric motors found in vehicles typically use both permanent and electromagnets. The permanent magnets provide the continuous force that rotates the electro magnets located at the motor's center. Unfortunately, ordinary permanent magnets won't work efficiently in cars. The reason: cars get hot. Common magnets made from neodymium-iron-boron lose half their power when temperatures reach 100 to 125 degrees Celsius. But an Ames Lab team led by Iver Anderson and colleagues, Bill McCallum and Matthew Kramer, created an alloy from neodymium, yttrium and dysprosium that holds most of its strength at 200 degrees Celsius.

Creating vehicle-friendly magnets was only half the battle for Anderson's team. To be commercially viable, large numbers of the magnets need to be produced cheaply and efficiently. And that required a novel production method. The researchers figured out how to process their alloy into a fine, spherical powder using what's called gas atomization. The technique first reduces the magnetic alloy into a stream of liquefied metal, which is then blasted with supersonic jets of gas. The resulting immense force causes the metal to break up into tiny droplets, which are then deposited in a mold. The process is actually a high-tech variation of injection molding, a mainstay manufacturing technique. Someday it may prove key to making zero-emission electric cars affordable to millions.



Source: Encyclopaedia Britannica, Inc.

Cooling with magnetic refrigeration

When Ames Laboratory senior metallurgist Karl Gschneidner sees a refrigerator or an air conditioning unit, he thinks of the potential energy savings these essential appliances could offer if magnetic refrigeration, a technology he's helped pioneer, becomes reality.

Magnetic refrigeration isn't a new idea. The technology is centered on the giant magnetocaloric effect exhibited by some rare-earth metals that, when placed in a magnetic field, heat up and, conversely, cool down when removed from the field. Such a system is 20 to 30 percent more energy efficient than traditional gas compression cooling and also uses environmentally benign coolants instead of ozone-depleting refrigerants.

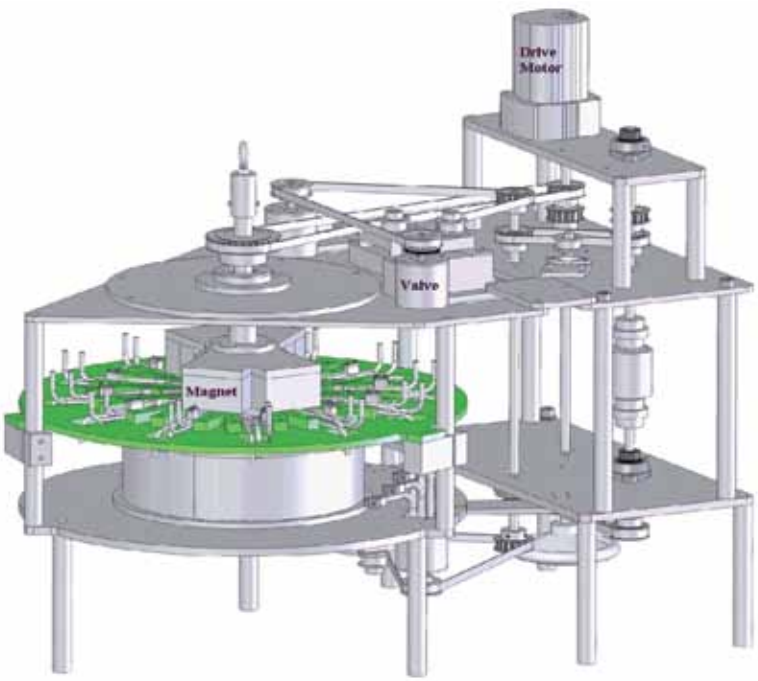
Ames Lab and Astronautics Corporation of America built a proof-of-principle refrigerator in 1997, with Gschneidner's group developing a gadolinium-germanium-silicon alloy and also designing high-strength magnets. Since that time, more than 25 different cooling units have been built and tested throughout the world, though none of the designs has taken off.

Ames Laboratory scientist Yaroslav Mudryk, left, explains how samples are placed in a calorimeter so the effect of magnetic field can be studied at low temperature during a tour of Ames Laboratory by participants in the Thermag III conference.

"At this point, it's really an engineering issue,"Gschneidner says. "We know the concept works, it's just a matter of working around some of the problems."

One of the problems is that the giant magnetocaloric materials are brittle. And because they also change volume in the magnetic field, there's a tendency for cracks to develop over time. Another problem is increasing or concentrating the strength of the magnetic field while keeping the mechanism reasonably compact and cost effective.

Gschneidner hoped to address those and other issues at Thermag III, the 3rd International Conference of IIR on Magnetic Refrigeration at Room Temperature. Hosted by Ames Laboratory and Iowa State University, 150 of the top researchers from around the world gathered in Des Moines in May to discuss emerging trends and research in the field.



This diagram shows a design by Astronautics Corporation of America for a rotary magnetic refrigerator that's 20 to 30 percent more efficient than today's gas compression designs.

Spinning technology into "Gold"

BY MARK INGEBRETSEN

TECHNOLOGY TRANSFER PROFESSIONALS CALL IT "THE VALLEY of Death," the arduous, expensive path companies must follow in order to turn research-lab intellectual property into viable products.

"We do the basic research here at the Lab, and it's normally workbench scale," says Ames Laboratory Associate Director Deb Covey. "Companies must take it from there, and typically, the majority of them never make it through the valley."

That may be true, overall. But an impressive number of companies spawned by Ames Lab technology have beaten the odds. Their success has enabled Ames Lab to earn more in licensing fees than any other Department of Energy facility, even though the Lab is smallest among its counterparts.

Spinoff companies using Ames Laboratory technology have also helped build a high-tech infrastructure destined to renew Iowa's economy as the recession ends. Moreover, the technologies being commercialized by Lab spin-off companies are invariably green, providing new ways to preserve the planet.

A good example is Catilin Corp. The 20-employee Nevada, Iowa, company promises to revolutionize how biodiesel is refined. Caitilin produces catalysts developed by Ames Lab researcher Victor Lin and his team. Lin's catalysts, which Catilin sells to biodiesel refining operations worldwide, can create fuel using any number of substances. Importantly, the catalysts do their work without using precious water resources, which could make them a godsend to the world's poorer, water-deprived nations.

Larry Lenhart, Catilin's CEO, was instrumental in launching the company. Lenhart serves as executive in residence at Mohr Davidow Ventures, a Silicon Valley venture-capital firm with roughly one-third of its portfolio in green tech.

"We saw Victor Lin at a conference," Lenhart says, "and we were very impressed both with his knowledge of the technology and his business sense."

Seizing the opportunity, Lenhart and his MDV colleagues worked with the Iowa State University Research Foundation, which manages tech transfer for Ames Laboratory. An agreement emerged two months later, and Catilin launched, backed by a combination of public and private funds. MDV is currently working with Catilin on another Ames Lab innovation: specially engineered nanoparticles that can produce biofuels from algae. The process could reduce the renewable fuel's production costs – a lot. Ten thousand gallons of biofuels can be made from algae grown on a single acre. (See story on page 8)

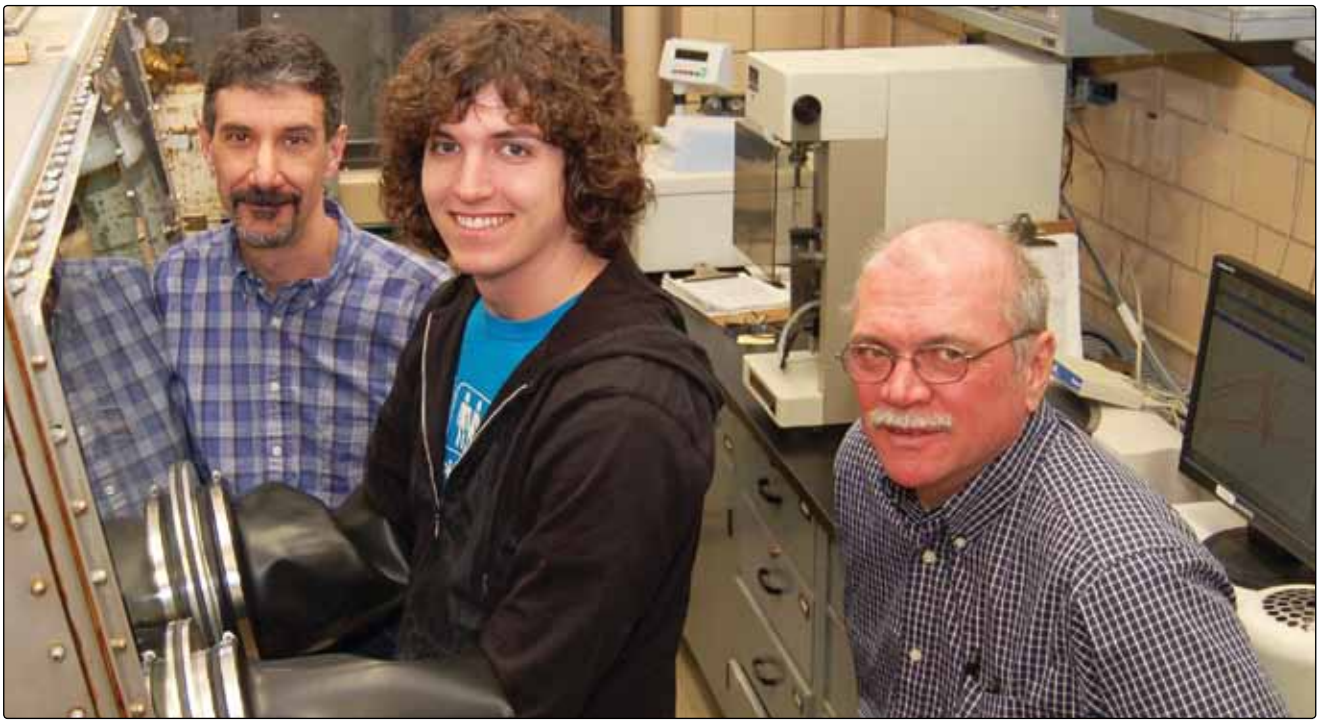
The biggest Ames Laboratory technology-transfer success story, lead-free solder, is also a green solution to a pressing environmental concern. Created by Ames Lab scientist Iver Anderson, lead-free solder was developed to reduce the potential hazards created by the millions of electronic gadgets tossed in landfills. Lead found inside this electronic waste can leech out and poison ground-water supplies. Restrictions on lead content in electronic components in the European Union and elsewhere have helped make the Ames Lab alloy the biggest royalty generator of any invention commercialized by a DOE lab. Today it's licensed by more than 60 companies worldwide.

Catilin employees at the company's facility in Nevada, Iowa.

Recently, an Iowa firm, New Tech Ceramics, licensed Ames Lab-developed nanocoatings, nicknamed BAM and developed by Ames Laboratory scientist Bruce Cook and his team, that reduce friction in pumps and other devices where water is present. The coatings might someday cut U.S. energy use by $179 million annually. (See story on page 12)

Though companies like New Tech and Catilin have already found ripe opportunities in Ames Laboratory technologies, plenty of leading-edge intellectual property remains, says Covey. That is, if the acquiring company is willing to risk traversing the Valley of Death.

One example: a paradigm-shifting incandescent bulb that reflects heat energy back to the filament. Although not yet prototyped, Ames Lab associate Kristen Constant and her colleagues have calculated that the bulb would be more efficient than currently popular, energy-saving fluorescent and LED lights, while retaining an incandescent bulb's pleasing glow. Any takers?



Ames Laboratory Pre-Service Teacher Patrick Rodenborn (center) with mentors and Ames Lab scientists Kevin Dennis (left) and Bill McCallum.

Turning Lab Experience into Classroom Expertise

BY KATIE PARR

SPRING 2009 MARKED THE LAUNCH OF A NEW education program at Ames Laboratory called Pre-Service Teachers, or PST. The program provides Iowa State University pre-service science teachers a chance to work in a research lab and gain first-hand experience that will equip them with a better understanding of the scientific research process. They will then be able to carry their experiences to the classroom.

"Research design and analysis, critical thinking, and teamwork are essential elements to understanding the nature of scientific research, and a student cannot learn them from a textbook nor from a lecture or even a course that includes a lab component," says PST coordinator Adah Leshem-Ackerman.

The program began with one student, Patrick Rodenborn, a senior at Iowa State University majoring in physics. He is currently working on becoming a certified teacher in Iowa, endorsed to teach science. Rodenborn was paired with scientist mentors to provide him with hands-on research experience. Rodenborn's scientist mentors were senior scientist Bill McCallum, assistant scientist Kevin Dennis, and Youwen Xu, a physics professor at Minnesota State University-Mankato who spent her sabbatical year at Ames Laboratory.

"The PST program was a really good way to see what science is really like as opposed to what it appears to be in the classroom," Rodenborn says.

Rodenborn assisted the McCallum research group in determining the best process for the synthesis of a new class of superconductors based on iron and arsenic. Their goal is produce a sample free from impurities that form during the standard processing procedures.

McCallum says he participated in the PST program because "it allows a prospective teacher to experience science as a discovery process rather than an accumulation of facts taught in the classroom. Experiencing the excitement of discovery first hand should help these teachers convey to their students what a career in science is really about."

The PST program also pairs students with a teacher mentor, who will helps them relate what they learn in the lab to teaching in the classroom. Participants' teacher mentors must also be master teachers, which, Leshem-Ackerman explains, are "high school science teachers who have gained much experience in a particular area and are highly respected as a leader in his/her field."

The Ames Laboratory PST program is currently funded by the Iowa Board of Regents Initiative for Math and Science Education Program (IMSEP), and a proposal to continue funding for a summer PST program has been submitted to the Department of Energy's Office of Work Force Development. Only ISU students are allowed to apply for the fall and spring PST programs, but the summer program will be open to all pre-service science teachers who are U.S. citizens.

"We're looking forward to making this program for pre-service teachers a prominent part of the Lab's overall education strategy and to building upon our new relationship in this area with ISU," says Steve Karsjen, Ames Lab's education director

Ames Lab also has an educational program for in-service teachers called Academies Creating Teacher Scientists, or ACTS. This program is offered in the summer and gives current teachers the opportunity to work in a research lab with an Ames Lab scientist.

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