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TransForum

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Special Issue: Batteries—August 2010

China's Minister of Science and Technology Visits Argonne

Wan Gang, Minister of Science and Technology of the People's Republic of China, visited Argonne on Wednesday, July 21, to learn about the laboratory's transportation research program. Wan Gang was accompanied by David Sandalow, Assistant Secretary for Policy and International Affairs, U.S. Department of Energy (DOE).

Wan Gang, Minister of Science and Technology, walks with David Sandalow, Assistant Secretary for Policy and International Affairs, U.S. Department of Energy.

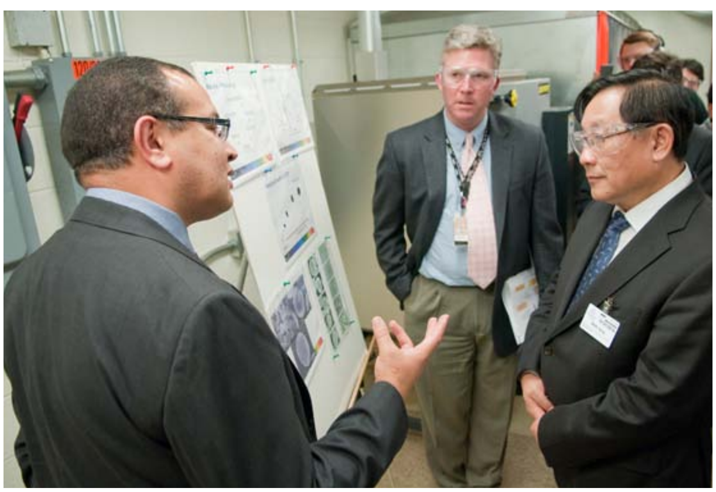
The visit consisted of an overview of Argonne by Al Sattelberger, associate laboratory director for Energy Engineering and Systems Analysis, a tour of Argonne's advanced battery research facilities, a visit to the vehicle and engine dynamometer labs, and a stop at the Advanced Photon Source for X-ray and transportation research highlights.

Wan is an expert on automobiles, and was the president of Tongji University. He was appointed the Minister of Science and Technology of the People's Republic of China on April 27, 2007.

Speaking through a translator, Wan said, "The development of clean and electric vehicles is a national strategic emerging industry…we will devote every effort to promote this industry."

Wan continued, "China is devoted to cutting emissions and saving energy…to realize these goals and commitments, we have to develop clean and electric vehicles. China and the United States both have these national priorities and will work together closely on their common goals."

Representatives from DOE, Argonne and the Chinese Ministry of Science and Technology will meet again in late August.



Argonne materials scientist Khalil Amine (left) explains a research point to Wan Gang (right) while Argonne's Jeff Chamberlain looks on.

Mechanical engineer Thomas Wallner (left) explains Argonne's engine work to Wan Gang (center) and David Sandalow of DOE.

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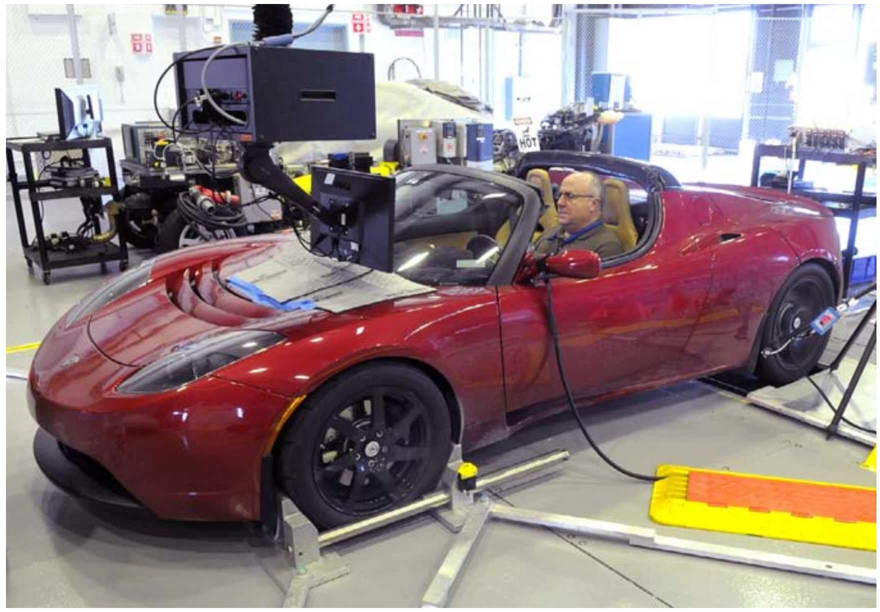
Testing the Tesla

Argonne transportation engineers recently evaluated an all-electric Tesla Roadster at the Advanced Powertrain Research Facility's (APRF's) new two-wheel drive dynamometer laboratory.

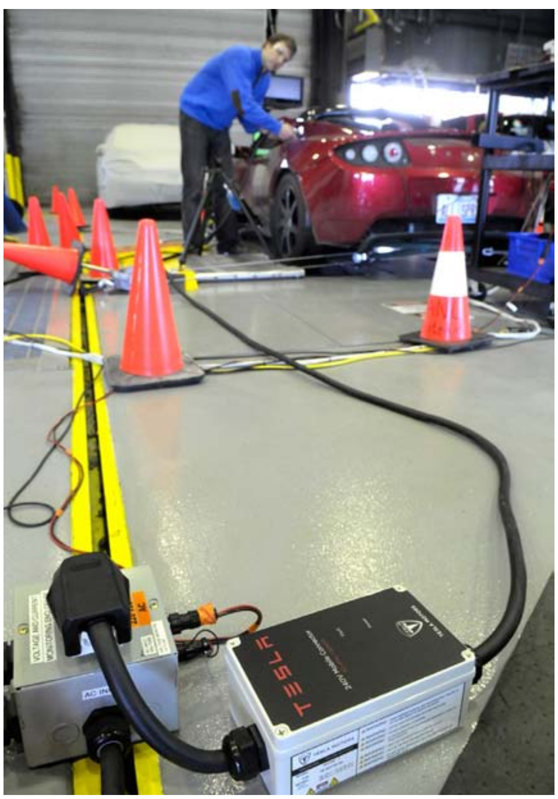
Data obtained from the Tesla will help researchers develop test procedures that provide an unbiased, consistent and practical approach to evaluating electric vehicles.

"As we study these advanced vehicles, our knowledge base of the progression of vehicle electrification technology is enhanced," said chief engineer Mike Duoba. "In a rigorous, controlled manner, we are able to study many vehicle operating conditions to determine the impact on fuel consumption.

"Testing the Tesla at Argonne resulted in some of the best information we've obtained from electric cars," he added.



Geoff Amann, senior technician at Argonne's APRF, takes the all-electric Tesla Roadster through a driving cycle at the Lab's two-wheel dynamometer laboratory.



Mike Duoba, chief engineer at APRF, prepares the all-electric Tesla Roadster for testing.

For example, researchers were able to evaluate several shortcut procedures used to report electrical energy consumption. This could potentially reduce dynamometer test time from 12 hours to 2 hours.

Argonne's work with the Tesla continues its support of the Society of Automotive Engineers (SAE) J1634 standard on electric vehicle testing. Ultimately, the new standard will result in more accurate assessments of electric vehicle range and electrical energy consumption.

The Tesla is owned by a private citizen, who allowed Argonne to test the car for several months.

According to the Environmental Protection Agency, the Tesla Roadster can travel 244 miles on a single charge of its lithium-ion battery pack. The all-electric sports car can also accelerate from 0–60 mph in 3.7 seconds.

Funding for this project was provided by the U.S. Department of Energy, Vehicle Technologies Program under the direction of Lee Slezak.

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Six Myths about Plug-in Hybrid Electric Vehicles

Plug-in hybrid electric vehicles (PHEVs) hold great promise as the key to weaning America from its dependence on imported oil, which represents nearly two-thirds of all the petroleum burned in the United States today.

The U.S. Department of Energy's Argonne National Laboratory has taken a lead role in developing and testing plug-in hybrid technologies. At the Lab's Center for Transportation Research (CTR), principal mechanical engineer Forrest Jehlik and his colleagues work to bring these cars to market quickly and cheaply. Here, Jehlik dispels some commonly held myths about plug-in hybrids.

Myth #1: A significant number of plug-in hybrids are currently for sale.

Although several major auto manufacturers—including General Motors, Toyota, Ford, Volkswagen, and Volvo—have plug-in vehicles currently in the development pipeline, the first wave of these cars is still at least a year away from officially hitting the market, Jehlik said. The first plug-in hybrid for sale will likely be the Chevrolet Volt, which General Motors claims can travel up to 40 miles on a single charge. The Toyota Prius and other hybrids currently on the roads are not plug-ins—their batteries are charged by kinetic energy transferred from the brakes and wheels.

Forrest Jehlik, principal mechanical engineer, dispels PHEV myths.

Myth #2: Researchers can measure the fuel economy for a plug-in hybrid just as easily as they can for gasoline-powered cars.

Establishing fuel economy standards—how many miles a plug-in hybrid vehicle can travel per gallon of gasoline burned—is a complicated question. The answer, Jehlik said, depends entirely on the driving and charging habits of the vehicle's owner. If a particular plug-in hybrid gets 40 miles on a single charge, then a driver who has a 15-mile commute each way to work and does 10 miles of additional driving each day before charging the battery overnight would, theoretically, use no gasoline at all. If the same driver had a five-mile-longer commute, she'd probably burn just over a gallon of gasoline per week, despite driving 250 miles.

Myth #3: Prices for plug-in hybrid vehicles are currently so high because manufacturers are trying to make a killing on them.

"The truth of the matter is that the components required to build a viable plug-in hybrid are still quite expensive," Jehlik said. In many cases, the battery for a plug-in vehicle by itself costs nearly $10,000. Because the price of petroleum remains relatively low, consumers may not yet be willing to invest the extra money in a plug-in vehicle—even with sizable government rebates.

Myth #4: The batteries in plug-in hybrid vehicles are unreliable, possibly unsafe and require frequent replacement.

Most plug-in hybrids currently under development use lithium-ion batteries in their battery packs. Although complex chemical processes produce energy within the battery, vehicle system engineers have built in advanced control systems to prevent fires or other safety issues. "Researchers have devoted just as much time and effort to developing inner-pack safety systems as they have to the batteries themselves," Jehlik said. "Consumers don't need to worry about battery malfunction."

MATT – Argonne's wheeled Mobile Advanced Technology Testbed is outfitted with scalable motor components, extensive instrumentation and a rapid prototyping control system to allow testing of plug-in hybrid electric vehicle systems.

Jehlik and his colleagues in the CTR have also tested the current generation of lithium-ion batteries in what are known as "life cycle vehicle tests," which take the car through its paces for more than 150,000 miles. Even at the end of the car's life, the vast majority of batteries still function quite well, Jehlik said. "When these cars become available for sale, the batteries are going to last as long as any part of them will," he said.

Myth #5: Scientists have identified lithium-ion batteries as the only battery technology that could work in plug-in hybrid cars.

Although lithium-ion technology came to replace nickel-metal hydride (NiMH) batteries as the preeminent focus of electric vehicle development efforts, scientists at Argonne and around the world are currently investigating several different approaches for energy storage that could help to bring down the cost of plug-in hybrids. "Manufacturers are looking at these possible solutions not as silver bullets but as silver shotgun pellets," Jehlik said. "The organizations that hedge their bets among a number of different technologies will likely be the ones that bring vehicles to market the earliest and the most successfully."

Myth #6: America's electric grid can't handle the increased load caused by the charging of millions of electric vehicles.

According to Jehlik, the nation's current electric grid has the capacity to accommodate the imminent rollout of plug-in hybrids onto the country's roads. "If everyone were somehow able to buy a plug-in hybrid tomorrow, that would probably present a problem as far as the supply of electricity is concerned," Jehlik said, "but given the pace that they are likely to enter the market, we won't face a system-wide failure."

However, Jehlik noted that the country's electric infrastructure would need to change eventually—not only to keep up with added demand, but to ensure the smarter transmission, distribution and consumption of electricity.

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Charging Ahead: Taking PHEVs Farther on a Single Battery Charge

Every six months, we're reminded to change the batteries in our household appliances: smoke alarms, flashlights and radios. But what if you had to change the battery in your plug-in hybrid electric vehicle (PHEV) just as often?

Fortunately, researchers at Argonne may have found a way to exponentially increase the calendar and cycle lifetimes of lithium-ion batteries. Electric double-layer capacitors—typically referred to as ultracapacitors—have an energy density thousands of times greater than conventional capacitors and a power density hundreds of times greater than lithium-ion batteries.

> **"Ultracapacitors give an electric vehicle the initial boost it needs to get going."**

In an electric vehicle drivetrain, energy density provides sustained speed, while power density facilitates acceleration. "Energy density is what allows you to run a marathon; power density is what enables you to sprint," said Ted Bohn, an automotive engineer in Argonne's Center for Transportation Research.

Ultracapacitors will dramatically boost the power of lithium-ion batteries, enabling plug-in vehicles to travel much further on a single charge.

"Ultracapacitors aren't of much use just by themselves," he added, "but when you couple them with lithium batteries, they dramatically boost the performance of the entire vehicle."

When an electric vehicle merely needs to maintain a particular speed, it requires little of the battery's power density. However, when the car needs to accelerate from a standstill to a cruising velocity, today's lithium-ion batteries must strain to provide the necessary "oomph."

"Ultracapacitors give an electric vehicle the initial boost it needs to get going," Bohn said.

A PHEV or pure electric vehicle needs a battery with sufficient power density to accelerate the vehicle quickly. A vehicle that uses an energy-dense battery that lacks sufficient power density will fail prematurely, possibly in a matter of months if driven aggressively. By using the same potentially lower cost energy-dense battery, in combination with ultracapacitors, the vehicle will have sufficient performance and the batteries should last 10 years or more.

Today's hybrid cars recharge their batteries by transforming kinetic energy from the wheels into potential electrical energy as the driver brakes. Conventional lithium-ion batteries, however, absorb this energy slowly and inefficiently. By contrast, ultracapacitors, because of their immense internal surface area, sort of soaking up reclaimed energy like a sponge.

"By integrating the entire system," Bohn said, "we can drive down the cost. When we can put these various electronic elements together, we'll transform an $8,000 battery into a $4,000 all-electric drivetrain system."

Funding for this project was provided by the U.S. Department of Energy's Vehicle Technologies Program under Lee Slezak.

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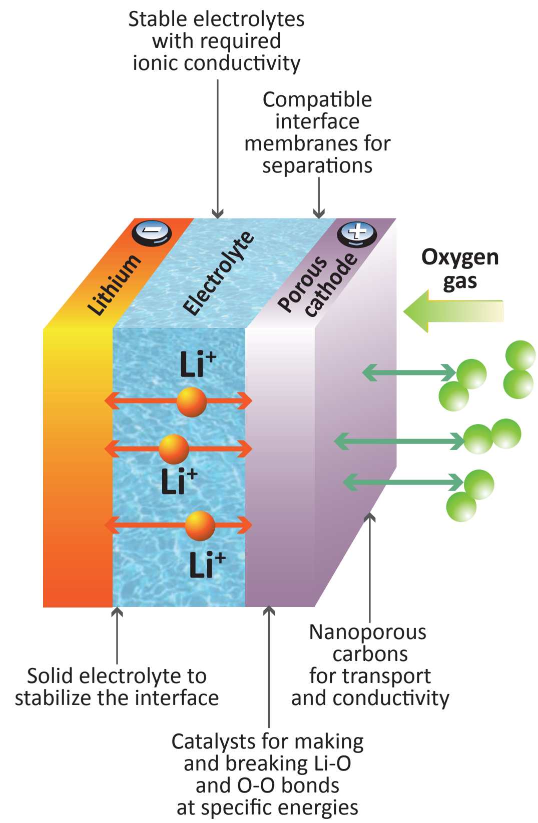
Argonne to Explore Lithium-air Battery

Argonne National Laboratory will begin exploring lithium-air (Li-air) batteries that have the capacity to store up to five to 10 times the energy of lithium-ion (Li-ion) batteries, or almost as much energy as a tank of gasoline of the same size.

Researchers Khalil Amine and Michael Thackeray lead the team that will explore innovative and radically new concepts for dramatically advancing lithium-air batteries.

To develop the Li-air battery, Argonne will leverage its experience with Li-ion batteries, fuel cells and catalysts, its expert staff of scientists and engineers and its most advanced research facilities, including the Advanced Photon Source, the Center for Nanoscale Materials and some of the world's fastest supercomputers.



Li-air batteries hold the promise of increasing the energy density of Li-ion batteries by as much as five to 10 times.

How Does a Lithium-air Battery Work?

A Li-air battery has a positive electrode made of lightweight porous carbon and a negative electrode made of lithium metal. To make electricity, oxygen from the air moves through the porous carbon electrode, where it reacts catalytically with lithium ions and electrons from the external circuit to form a solid lithium oxide.

The solid lithium oxide gradually fills the pore spaces inside the carbon electrode as the battery discharges. When the battery is recharged, the lithium oxide decomposes again, releasing lithium ions and freeing up pore space in the carbon. Resulting oxygen is released back into the atmosphere.

Argonne's Team

Realization of a viable Li-air battery will require a technological breakthrough and it may take one to two decades before the product can be adopted in a commercial application.

"Research programs in lithium-air batteries are few and scattered at the moment," Amine said. "This is an opportunity to put together an interdisciplinary team of scientists and engineers from across the Lab to attack all problems and barriers of lithium-air in a concerted and collaborative way. We can take advantage of the expertise that Argonne has built in batteries, fuel cells, catalysts, modeling and the powerful characterization tools at the user facilities that we have on site."

The team members who will work with Amine and Thackeray are prominent Argonne scientists in materials and systems synthesis, characterization and computer modeling, and include Larry Curtiss, Mali Balasubramanian, Yugang Sun, Nenad Markovic, Di-Jia Liu, Yang Ren, Zonghai Chen, Zhengcheng Zhang, Lynn Trahey, Christopher Johnson and Jeffrey Greeley.

Argonne will also leverage existing relationships with start-up companies and other business partners who will be able to collaborate on commercializing the Li-air battery.

Funding for this project is provided through Argonne's Laboratory-Directed Research and Development Director's Grand Challenge program. The proposal, "Beyond Li-ion Battery Technology for Energy Storage," was submitted by Amine and Thackeray.

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Press release and video interviews: www.anl.gov/Media_Center/News/2009/batteries090915.html

Argonne's Lithium-ion Battery Research Produces New Materials and Technology Transfer Successes

Argonne's highly regarded battery research was recently recognized for three significant accomplishments in the development of new battery materials and the transfer of Argonne-developed advanced high-energy cathode and processing technologies to the private sector. According to Argonne Director Eric Isaacs, "These battery research accomplishments have the potential to put the United States several steps closer to reaching President Barack Obama's goal of putting more than one-million plug-in hybrid electric vehicles on the road by 2015."

Argonne researchers (left) Zonghai Chen, Khalil Amine and Ilias Belharouak won an Excellence in Technology Transfer Award for a battery system expected to help reduce greenhouse gas emissions and America's dependence on imported oil.

Argonne-EnerDel Battery Partnership Wins Tech Transfer Award

Argonne scientists Khalil Amine, Ilias Belharouak and Zonghai Chen won an Excellence in Technology Transfer Award from the Federal Laboratory Consortium for Technology Transfer for their work with EnerDel, Inc., on a very high-power battery system for hybrid electric vehicles (HEVs). This nano-lithium titanate-based battery technology also won an R&D 100 Award in 2008.

Funded by EnerDel, Inc. under the United States Advanced Battery Consortium (USABC) program, the Argonne-developed system has the potential to meet most of the USABC requirements for HEVs. The technology has enormous commercial potential because it enables the development of safe, long-lasting high-power batteries for HEVs. EnerDel gave the Argonne researchers one year to conduct the research in support of the company's two-year commercialization goal.

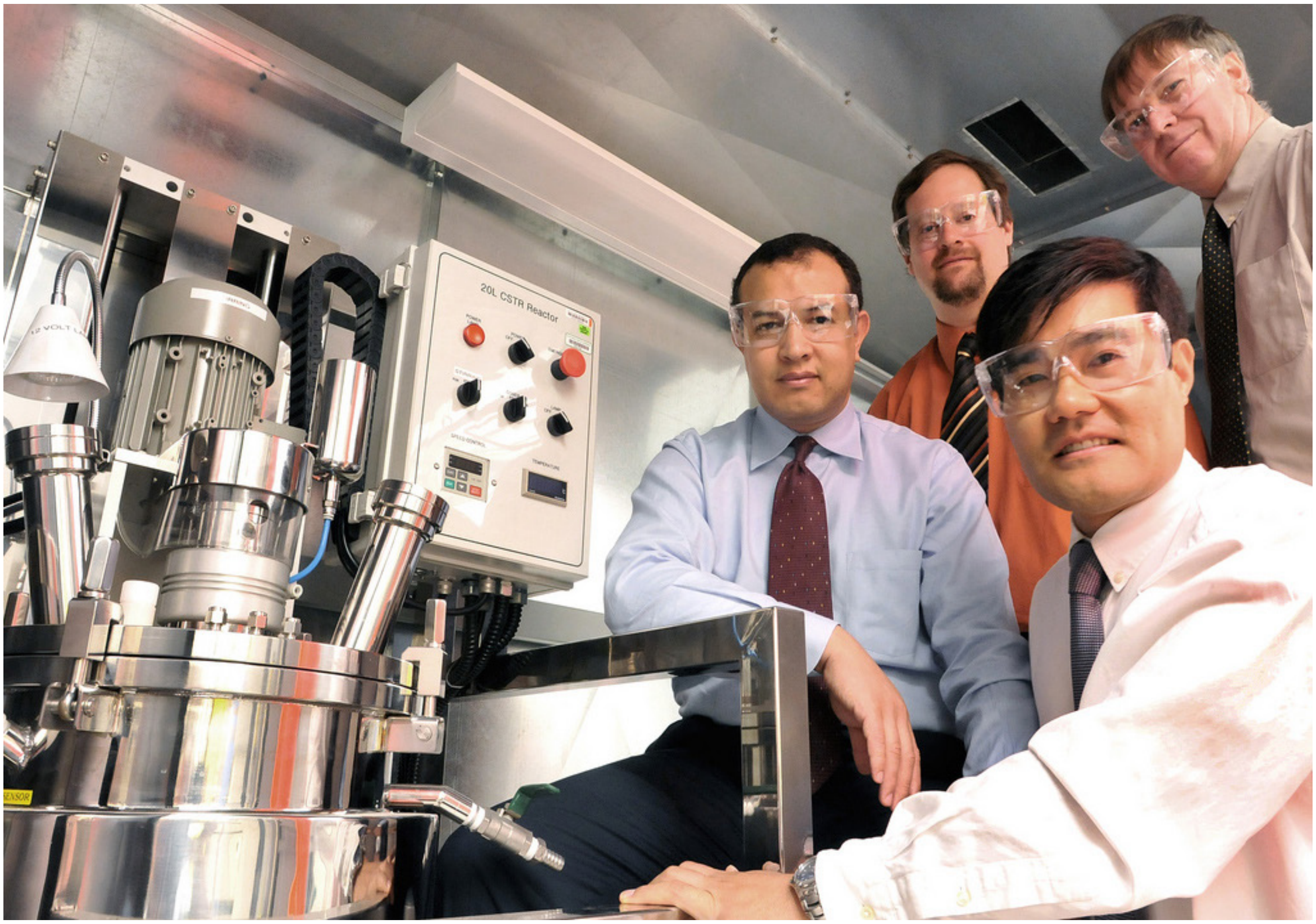
Benefits of the new Li-ion battery include:

- Long cycle life
- Unmatched safety performance compared to other Li-ion battery technologies
- Resistance to overheating during high-rate cycling
- 5-kilowatt cold cranking at -30 °C
- Highest power ever reported in a Li-ion battery, when combined with a lithium manganese spinel
- Reliability
- Low cost

Argonne developed the technology under a Work-for-Others agreement. The U.S. Department of Energy (DOE) Vehicle Technologies Program provided precompetitive research funding.

BASF to Produce and Market Argonne-developed High-energy Composite Cathode Materials

Continuing the theme of transferring DOE-funded research from lab to market, Argonne and BASF (the world's largest chemical company) signed a global licensing agreement that enables BASF to produce and market Argonne's composite cathode materials to manufacturers of advanced Li-ion batteries. The patented cathode materials and the process for making them are licensed to BASF as part of a diverse suite of Li-ion battery inventions and patents developed at Argonne, with funding from DOE's Vehicle Technologies Program.



Argonne National Laboratory battery researchers (left) Khalil Amine, Chris Johnson, Sun-Ho Kang and Michael Thackeray flank a continuously-stirred tank reactor used to produce scaled-up quantities of cathode materials for lithium-ion batteries. Argonne's lithium-ion battery technology will be commercialized by chemical company BASF under a licensing agreement.

The advancement and commercialization of the Argonne-developed cathode materials will result in batteries that perform better, last longer and are safer than today's Li-ion batteries, which is critical for the advancement of plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs).

Argonne's composite cathode materials incorporate a unique combination of lithium- and manganese-rich mixed-metal oxides. Manganese enhances the structural and thermal stability of the electrode, which increases battery safety, according to Michael Thackeray, Argonne Distinguished Fellow and director of the Center for Electrical Energy Storage at Argonne. Manganese is also more abundant and less toxic than cobalt or nickel.

Enhanced stability also permits battery systems to charge at a higher voltage, resulting in much greater energy storage capacity than exists in today's cathode materials—an especially important consideration for vehicular applications.

"Argonne's technology offers a 50–100 percent increase in energy storage capacity over conventional cathode materials," says Thackeray. "In short, it offers the longest-lasting energy available in the smallest, lightest package." In addition, "Argonne's composite cathode materials exhibit outstanding safety characteristics compared to other layered metal oxide cathodes and have the potential to meet the energy requirements for a 40-mile, all-electric range PHEV," according to Khalil Amine, Argonne senior scientist and leader of the Battery Technology group.

Continues on page 10 ⏩

“Battery” from page 9

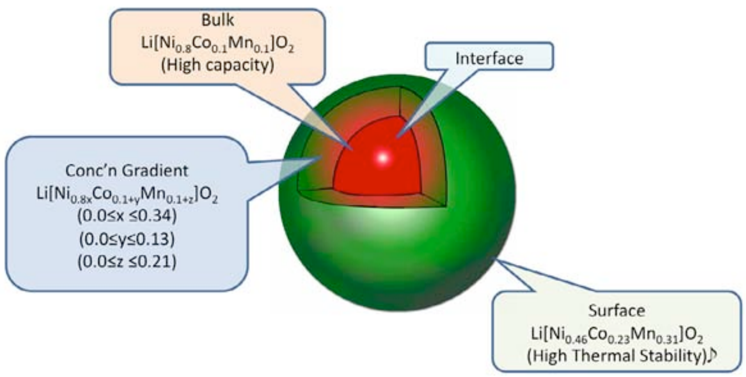
“This licensing agreement has tremendous potential,” says Stephen Ban, Director of Argonne’s Office of Technology Transfer. “BASF’s ability to make these advanced materials widely available will significantly advance the penetration of next-generation lithium-ion batteries into the U.S. marketplace.”

BASF will conduct further Li-ion battery material application development. It plans to build one of North America’s largest cathode material production facilities in Elyria, Ohio.

Global Partnership Produces Safer, Longer-lasting Cathode Material

Researchers at Argonne and Hanyang University in South Korea have developed a new high-energy cathode material that greatly increases the safety and extends the lifespan of Li-ion batteries. This new cathode material is based on a layered lithium nickel cobalt manganese oxide. Each particle has a central bulk that is rich in nickel (Ni) and a manganese-rich (Mn-rich) outer layer, with decreasing Ni concentration and increasing Mn and cobalt (Co) concentrations as the surface is approached. The former provides high capacity, while the latter improves thermal stability.

The transitional nature of the new material’s composition makes it more functional. Says Argonne’s Khalil Amine, “The high-energy material we developed makes up a new class of oxide materials in which the composition of each particle changes from the bulk to the outer layer. Most oxide cathodes have a uniform composition throughout each particle, and offer low capacity and high surface reactivity with the electrolyte.” The new material’s characteristics greatly improve the life and safety of lithium battery materials, while offering very high-energy characteristics for possible use in PHEVs.



Schematic diagram of positive-electrode particle with Ni-rich core surrounded by concentration-gradient outer layer.

“The material has also demonstrated a very high power capability,” said Yank-Kook Sun, co-principal investigator and a professor in the Department of Chemical Engineering at Hanyang University. “We are able to charge the material to 4.3–4.4 volts and attain a very high capacity of more than 210 milliampere hours per gram (mAh/g), with good power capability,” he said. “Conventional cathodes have a capacity of 140 to160 mAh/g.”

Argonne National Laboratory works with DOE’s Office of Vehicle Technologies to develop advanced anode and cathode materials and improve very high-energy lithium-ion (Li-ion) battery technologies for transportation applications. When used in light-duty vehicles, very high-energy batteries will help reduce greenhouse gas emissions and America’s dependence on imported oil.

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New Battery Facilities Will Help Accelerate Commercialization of Technologies

Argonne will soon have three new battery facilities to bolster its research and development of battery materials and batteries for hybrid electric vehicles, plug-in hybrid electric vehicles and all other electric vehicles.

The Lab was recently awarded $8.8 million in American Recovery and Reinvestment Act (ARRA) funding to build a Battery Prototype Cell Fabrication Facility, a Materials Production Scale-Up Facility and a Post-Test Analysis Facility.

After more than a decade of experience in lithium-ion battery research, Argonne scientists are well aware of the challenges of getting manufacturers interested in advanced materials for their batteries. The new facilities will help to greatly accelerate this process.

"Argonne has developed a great number of new and innovative battery materials but most never make it to industrial production," said Gregory Krumdick, a principal systems engineer at Argonne, who will lead the Materials Production Scale-Up Facility. "This facility will be the link to connect the bench-scale research with the battery manufacturing industry."

He said the purpose of the facility is to develop manufacturing processes for producing advanced battery materials in sufficient quantity for industrial-scale testing.

"Processes developed in the lab are not always suitable for large-scale production," Krumdick said. "This facility will provide the means to scale up these processes, as well as to actually produce larger quantities of the materials for evaluation."

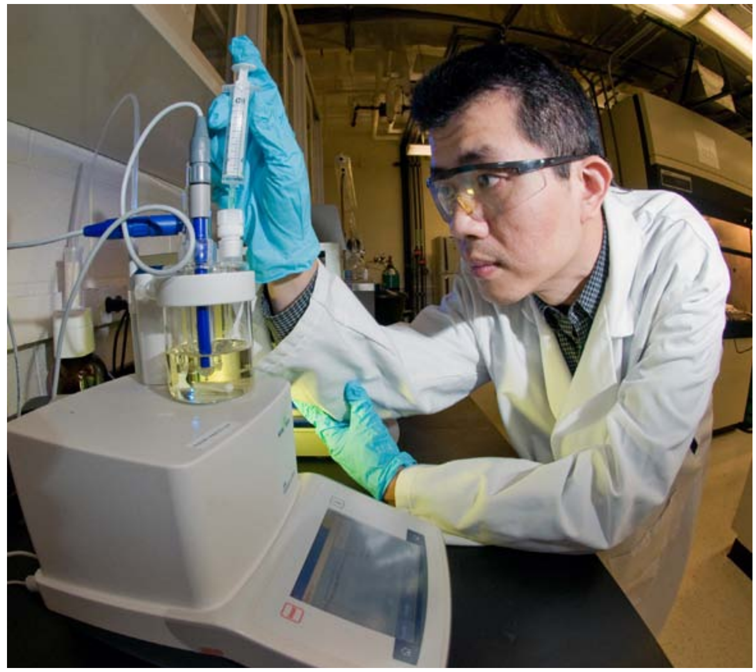
The Materials Production Scale-Up Facility will receive $5.8 million of the ARRA award.

Dennis Dees, an electrochemical engineer at Argonne, will help oversee the new Prototype Cell Fabrication Facility.

"This facility will create a direct pipeline between materials research and battery developers," said Dees. "It will greatly reduce the time to get battery improvements into production."

Dees said the laboratory will spend $1 million on equipment designed to improve the quality and evaluate the performance of newly fabricated cells.

Ira Bloom, a chemist at Argonne, will run the Post-Test Analysis Facility, which is slated to receive $2 million in ARRA funding.



At existing Argonne battery testing labs, researcher Gang Cheng conducts an experiment to detect moisture in battery electrolytes. Moisture is detrimental to the performance and longevity of battery cells.

"Post-test analysis is the natural extension of the battery testing that Argonne has been doing for many years," he said. "As a battery ages during use or testing, performance degrades and changes occur in the battery materials. Post-test analysis lets us see what physical changes occurred."

Bloom said his facility will be up and running in the next two years. Its activities' data will inform scientists and engineers of deficiences so they can make improvements in battery performance and life.

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Argonne Charges Ahead with Smart Grid Research

President Barack Obama has called for one million plug-in hybrid electric vehicles (PHEVs) to hit the road by 2015. Subsidies encouraging both PHEVs and electric vehicles (EVs) support this goal. If the combined demand for these vehicles skyrockets, utilities' power networks could be strained to the limit, requiring upgrades.

That is why the U.S. Department of Energy (DOE) is analyzing how the power grid can be redesigned to better meet America's energy needs. A multidisciplinary mix of scientists and engineers from Argonne National Laboratory is working to help develop a "smart grid" that will not only adapt in real-time to handle larger electricity loads, but also operate more efficiently and reliably than the existing grid.

The smart grid will move our country's electrical grid into the digital age. By integrating real-time, two-way communication technologies into the power grid, the nation will have a more robust and efficient system that empowers consumers to "talk" to the grid to choose where their electricity comes from and when they want it delivered.

"The smart grid doesn't propose to revolutionize the way we do power," said Ted Bohn, an electrical engineer at Argonne's Center for Transportation Research. "It's just about doing the same things more efficiently—smarter."

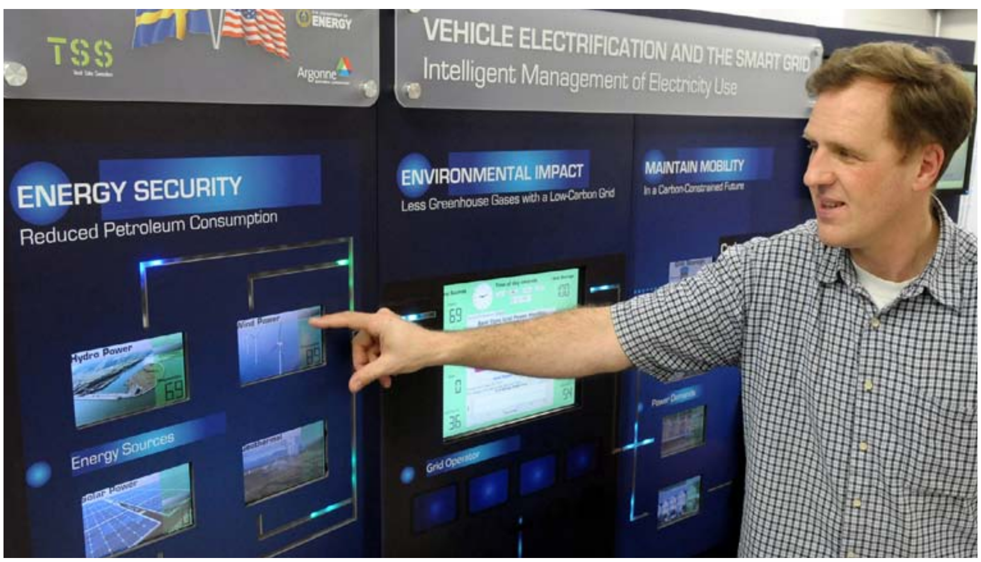
Plugging Away with Electrified Vehicles

Argonne transportation engineers are working to develop suitable standards for PHEVs and EVs, enabling cost-effective and smart interaction with the grid. For example, Bohn sits on the international committee working to develop the Society of Automotive Engineers' new connection standard called J-1772. The group is defining this standard, so manufacturers can build compatible connectors and vehicle sockets that will support both charging and two-way communication.

Transportation researchers are also validating some of the communications technologies that are being proposed to communicate between the vehicle's smart charger and the electrical infrastructure smart meters.

In December 2009, Bohn and Keith Hardy represented Argonne at the Bright Green Expo in Copenhagen, Denmark. They were on hand to discuss the efforts of DOE and Argonne to help facilitate the interaction of PHEVs and EVs with an updated smart grid.

To help visitors grasp the big picture, Bohn and Hardy brought along an interactive demonstration created by Argonne that illustrates the possible relationships between the nation's energy supplies, electric power grid operators and utilities, vehicles and consumers.



Using Argonne's interactive demonstration, engineer Ted Bohn demonstrates how the Smart Grid can play a role in lessening our country's dependence on foreign oil. The demo shows the possible relationships between energy supplies, operators and utilities, PHEVs and consumers.

The Argonne display features a mock-up of the J-1772 standard for connectors being developed for plug-in vehicles.

Supply and Demand

Les Poch and Matt Mahalik of Argonne's Center for Energy, Environmental, and Economic Systems Analysis (CEEESA) are concerned with the demand on the existing power grid as more and more electric vehicles hit the road. Poch and Mahalik model the generation capacity needs and the potential strain on the transmission grid if millions of new PHEVs and EVs were to plug in every night.

"Depending on what Americans do with their new cars, electricity suppliers could be overwhelmed—or they could stand to gain a lot," Poch said.

Electricity suppliers closely monitor regional demand. To prevent shortages, they must predict how much electricity will be needed at any given time.

Electric vehicles stand poised to throw off the now stable pattern. No one knows how quickly electric cars will catch on, in what areas they'll be most popular, or when everyone will choose to plug in their cars.

Today's electricity demand follows well-defined cycles. Demand increases during the daytime when commuters head to work, as homes and offices turn up the air conditioning and factories power up the machinery, and falls sharply during nighttime.

"The way we build power plants now is to make sure we have enough to meet the highest demand possible—the maximum amount of power on the afternoon of the hottest day of the year," said Vladimir Koritarov, deputy director of CEEESA. "Then they add some more for backup in an emergency. The rest of the year we won't need nearly so much power, but we have to be prepared for that one day."

For this reason, utilities must maintain a large reserve capacity that is unused for the majority of the year. Koritarov thinks that with the right approach, the smart grid could work out to everyone's advantage.

By using incentives to smooth out demand for electricity between day and night, a utility can produce power more economically. Also, smart charging of electric and hybrid vehicles during the off-peak periods can significantly help with that goal by filling up "demand valleys."

Grid Energy Storage

A significant stumbling block for power distribution is the lack of technology to store power for extended periods. Stored energy from variable resources, such as solar and wind, could be fed back into the grid at peak times to reduce the strain on the grid and conventional power plants.

Vehicle charging stations, like Coulomb Technologies' ChargePoint, will enable communication between the vehicle, consumer and electric utility companies. Argonne engineers are active in validating these technologies.

A team of Argonne materials scientists, chemists and engineers—already renowned for their successes in the field of advanced battery development for vehicles—is working to develop large-scale energy storage technologies that will capture energy whenever it's available and store it for use at a later time.

"The smart grid isn't a theoretical concept," said Bohn. "It's happening now."

Across the country, aspects of the smart grid are being tested in homes and neighborhoods. As America moves forward, science and Argonne work to improve the future—for households, businesses and utilities alike.

Funding for this research effort was provided by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's Fuel Cell Technologies Program under Fred Joseck and Vehicle Technologies Program under Patrick Davis.

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Center for Electrical Energy Storage Promises Advances in Transportation Technologies

Background

The U.S. Department of Energy's (DOE's) Office of Science recently awarded Argonne two Energy Frontier Research Centers (EFRCs). With these awards comes the possibility for important discoveries in advanced transportation technology. The Centers, each funded at $19 million over five years, will work with partnering universities to advance basic science in electrochemical energy storage and in catalysis. DOE established the EFRCs as a means to enlist the talents and skills of the very best American scientists and engineers to address current fundamental scientific roadblocks to U.S. energy security.

Center for Electrical Energy Storage

The Center for Electrical Energy Storage (CEES) will explore the challenges that have limited the advancement and use of electrochemical energy storage (EES) technologies, including batteries and supercapacitors for transportation, residential, and commercial use. Although EES devices have been available for many decades, there are fundamental gaps in understanding the atomic- and molecular-level processes that govern their operation, performance limitations and failure. With a full understanding of these processes, new concepts can be formulated for addressing present EES technology gaps and meeting future energy storage requirements.

Under the leadership of Argonne's Michael Thackeray, the CEES brings together 17 scientists from Argonne, the University of Illinois at Urbana-Champaign and Northwestern University. "CEES' main goal," Thackeray said, "is to gain a fundamental understanding of the interfacial phenomena that control electrochemical processes in electrical energy storage devices. This understanding will lay the foundation for the synthesis and design of electrode and electrolyte architectures that will lead to the discovery of future generations of energy storage materials and enable the development of batteries with enhanced capacity, power, safety and longevity."

The Center's emphasis is on lithium batteries since they provide the best opportunity for greater-than-incremental advances.

Scientists for CEES will use the research facilities of each partnering organization, including Argonne's Advanced Photon Source, Center for Nanoscale Materials and the Argonne Leadership Computing Facility. The CEES also will use the resources of Argonne's Applied Battery Research and Development Program.

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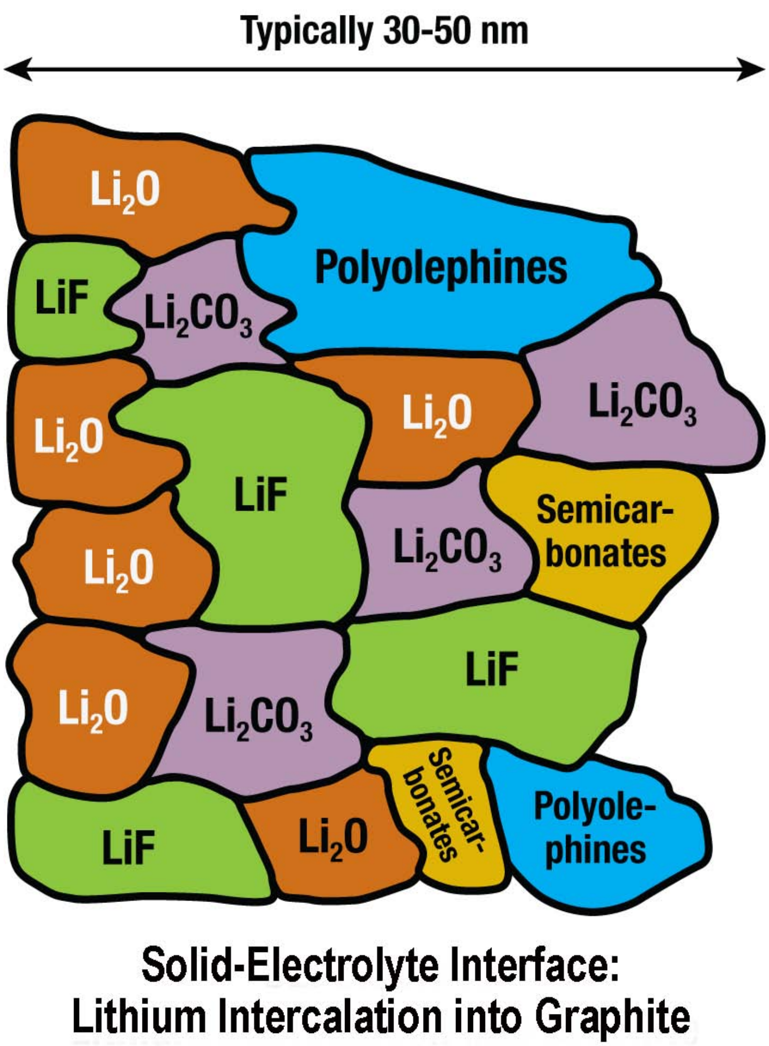

The solid-electrolyte interface is a critical component in electrochemical energy storage. Because of the high reactivity between the electrolyte and the electrodes at the SEI interface, Li-ion batteries show limited calendar and cycle life--less than two years, which is much lower than the 15 years required for enabling this technology in vehicles.

For more information on CEES, contact
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EFRC Web site: www.er.doe.gov/bes/efrc.html
CEES Web site: www.anl.gov/energy-storage-science

PHEVs Need Further Research for Acceptable Payback

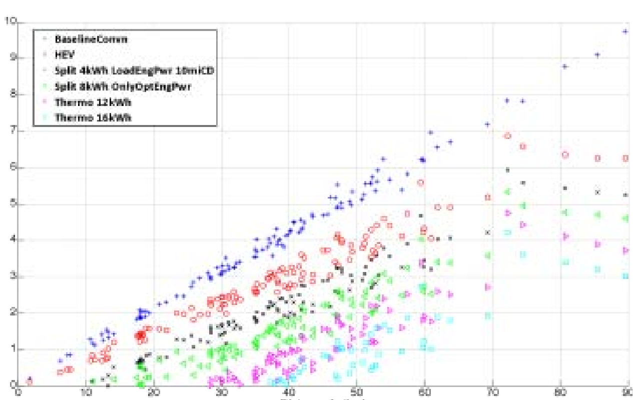
Aymeric Rousseau and his team at Argonne studied the impact of real-world drive cycles on the fuel efficiency and costs of different plug-in hybrid electric vehicle (PHEV) configurations. They found that while different PHEV configurations all demonstrated great potential for replacing gasoline (with less gasoline consumed as more electricity was used), the benefit of adding a larger battery seemed to decrease with increasing battery pack size.

“In general, the larger the battery, the more fuel saved,” said Rousseau, principal investigator of the vehicle modeling and simulation group. “But with every increase in battery energy, there was no proportional decrease in fuel consumption.”

The study used Argonne’s Powertrain System Analysis Toolkit© (PSAT) for test simulation. The battery power was sized to follow a specific all-electric mode driving cycle to meet the all-electric range (AER) requirements. Results showed that the fuel saved by going from 4 to 8 kilowatt-hours (kWh) was much greater than the fuel saved going from 12 to 16 kWh (see chart below).

Battery energy use improved with the smaller batteries. For the 4kWh battery, 100 percent of the usable stored energy was consumed by the vehicle. While using the 8kWh battery, only 93 percent of the available energy was consumed. Some available energy remained for the larger batteries due to shorter trips. However, the vehicle continued to carry the battery energy that was not used, and the added weight of the larger battery impacted the vehicle’s fuel efficiency.

Fuel Consumption as a Function of Distance



Drive Cycle Description and Analysis

Real-world drive cycles were measured by the U.S. Environmental Protection Agency in a 2005 study in Kansas City, Missouri, with more than 100 different drivers participating. PHEVs produced in 2001 and later were instrumented and their driving statistics were collected for a day. Vehicle speed was collected independently from the conventional vehicles on a second-by-second basis through an onboard diagnostic port and a global positioning system device.

Key Findings

Since drive cycles had different characteristics based on distances driven, the benefits of each vehicle configuration were dependent on how far the vehicle was driven. While electrical consumption was similar for short and long driving distances because they depended more heavily on the electrical power, the main differences occurred during medium distance trips. With medium trips it was more difficult to measure the benefits since there were low and high electrical energy driving demands.

Based on these characteristics and cost assumptions, the cost of PHEVs remains high. For the average driver, results of a cost-benefit analysis showed that assuming an electrical cost of $0.09/kWh and a fuel cost of $4/gallon, it would take 8 to 12.5 years to recover the additional cost of the PHEV and 7.5 years of driving an HEV to recover that vehicle’s additional cost, compared to a conventional vehicle. More research and development are needed to improve the cost efficiencies of batteries and fuel.

A portion of this broad study was presented at the 2009 Advanced Automotive Battery Conference (AABC) in Long Beach, California, on June 11, 2009.

This research was supported by the Department of Energy’s Vehicle Technologies Program under the direction of Lee Slezak and Phil Patterson.

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Engineering specialist Panos Prezas examines lithium-ion battery cells at Argonne's Battery Test Facility. Argonne's already renowned battery research program will soon take a significant leap forward with the addition of three new facilities—Cell Fabrication Facility, Materials Production Scale-up Facility and Post-test Analysis Facility (see story on page 11).

PUTTING ARGONNE'S RESOURCES TO WORK FOR YOU

Industrial technology development is an important way for the national laboratories to transfer the benefits of publicly funded research to industry to help strengthen the nation's technology base. The stories highlighted in this issue of TransForum represent some of the ways Argonne works with the transportation industry to improve processes, create products and markets, and lead the way to cost-effective transportation solutions, which in turn lead to a healthier economic future.

By working with Argonne through various types of cost-sharing arrangements, companies can jump-start their efforts to develop the next generation of transportation technologies without shouldering the often prohibitive cost of initial R&D alone. Argonne has participated in dozens of these partnerships and has even been involved in helping to launch start-up companies based on the products and technologies developed here.

If working with world-class scientists and engineers, having access to state-of-the-art user facilities and resources, and leveraging your company's own capabilities sound like good business opportunities to you, please contact our Technology Development and Commercialization Division and see how we can put our resources to work for you.

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