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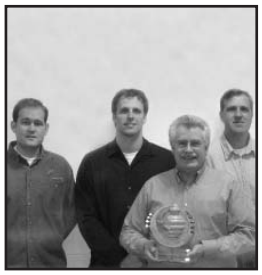

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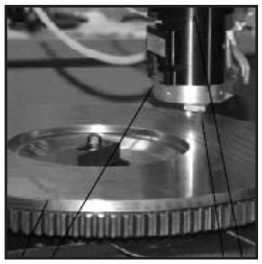

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VIEWPOINT

Argonne and Industry Leverage Resources to Turn "Shredder Residue" from Junked Vehicles into Marketable Materials

At the end of their serviceable lives, about 15 million vehicles annually are discarded and sent to recycling companies for shredding. Much of the nonmetallic material in these vehicles cannot be recycled. This leftover "shredder residue," comprising about 25 percent of every junked vehicle, must then be landfilled at a significant cost to the vehicle recycler. Together Argonne, the American Plastics Council, and USCAR will pursue an aggressive research program to develop and demonstrate technologies to recover and recycle automotive materials within the existing recycling infrastructure. *Page 2*

RESEARCH REVIEWS

Modeling Collaboration Is a Win-Win Situation for Fuel Cell Research

One of the primary advantages of large multidisciplinary research organizations like Argonne is the opportunity for synergistic collaborations between research groups. In a recent example of such a collaboration, researchers in Argonne's Center for Transportation Research and their colleagues in the Chemical Engineering and Nuclear Engineering divisions worked together on a project to establish the energy storage requirements for three vehicle platforms (compact car, mid-size car, and sport utility vehicle) that employed projected "midterm" (2005–2007) fuel cell technologies. *Page 4*

Argonne's Center for Transportation Research Honored for Technical Contributions to Challenge Bibendum

Argonne National Laboratory's Center for Transportation Research received an award for its significant contributions to Challenge Bibendum, the world's largest event designed to showcase and provide a real-world assessment of progress in the development and availability of earth-friendly vehicles. Argonne was the only national laboratory recognized for its technical contributions to this high-profile event. *Page 5*

Argonne's Weld Monitoring Technology Finding New Roles

The infrared (IR) sensing system developed by Argonne and industrial partners for real-time quality monitoring of laser welding processes may be adapted for similar use in heat-treating applications. A leading U.S. automotive manufacturer is evaluating the technology for its ability to monitor a heat-treating process for automotive parts. *Page 6*

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PUTTING ARGONNE'S RESOURCES TO WORK FOR YOU *Page 8*

Argonne and Industry Leverage Resources to Turn "Shredder Residue" from Junked Vehicles into Marketable Materials

White signs placed along the roads at the Argonne site on December 2, 2003, directed visitors to the "Vehicle Recycling Event." Although the signs were small and unremarkable, they pointed the way to something fairly momentous: the future of plastics recycling.

At the "Vehicle Recyling Event," the U.S. Department of Energy, Argonne National Laboratory, the Vehicle Recycling Partnership of USCAR (a partnership of DaimlerChrysler Corp., Ford Motor Co., and General Motors Corp.), and the American Plastics Council announced the signing of a five-year, multimillion-dollar cost-shared Cooperative Research and Development Agreement (CRADA) designed to enable cost-effective recycling of end-of-life vehicles.

"This project brings together the American Plastics Council's knowledge of polymers and recycling processes, Argonne's research expertise, and USCAR's understanding of the marketplace," said Harvey Drucker, Argonne's Associate Laboratory Director. "Together as a team, we can lead the development of viable solutions to the vehicle recycling challenges of today and the future."

With greater demands for better fuel economy and lower emissions, manufacturers are incorporating increasing amounts of lightweight and nonmetallic material into vehicles. At the end of their serviceable lives, about 15 million vehicles annually are discarded and sent to recycling companies for shredding. Much of the nonmetallic material in these vehicles cannot be recycled because it is too hard to separate and sort the materials and because there is no real market for the recycled plastics. This leftover "shredder residue," comprising about 25 percent of every junked vehicle, must then be landfilled at a significant cost to the vehicle recycler. Together Argonne, the American Plastics Council, and USCAR will pursue an aggressive research program to develop and demonstrate technologies to recover and recycle automotive materials within the existing recycling infrastructure. The CRADA team will solicit help from all the key stakeholders.

"Vehicle recycling can be a self-sustaining process that pays for itself in the United States," said Mike Fisher, Director of Technology for the American Plastics Council. "The headway we make in boosting vehicle recyclability will be a boon to the American recycling industry, and the American Plastics Council is pleased to be actively involved in the search for optimal, sustainable solutions to the management of end-of-life vehicles."

A new pilot recycling facility already operating at Argonne (see story on page 3) will serve as a focal point for the broader research that will be conducted by the CRADA partners.

Argonne's pilot facility begins with bulk separation of all shredder residues into four categories: fines (iron oxides, other oxides, glass, and dirt), polyurethane foams, polymers (polypropylene, polyethylene, acrylonitrile butadiene styrene [ABS], nylon, polyvinyl chloride [PVC], polyester, and other materials), and ferrous and nonferrous metals.

Plastic-rich streams, iron oxides, and polyurethane foam can each separately be recycled to other uses. Tests show that the resulting polyurethane foam meets performance criteria for new-material carpet padding and for reuse in automotive applications. The process is fully continuous, minimizing materials handling and labor costs.

AUTO RECYCLING AGREEMENT — Richard T. Gutowski of DaimlerChrysler Co. pours auto-shredder residue that has been cleaned and sorted for recycling. Watching are (left to right) Ed Wall of the U.S. Department of Energy, Harvey Drucker of Argonne National Laboratory, and James Kolb of the American Plastics Council. They are celebrating a five-year cooperative research agreement that will build on recycling technology developed at Argonne to create a cost-effective process for recycling end-of-life vehicles.

"The CRADA allows Argonne, the American Plastics Council, and USCAR to leverage significant technical resources," said Pat Flaherty, Executive Director of USCAR. "Together, we have the potential to make a substantial positive impact on the recycling of materials from end-of-life vehicles in the United States."

Award-Winning Researchers Introduce World's First Continuous, Multistage Plastics Separation Plant

What is the future of plastics recycling? According to Argonne's Bassam Jody, "plastics use is on the rise, and because plastics are not biodegradable, the need to recycle them will become more pressing with time." Thanks to the ongoing innovations of Jody and his colleagues, Ed Daniels and Joe Pomykala, Argonne has the technology to address this need: a new six-stage plastics recycling plant that builds on Jody's award-winning foam recycling process. "As far as we know, this is the first continuous, multistage plastic separation plant in the world — our new recycling process works for just about all mixtures of plastics generated by industry."

Ed Daniels, who is justifiably proud of his group's work, anticipates that the new process will offer key benefits for industry, consumers, and the environment. "For industry," explained Daniels, "the new process provides lower-cost raw materials. As a result, consumers will pay less for the products made with recycled materials." In terms of the environment, the new process reduces the amount of waste going to the landfill. It also saves energy that otherwise would be used to make plastics that would be replaced by recycled material.

This advanced recycling technology didn't happen overnight. "The current plant represents extension and improvement," explains Jody. "We learned from the previous plant about what types of equipment work reliably and adapted them to the new plant." Jody and his colleagues have overcome a number of technical hurdles. For example, they have identified properties of solutions that are selective toward an individual plastic, thereby maximizing recycled product purity and yield. The new plant also has an eddy current separator and a large-scale granulator. "We have also reduced the cost of the equipment by using innovative designs to make the process economical," Jody added. Plus, the plant will be far more extensively automated than the first one — and eventually, it could be computerized.

Once it is fully operational, the plant will be able to recover four to five products from a single waste stream. The new plant advances the state of the art because it is the only one — at an industrial scale — that can be used to separate plastics with overlapping density ranges, which it can do cost-effectively. One of the most noteworthy features of the process is its design capacity: it is able to process 1,000 pounds of plastics per hour.

Separating high-purity plastics from the rest of the waste stream has been a challenge because many conventional separation methods depend on material density — until now, plastics that were similar in density could not be separated to a high enough purity — or they employ large quantities of organic solvents, which pose environmental risks. Argonne's process is the only technology that can successfully produce recycled ABS with a purity of greater than 99%.

The hallmark of the new process — the key feature that separates the complex waste — is froth flotation. The new froth flotation process involves a series of six tanks. Each tank in the continuous process has a specific function, depending on the plastic that is being recovered. "The only difference between the tanks is the chemical composition of their contents. We can choose the most appropriate chemical to be used in a given tank to obtain the product we need," Jody said. For example, the light plastics go into the first tank. The second tank is used to separate heavy plastics, like PVC, and residual metals.

Already, Argonne's froth flotation process has successfully recovered selected plastics from automobile shredder residue, disassembled car parts, industrial scrap plastics, and consumer electronics. The technology is both highly selective and effective: it achieves high purities and high yields for the recovered plastics, and so it should be attractive to industry worldwide. According to Daniels, a two-year payback is realistic. "Because of the potential cost-effectiveness of plastics recyling," explained Daniels, "industries in Europe are pursuing this process more aggressively than in the United States. "In Europe, it costs $100–$200/ton to dispose of waste in landfills, while in the United States, it costs $20–$40/ton. Given rising disposal costs, though, U.S. industry is showing increased interest.

Before Argonne's technology, nobody had a way to cost-effectively separate high-purity plastics from a waste stream of incompatible mixed plastics. And plastics lose their value if they cannot be separated completely. Jody and his colleagues continue to advance the state of the art by applying their expertise in mechanical separation and froth flotation to create ever-more sophisticated technology. If history is any indication, they will make complex plastics recycling as simple, cost-effective, and environmentally sensible as other forms of recycling.

Highly pure recycled plastic emerges from one of several separation tanks at the U.S. Department of Energy FreedomCAR and Vehicle Technologies Program's demonstration facility at Argonne for recycling end-of-life vehicles.

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Modeling Collaboration Is a Win-Win Situation for Fuel Cell Research

One of the primary advantages of large multidisciplinary research organizations like Argonne is the opportunity for synergistic collaborations between research groups that meet the goals of the project and simultaneously benefit science on many fronts. A recent example of such a collaboration involved researchers in Argonne's Center for Transportation Research (CTR) and their colleagues in the Chemical Engineering (CMT) and Nuclear Engineering (NE) divisions.

The staff of Argonne's Fuel Cell Program was tasked by its U.S. Department of Energy (DOE) sponsor to establish the energy storage requirements for three vehicle platforms (compact car, mid-size car, and sport utility vehicle) that employed projected "midterm" (2005–2007) fuel cell technologies. The researchers from the Fuel Cell Program worked with researchers in CTR to develop baseline models for these conventional platforms using Argonne's Powertrain System Analysis Toolkit© (PSAT) software — a versatile powertrain modeling software that realistically simulates vehicle fuel economy, emissions, and performance. According to CTR's Aymeric Rousseau, "The plan was to use suitably sized fuel-cell-based powertrains for each platform, as indicated by PSAT, to compare fuel storage requirements, assuming that the fuel cells would be powered by compressed hydrogen. That meant, for example, modeling a 90-kW fuel cell that would offer the same performance (acceleration, maximum speed, etc.) as a compact car's 86-kW internal combustion engine."

Researchers in the NE division developed models for the pressurized, direct hydrogen, polymer electrolyte fuel cell systems needed for the different vehicle platforms. The fuel cell systems were designed by using NE's General Computational Toolkit (GCTool). The team quickly found that the comprehensive models in GCTool ran slowly in PSAT's vehicle environment. The models did not work optimally with PSAT because the two programs were written in different languages and there was no means of translating from one language to another. "What we had to do was to develop an alternative set of dynamic models for fuel cell system components and write a translator for the GCTool 'driver' to produce a dynamic link library for the fuel cell system that would interface with PSAT's language," says NE's Rajesh Ahluwalia.

The resulting modified GCTool software, called GCTool-Eng, worked like a charm — allowing the researchers to study the potential for gains in fuel economy with hydrogen fuel cell vehicles and determine the energy storage requirements for the three vehicle platforms. The study showed that the fuel economy of mid-term hydrogen fuel cell vehicles can be 2.5–2.7 times the fuel economy of the current conventional gasoline internal combustion engine vehicles on the same platform. The study also showed that the vehicles need 4.3–6.5 kg of onboard recoverable hydrogen to achieve a 320-mile driving range between refuelings. The researchers used these data to estimate the fuel tank weight and volume requirements if hydrogen was stored at 5,000–10,000 psi.

Fuel Economy (mpg) Conv/FC	28/74		23/62		20/50	
	Compact		Mid-size Car		SUV	
Tank Pressure (psi)	5,000	10,000	5,000	10,000	5,000	10,000
H_2 Stored (kg)	4.3		5.1		6.4	
Tank Volume (l)	205	150	240	165	295	200
Tank Weight (kg)	60	75	75	80	80	95

Argonne's multidisciplinary study revealed that the fuel economy of mid-term hydrogen fuel cell technology can be 2.5–2.7 times the fuel economy of present-day conventional vehicles on the same platform. Hybridization can further improve the fuel economy.

In a separate study, the researchers also investigated combining a Saft lithium-ion HP6 battery and the simulated fuel cell system in various hybridization schemes. It turns out, for example, that higher hybridization (more battery power) leads to increased regenerative braking energy but decreased fuel cell system cycle efficiency. The researchers also found that the increase in efficiency afforded by more regenerative braking does not always overcome the decrease in efficiency caused by downsizing the fuel cell and operating it outside its peak efficiency region. In other words, unless the design of the hybridization scheme is optimized, an overall decrease in fuel economy can result. According to Rousseau, "Argonne's work using GCTool-Eng and PSAT demonstrated that the best fuel economy is a compromise between hybridization degree, energy storage technology, driving cycle, and control strategies."

CTR researchers are by no means the only beneficiaries of the collaboration that led to the development of GCTool-Eng. CMT and NE division researchers now have a new tool that they intend to fully exploit in the years to come. "We created one dynamic link library for one particular type of fuel cell system, so now we are going to look at different systems," says Ahluwalia. In the near term, the researchers intend to use GCTool-Eng in investigating ambient pressure fuel cell systems and various hydrogen storage methods.

The U.S. Department of Energy's Office of FreedomCAR and Vehicle Technologies and the Office of Hydrogen, Fuel Cells and Infrastructure Technologies funded complementary aspects of the collaboration.

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Argonne's Center for Transportation Research Honored for Technical Contributions to Challenge Bibendum

Argonne National Laboratory's Center for Transportation Research (CTR) received an award for its significant contributions to Challenge Bibendum, the world's largest event designed to showcase and provide a real-world assessment of progress in the development and availability of earth-friendly vehicles. The award acknowledged CTR's technical contributions to the successful operation of the competition. Although awards were presented to major original equipment manufacturers (OEMs) participating in the Challenge, Argonne was the only national laboratory recognized for its technical contributions to this high-profile event.

Created and organized by Michelin, the goal of the Challenge Bibendum is to create an objective platform for all facets of the transportation industry to come together — to see, discuss, showcase, and measure the progress being made toward sustainable mobility.

Every year, the Challenge presents the best inventions from the world's largest vehicle manufacturers, equipment manufacturers, and energy suppliers through a series of tests (pollution analysis, noise, performance, safety, and design) conducted under normal road conditions. The diversity of the solutions proposed by various players in the event offers a glimpse into a new era of transportation.

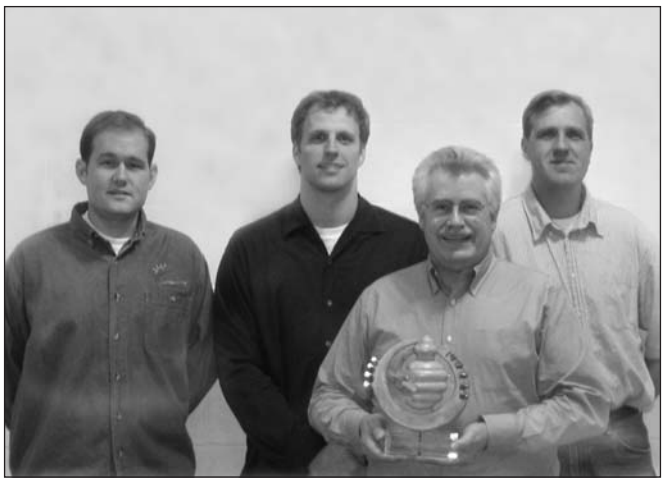
The entire event is organized by a project team and supported by an international team who validate the technical standards, decide upon the list of tests, and ensure that they are properly carried out.

In this year's event, held September 23–25, 2003, in Sonoma and San Francisco, California, 12 manufacturers entered 50 prototype and production vehicles. A Learning Center hosted 35 exhibitors showcasing technologies and environmental progress. Hydrogen-powered cars (fuel cells and internal combustion engines), diesels, and several hybrid technologies dominated the field for the 2003 Challenge Bibendum. Commercial vehicles — heavy-duty trucks and buses — were also added to the competition. More than 100 passenger and commercial vehicles competed at Infineon Raceway in Sonoma, with an estimated 1,400 in attendance.

CTR Director Bob Larsen served as Technical Advisor to the Challenge's International Design Jury, which selected vehicles for design awards. Two awards for style innovation and technical integration were presented for both production and prototype vehicles. The 2004 Toyota Prius won both awards in the production category, while the 2002 Mercedes Benz F-Cell A-Class — a fuel cell vehicle — won both awards in the prototype category.

Five CTR staff members were instrumental in ensuring the smooth operation of the Challenge. Justin Kern and Mike Duoba assisted the U.S. Environmental Protection Agency (EPA) in administering the on-road vehicle emissions test event and evaluated the technology used for these measurements. Ted Bohn played a key role in supporting the vehicle fueling and energy consumption measurements for the Bibendum organizers. Kristen De La Rosa and Steve Gurski provided support to the three 2003 FutureTruck vehicles and four vehicles from prior Argonne-organized advanced vehicle technology competitions that were entered in the event. They also assisted the event's organizers. In addition, CTR staff will be providing feedback to the organizers on improving operation of the competition in the future.

More details about the competition and the awards can be found on the Challenge Bibendum website *(www.challengebibendum.com).*



CTR staff (left to right) Justin Kern, Mike Duoba, Bob Larsen, and Ted Bohn shown with their award for technical contributions to the Challenge Bibendum. Also honored, but not pictured, were Steve Gurski and Kristen De La Rosa.

Argonne's Weld Monitoring Technology Finding New Roles

Heat treating: the latest automotive application for versatile sensing system

The infrared (IR) sensing system developed by Argonne and industrial partners for real-time quality monitoring of laser welding processes may be adapted for similar use in heat-treating applications. A leading U.S. automotive manufacturer is evaluating the technology for its ability to monitor a heat-treating process for automotive parts.

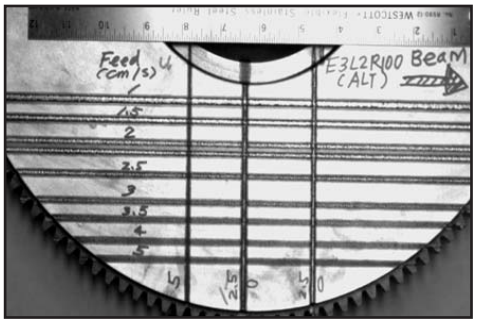
Argonne's IR sensing technology was originally commercialized by Spawr Industries (Lake Havasu City, Arizona). A Spawr customer, DaimlerChrysler, was the first to extensively implement the Argonne technology, employing more than two dozen of the units to monitor laser welding operations in its transmission plant in Kokomo, Indiana. Argonne's system replaced the plant's ultrasonic immersion tank weld-testing equipment and reduced scrap from bad welds by more than 10 percent.

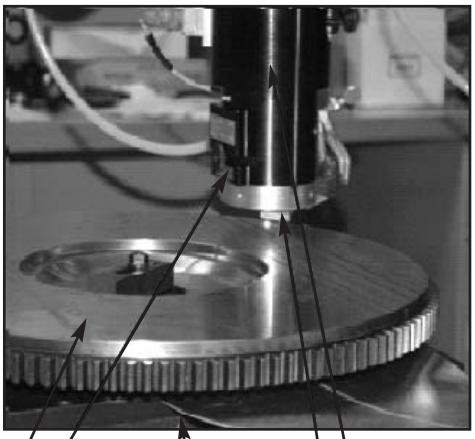
The same technology is also being used by Spawr customers in laser welding applications for airbag production and for assembling tailored blanks, which are used to produce automotive body panels. The economical, easy-to-operate system uses a passive sensor with integrated optics to measure IR emissions from the molten metal of a weld as it forms. The sensor detects the weld's infrared signature and instantly compares it to the expected profile. The system can automatically signal the welding unit to correct its operation if a weld signature does not fall within user-defined parameters.

In the new application that is currently being tested, the sensor monitors the quality of laser transformation surface hardening (LTSH) — a heat-treating method that is growing in popularity. Laser heat treating alters the microstructure of metals through controlled surface heating and cooling. The process offers the advantage of being able to treat precise areas of components without involving the entire part. The mass of the material being treated is generally adequate for rapid heat removal or "quenching." LTSH's self-quenching operation eliminates the need for oil or water quenching and results in little thermal distortion, so refinishing parts after heat treatment is unnecessary. The Argonne sensor system provides real-time monitoring of LTSH quality (i.e., surface hardness and case depth) and therefore does not add to cycle times, unlike conventional chemical, mechanical, visual, and eddy-current methods.

In tests for heat-treating applications, the IR monitor was integrated into the delivery optics of an Nd:YAG laser, and oversized, off-axis optics were used to collect the IR signature from the weld. Argonne engineer Keng Leong explains that "a direct relationship was found between the strength of the voltage produced and the hardness and case depth on the treated surfaces. This relationship means the Argonne system can provide accurate, real-time monitoring of an LTSH process to ensure quality and help reduce the scrap rates of treated parts."

Argonne researchers are currently exploring other applications for the IR sensor and are talking with potential partners, including a Tier One automotive supplier, about collaborative research projects.





Argonne's infrared sensor system monitored the operation as an Nd: YAG laser test system (bottom) produced horizontal and vertical heat-treated tracks on a cast iron component (top).

Khalil Amine of Argonne's Chemical Engineering Division has been named by *Scientific American* magazine as one of the top 50 research leaders of 2003. The "Scientific American 50" are recognized for their outstanding leadership in helping to make technology a constructive force for people and societies around the world. Dr. Amine leads a team of scientists and engineers in the development of advanced lithium battery materials and cell chemistries for emerging applications, one of which is hybrid electric vehicles. Amine's team has developed a high-power lithium cell chemistry that costs less than previous cell chemistries proposed for this use and is safer. The team's work on other high-energy chemistries, a lithium-iron phosphate and a lithium manganese nickel system, led to a long-life, safer battery suitable for use in implantable medical devices, satellites, and military applications. Eleven patents are pending on this work. According to Jim Miller, Director of Argonne's Electrochemical Technology Program, it is scientists like Amine who have made Argonne a leader in advanced battery development. "Khalil Amine is known internationally for his innovations in battery chemistry," said Miller. "He and his team are a tremendous asset to the program, and one of the reasons Argonne is known everywhere as the 'go to' place for leading-edge battery R&D."

Khalil Amine

Romesh Kumar, of Argonne's Chemical Engineering Division, will receive the Forest B. McFarland Award from the Society of Automotive Engineers' (SAE's) Engineering Meetings Board (EMB). The award recognizes outstanding services rendered to EMB, particularly in the organization of SAE meetings and conferences. Kumar is being specifically recognized for his efforts and leadership contributions as a reviewer for the Powerplant/Future Car Congress.

Bassam Jody and **Edward Daniels** of Argonne's Center for Transportation Research and Joseph Libera (formerly of Argonne) have been selected as the 2003 Inventors of the Year by the Intellectual Property Law Association of Chicago (IPLAC) for the process they invented to recycle flexible polyurethane foam from auto shredder residue. IPLAC is a not-for-profit organization dedicated to maintaining a high standard of professional ethics in the practice of patent, trademark, copyright, trade secret, and associated fields of law.

Each of the technical teams in the FreedomCAR Partnership, which comprises industry and government representatives, was asked to select one of their members for formal recognition.

Walt Podolski of Argonne's Chemical Engineering Division was elected by his peers on the Fuel Cell Tech Team, on which he has served for five years. The nomination reflects his contributions to revising and updating the *Fuel Cell Power Systems Roadmap*, for which he shouldered a major portion of the burden. Walt also participates in the Hydrogen Storage Technical Team. The individuals selected were acknowledged at the FreedomCAR All-Tech-Team Meeting on December 9, 2003.

Bassam Jody, **Joseph Pomykala**, **Jr.,** and **Edward Daniels** received the 2003 Society for Automotive Engineers (SAE) Arch T. Colwell Merit Award for a paper entitled "A Process to Recover Carbon Fibers from Polymer Matrix Composites." The award will be presented at the Honors Convocation during the SAE 2004 World Congress.

Ali Erdemir of Argonne's Engineering Technologies Division shared an R&D 100 award, in recognition of the 100 most technologically significant new products of the year, with Michael J. McNallan, professor at the University of Illinois at Chicago; Yury Gogotsi, director of the A.J. Drexel Nanotechnology Institute; and Sascha Welz and Daniel Ersoy, both Ph.D. students at the University of Illinois at Chicago. The group developed a Nanostructured Carbide-Derived Carbon (CDC) technology — a coating for sliding and rotating equipment applications. The coating can be grown at rates up to 100 micrometers per hour, bonds strongly to substrates, and does not come free during severe loading or sliding. CDC has exceptional friction and wear resistance in many applications, such as a coating for seal water pumps in automotive engines to prevent dry-run failure and extend the engine's lifetime. The development of this coating could save billions of dollars and reduce energy consumption.

Renée Nault of Argonne's Information and Publishing Division won an Argonne Pacesetter Award for her work with **George Crabtree** of Argonne's Materials Science Division to produce a report entitled "Basic Research Needs for the Hydrogen Economy," which summarizes the findings of a workshop that DOE's Basic Energy Sciences Advisory Committee conducted in May on how fundamental research by the Office of Science could contribute to hydrogen production, storage, and use. The report has drawn attention in the United States and abroad; it has been featured on the "The Newshour with Jim Lehrer," was highlighted by a major newspaper and talk show in Brazil, and will be covered on the PBS science series "Nova."

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 startup 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 Office of Technology Transfer and see how we can put our resources to work for you.

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