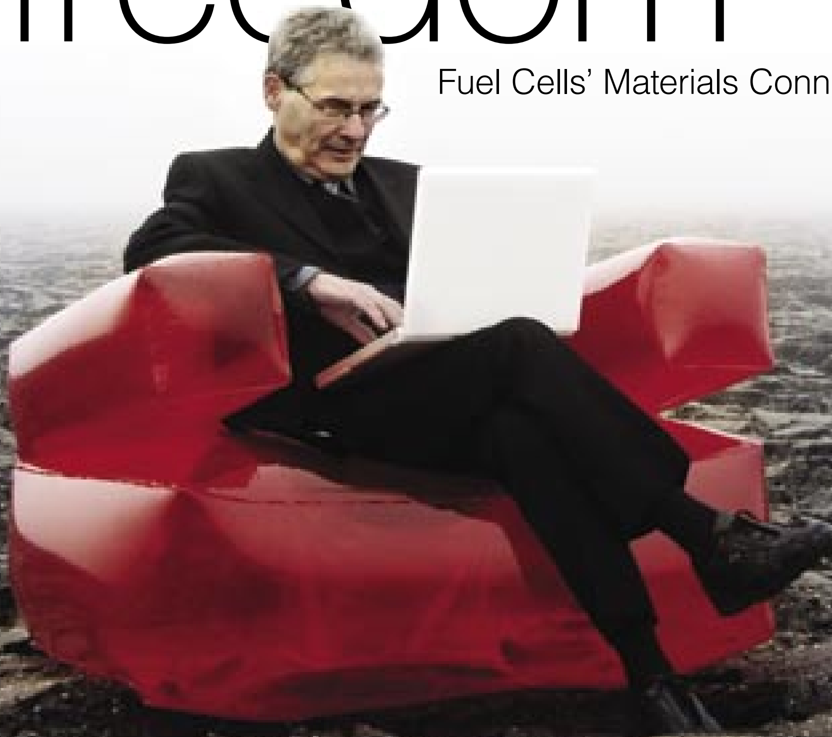
Energy freedom

Fuel Cells' Materials Connection



PURDUE **MATERIALS** ENGINEERING

impact

FALL 2005

up front

On My Mind

There's no doubt that the personal connection we enjoy with our alumni and friends is one of the keys to our success. It's my pleasure to welcome you to our new magazine—which will help us maintain that connection with you as our school grows.

Purdue's School of Materials Engineering is engaged in a rapid increase in the number of its faculty, along with an expansion in student enrollment. Given this, maintaining the attributes of our school that make studying, teaching, and conducting research a rewarding experience is of paramount importance. More so, managing our needs in our current location while planning for our new facilities in the Neil Armstrong Hall of Engineering (to be completed in 2007) requires a strong dedication of the faculty, staff, and students.

We're pleased to also report that our undergraduate enrollment has continued to increase while our graduate enrollment has expanded by nearly 100% in the last five years. During this same period, the faculty has increased from 12 to 20—including the addition of five new faculty this fall.

These new faculty have been competitively recruited from positions and training at national laboratories and universities including the National Institute of Standards and Technology, Los Alamos National Laboratory, Lawrence Berkeley Laboratories, University of California–Berkeley, Massachusetts Institute of Technology and the California Institute of Technology.

With these additions, we've added new research and education areas in nanoscale processing and multiscale modeling of materials phenomena, electronic materials processing, and bio-initiated patterning of molecular structures.

We also welcome the active support of our alumni and friends to ensure that we maintain and continue to enhance the educational environment for our current students while simultaneously making the rest of the world aware of the accomplishments of our program. Please let us know how you are doing and what you think of our growth.

Keith Bowman
Interim Head, School of Materials Engineering

* Alexander H. King, Head of the School of Materials Engineering, is spending the academic year (2005-2006) serving as a U.S. Department of State Jefferson Science Fellow in Washington, D.C.

From the Editor

After countless e-mails, phone interviews, meetings, photo shoots, and edits—this magazine was brought to life (thanks to the individuals listed in the credits). Its pulse originates from the enormous energy contained within the faculty, staff, students, and alumni that make up the MSE family—a group that's having an extraordinary impact on our globe and daily lives. In this first issue, we look into materials engineering's contributions to solving the world's energy challenges. Enjoy!

Lee Lamb
Editor

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Introducing New Faculty

John Blendell (Professor)

Education:
- B.S., Alfred University, Ceramic Science, 1974
- B.A., Alfred University, Mathematics, 1974
- M.S., MIT, Ceramics, 1976
- Sc.D., MIT, Ceramics, 1979

John Blendell's early interest in chemistry, physics, and mathematics led him to pursue a degree in ceramics at Alfred University in New York, and then to graduate school at MIT. He completed a post-doc at the Max Planck institute in Stuttgart, Germany, where he worked on an iron-zinc alloy system, and then returned to MIT in 1980 to complete a second post-doc.

Blendell joins Purdue after 22 years at the National Institute of Standards and Technology. His interests include microstructure evolution, interfacial anisotropy effects on sintering and grain growth, and ferroelectric thin films.

R. Edwin Garcia (Assistant Professor)

Education:
- B.S., National University of Mexico, Physics, 1996
- M.S., MIT, Materials Science and Engineering, 2000
- Ph.D. MIT, Materials Science and Engineering, minor Applied Mathematics, 2003

Edwin Garcia joins Purdue from the Center for Theoretical and Computational Materials Science at the National Institute of Standards and Technology. He's interested in applying theoretical and computational materials science to improve materials response through the detailed understanding of the relations that exist between materials processing, properties, and microstructure.

He has set his goals high while at Purdue:

"I came to Purdue to contribute to the strengthening of the academic curricula and push the boundaries of science. I came to collaborate and help Purdue be the best materials science and engineering program in the country," says Garcia.

Lia Stanciu

Education:
Ph.D., University of California- Davis, Materials Engineering, 2003

Before coming to the United States to study, Lia Stanciu grew up in communist Bucharest—where television was allowed only four hours out of every day. "We didn't have a television, so the only thing to do was to study," she says.

In 1995, Stanciu completed her bachelor's degree in chemistry at the University of Bucharest, followed by a master's in chemistry from the same university.

She worked as a researcher at the Romanian Academy of Sciences before starting her Ph.D. in Materials Engineering at the University of California- Davis. Stanciu received her Ph.D. in December, 2003. Her research topic was the electrical field effects on nanomaterials processing. Before coming to Purdue, she did research in Structural Biology at Baylor College of Medicine in Houston, Texas.

Alejandro Strachan (Professor)

Education:
- M.Sc., University of Buenos Aires, Physics, 1995
- Ph.D., University of Buenos Aires, Physics, December, 1998

Alejandro Strachan joins the faculty of MSE faculty from Los Alamos National Laboratory where he served as a staff member in the Theoretical Division.

His research revolves around developing methods to predict how materials behave using computer simulations and applying these methods to a wide range of materials. Strachan focuses on atomistic and mesoscale modeling of condensed-phase chemistry, active materials and nanotechnology and mechanical properties of structural materials.

"My greatest accomplishment so far is raising a family," says Strachan.

Strachan and his wife, Marisol, have two kids: Camila (three years old) and Ian (three months old).

NIST Division Chief Joins Faculty

Eager to Teach and Solve Large-Scale Problems—**Lee Lamb**

My knock on the slightly opened door prompts a warm, "come in!" I gently step into a bare-walled, empty office with a few personal mementos, bookshelf, and large wooden desk, where I find Professor Carol Handwerker standing, smiling, and getting ready for her first semester at Purdue.

For the past nine years, Handwerker served as a senior scientist and chief of the Metallurgy Division at the National Institute of Standards and Technology (NIST). There, she worked in many areas of materials science, including spearheading the electronics industry's transition to lead-free solder—a project she'll continue at Purdue.

"There's a problem that's worrying the electronics industry—the spontaneous formation of tin whiskers," she says.

Handwerker begins a brief lesson explaining that, with the ban of the use of lead in electronics, the materials that replace lead are prone to grow tin whiskers from the solder that's used to connect the electronic components to, for example, a computer's circuit board.

"All of a sudden, in two regions that weren't connected electrically in any way, whiskers that spontaneously formed from the component surfaces touch other areas they weren't supposed to touch, causing an electrical short circuit," she explains.

"This is something that I've worked on and will continue here: trying to understand what causes these whiskers and how to mitigate them."

In fact, Handwerker has been widely commended for her work—receiving the Department of Commerce's Gold and Silver Medals for her contributions to solder science and the department's Bronze Medal for her contributions to the understanding of interface reactions in composites.

East Coast to Purdue

Handwerker spent her undergrad days at Wellesley College studying art history. "I loved art and iconography, and I found the work beautiful…I've always been attracted to color and symmetry and the three-dimensionality of things," she says.

It's this love for art that encouraged her to pursue art restoration and eventually to study materials science and microelectronics at MIT.

After working with an art historian to understand how ancient Korean ceramics were made, she was "hooked" on microstructures, thermodynamics, and the kinetics of phase transformations.

She stayed at MIT for three degrees: a B.S. in materials science, and an M.S. and Sc.D. in ceramics.

How'd she do it?

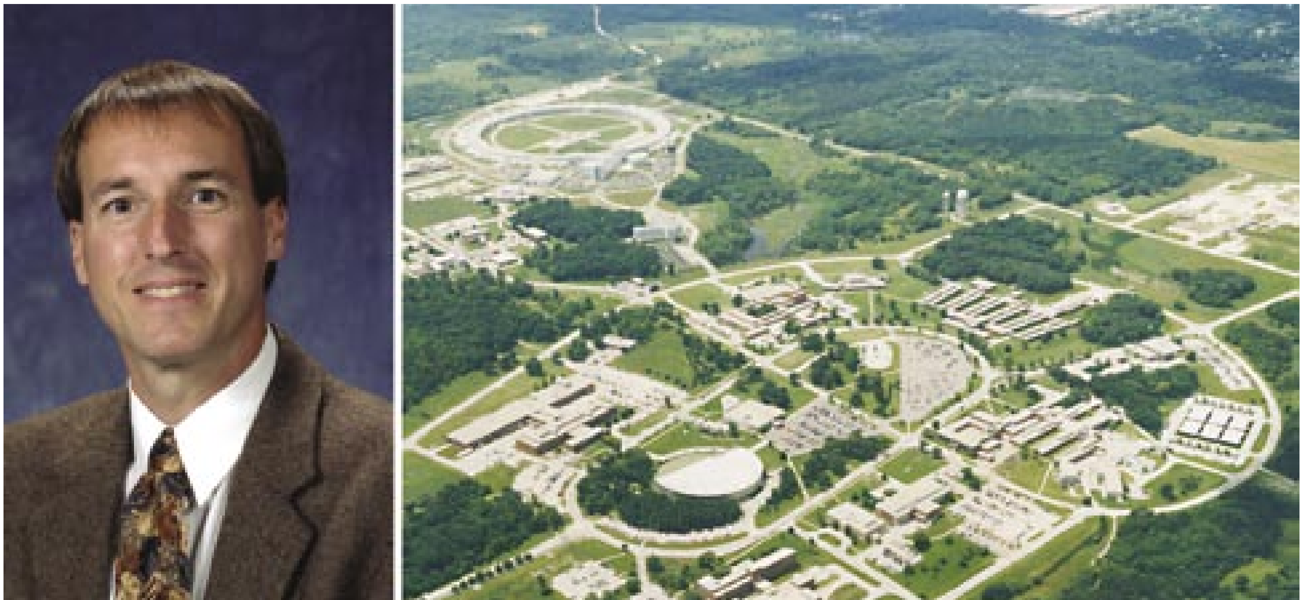
"In my family, there were four girls and for all of us—we were told that we can do anything we wanted to do, as long as we were the best. I was never discouraged from doing anything that I wanted to do."

From a small high school in Tennessee to Wellesley and MIT—Handwerker is sure to bring a wealth of her own educational experience into the classroom as a professor.

Handwerker explains that, "It's important to educate students and make them comfortable enough to learn, and to have them realize that they'll be working on large-scale problems that are going to require large-scale solutions."

Admired as a researcher, engineer, and leader—there's no doubt that Handwerker will be quickly admired as a teacher. Her infectious optimism and determination are sure to impact her colleagues and students—and serve to strengthen Purdue's School of Materials Engineering. ■

Education:
- **B.A., Art History, Wellesley College, 1973**
- **B.S., Material Science and Engineering, MIT, 1978**
- **M.S., Ceramics, MIT, 1978**
- **Sc.D., Ceramics, Department of Materials Science and Engineering, MIT, 1983**



Dr. Mark C .Petri (left), and Argonne National Laboratory

Energy Needs and the Role of Hydrogen

Humanity's Big Problem—**Mark C. Petri**

World energy demand is rising and will double by 2050. Most of this growth will come from developing countries such as China and India, and it will be a significant burden on our environment—especially in the form of greenhouse gas emissions such as carbon dioxide.

Much of this energy demand will be in the form of transportation fuels. In the United States, transportation has recently overtaken industry as the most energy-intense sector of the economy. Transportation will continue to outpace other sectors in terms of energy consumption over the next 20 years. Ultimately, this need may be met in the form of hydrogen-powered fuel cells, but there are many hurdles that will have to be overcome for the direct use of hydrogen for transportation.

First, costs for the entire system (hydrogen production, distribution, storage, and end use) will have to decrease. Second, since hydrogen gas is such a diffuse energy carrier, ways will have to be found to pack hydrogen into small volumes suitable for trucks and automobiles. Third, an entire new infrastructure for producing and distributing hydrogen will have to be created. It will likely be decades before these barriers can be overcome and hydrogen can displace a significant fraction of our transportation fuel.

Our needs for a reliable supply of transportation fuel are much more immediate, however, especially as countries such as China compete for dwindling petroleum resources and as the costs of global climate change mount. Here, too, hydrogen has an important role.

Hydrogen is already a key commodity for sweetening heavy petroleum into lighter hydrocarbons. Indeed, over 4 million metric tons of hydrogen were used for oil refining in the United State in 2003, and that number is growing. Other carbon-based substances can also be transformed into transportation fuels with the introduction of hydrogen. Alberta oil sands, which represent a vast resource, now provide more petroleum (over 1 million barrels per day) than conventional oil production in that region of Canada. Researchers are also continuing to look at U.S. oil shale and coal as potential feedstock for liquid fuels. Converting these heavier hydrocarbons, of course, requires a significantly greater amount of hydrogen.

So, aside from the long-term prospect of hydrogen as the ultimate transportation fuel, there is a near-term need for hydrogen to produce alternative liquid fuels to wean us off of uncertain foreign petroleum supplies.

Where will that hydrogen come from?

Hydrogen is not freely available in nature; it has to be extracted from other compounds. Currently almost all hydrogen today comes from steam reforming

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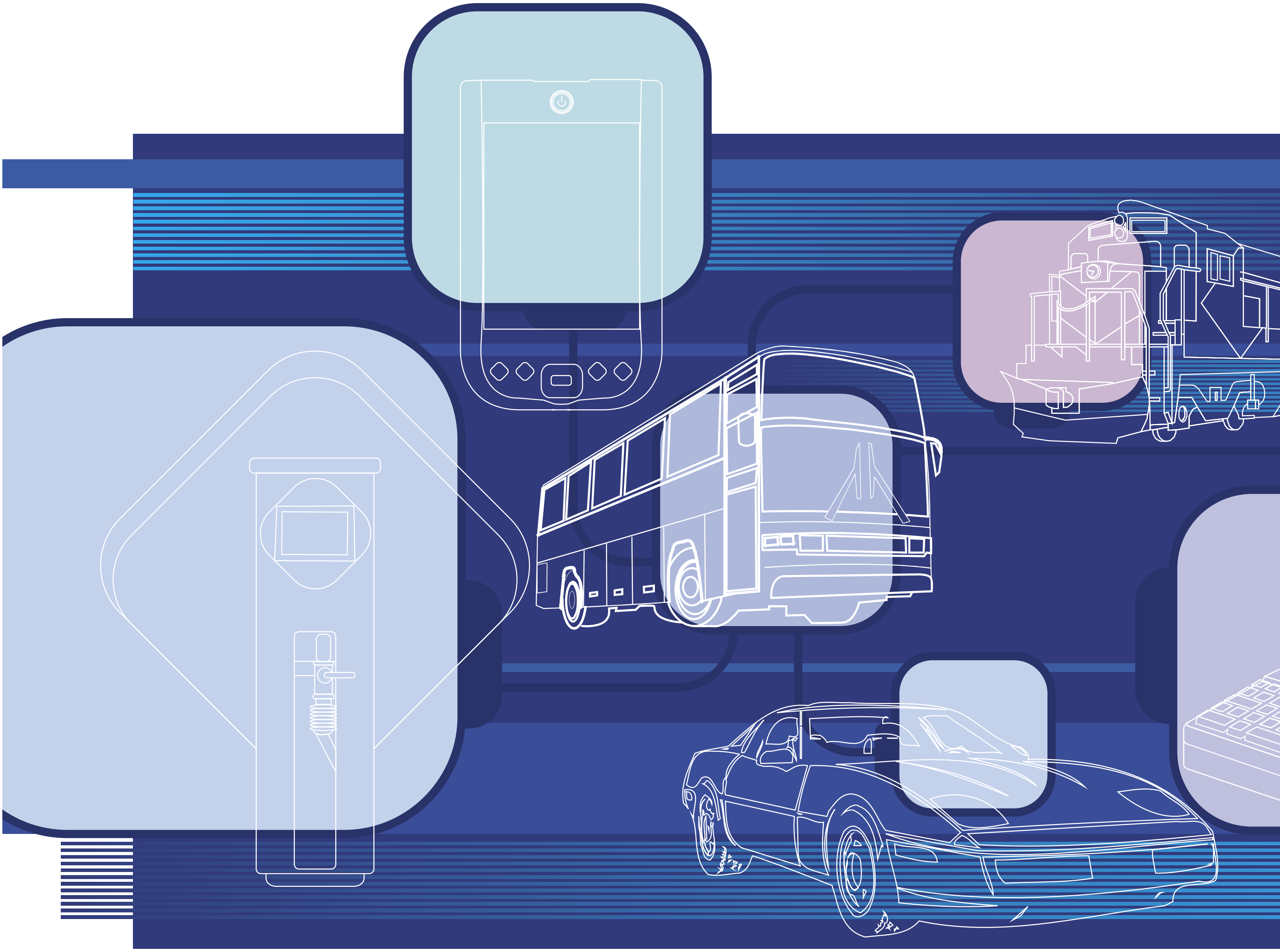
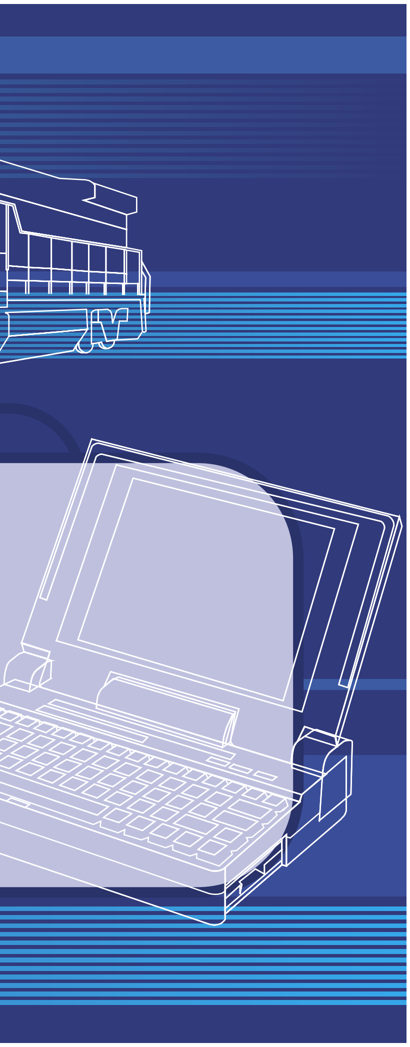


Fuel Cell

SUCCESS HINGES ON MATERIALS ENGINEERS

Purdue Takes on the Task —**Kathy Mayer**



Resources depleting at skyrocketing rates, prices for gasoline and home heating escalating to poverty-fearing levels, and air pollution threatening to smother the Earth and its people: The energy crisis has reached a new level, fueling researchers to seek solutions.

One with promise is the fuel cell, an energy-conversion device that uses hydrogen or other gaseous fuel and oxygen in an electrochemical process to create electricity. The cell itself is simple—an electrolyte sandwiched between two electrodes—one a porous anode, the other a cathode. It has no moving parts, making it durable. You can add fuel as needed. And you can stack the cells for applications demanding greater power.

Fuel cells have been around since 1839, with recent uses in submarines and space shuttles, but they're not yet ready for practical or common use. As energy demand rises in our highly powered world and as concerns grow about pollution and depletion of natural resources, interest in fuel cells is growing.

Today, work at Purdue University's School of Materials Engineering and other labs is focusing on developing fuel cells for everyday portable, stationary and mobile uses, from multi-function electronic devices you carry in your pocket to automobiles, homes and power plants.

With researchers exploring and developing the promise of fuel cells as energy sources, we'll likely soon tap the benefits in temperature-perfect homes that don't use depletable resources and in quiet, clean running cars and boats that don't burn fossil fuels. We'll carry PDAs and cell phones with features we've only dreamed of packing into a single unit. Our flashlights and video cameras will be powered to go no matter how long they've been on the closet shelf, and we'll forever give up replacing and recharging batteries.

Before all that can happen, though, some fuel cells need to thin down and some need to cool down. And they all need to get less expensive and more efficient. Those are among the challenges researchers must conquer before fuel cells become practical, everyday sources of energy.

Whatever the next steps, one is certain: materials engineers will play a key role.

"The main limitations on fuel cell applications today are materials-related," says Keith Bowman, MSE interim head. "If we talk about long-term performance and the cost of producing fuel cells, it's got to involve materials engineering. You can't make them without us."

Associate head Mysore Dayananda agrees. "Materials engineering is crucial. Without materials, no one in any other discipline can do what they think they can."

With research underway and more on the horizon at Purdue's Materials Engineering, the school that's growing in space, faculty and student enrollment is poised to be among the players.

▶ Continued on next page

Testing concepts

Fuel cells are a focus for professor Elliott Slamovich—in his ceramics class, writings, and new research. And his graduate student Jeffrey Reding is working on the alternative energy source under a fellowship from Government Assistantships in Areas of National Need (GAANN) from the U.S. Department of Education. (See Pg. 7)

"Right now it's in the concept stage," Slamovich says of his work. "What we'll be doing is working on reducing the size of fuel cells, lowering their operating temperatures, and also making them useful for smaller types of devices—not just for cars, but for tools that you use in the field. That's the big picture. Those are the systems we're going to be making and what approach we'll be using.

"I like doing experiments that test concepts," he says. "My job is to make sure these structures simulate reality so we can see whether the computational work plays out in the real world."

Calling materials engineering work crucial, Reding says his goal is to design a solid oxide fuel cell that operates efficiently at less than 800 degrees centigrade and uses affordably implemented processes.

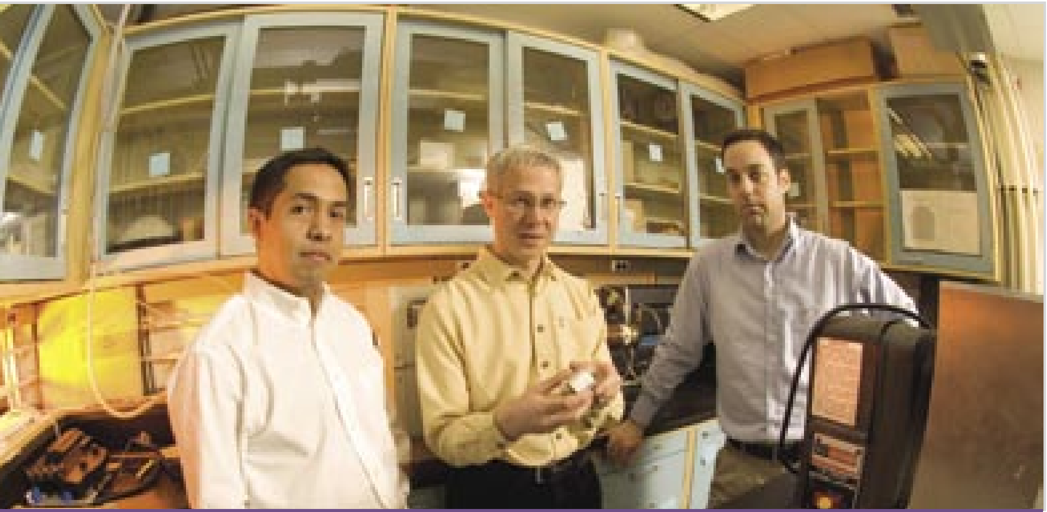
"Many of the issues dealt with by other engineering disciplines are device refinements after key materials issues are worked out," he says. "Fuel cells are still at the point where many of the decisions are materials-related."

Providing computational modeling

Others in the MSE school eyeing fuel cell projects are R. Edwin Garcia and Alejandro Strachan, both known for their computational work. The two assistant professors came to Purdue in Fall 2005, bringing experience and interest in fuel cells.

"I'm specifically interested in addressing the microstructural issues of fuel cells—grain size, texture, how they relate to properties and affect conductivity, and how those microscopic properties impact the power density of the fuel cell," Garcia says. "As far as I know, it's an open problem that hasn't been solved. Most say it's too complicated right now. But it's the kind of modeling I do, so I can address this."

Strachan is working on theoretical and computational tools to understand materials issues in fuel cells "The models I'm developing are applicable to fuel cell issues and can give an understanding of nanostructure and property relationships in fuel cells," he says. "Among other things, I want to be able to predict how fuel cell materials work."



Edwin Garcia, Elliott Slamovich, and Alejandro Strachan

Fuel cell research is a growing activity in the school, Bowman notes. "We are looking at what contributions we can make on a fundamental level. A lot of it is understanding what the limitations are and finding ways to get around them."

Many of the challenges have to do with bulk and mass, he says. "That's one problem. Another issue is whether or not they can perform efficiently. And some concerns are more related to economics."

Another challenge is the current use of precious metals, such as platinum in one type of fuel cell. More environmentally friendly alternatives are being sought.

Critical work ahead

The bottom line, Bowman believes: "Materials engineers play a critical role in expanding the boundaries of what is possible with fuel cell technology, both in the range of operations and extension of performance."

The work has far-reaching impact.

"Fuel cells offer the potential for quieter, cleaner power and reduced dependence on oil," Reding notes.

The potent energy sources could fill the bill for greater demand, Garcia suggests. "We've seen increasing demand for energy over the years, especially portable energy, and this is just going to increase, with faster computers and gadgets that need energy. We want to pack the features in cell phones with calculators and e-mail. The more features, the more energy we consume.

"Fuel cells fill a niche for providing high power in specific applications," he says. "Finding better and more efficient energy sources is important and always will be."

Look for Purdue's School of Materials Engineering to make significant contributions, says Dayananda. "There's no question Purdue MSE will play a role. We may not be in the limelight at this point, but Purdue's involvement will be part of the package." ■

Researcher's Goal: Reducing Heat, Materials, Cost

Jeffrey Reding is thinking small these days, but his work could have big implications for energy production and future generations.

The Purdue Materials Engineering graduate student from Puyallup, Washington, has stocked his lab, brought in his children's photographs, constructed equipment, and is now building solid oxide fuel cells. He's tackling a project to cut fuel cell temperatures, thin down materials, and curb costs so the technology can be an everyday option anywhere batteries are used.

His work is one step in solving the looming energy crisis—for his daughter, pictured in a green-and-yellow raincoat on his screensaver; his son, surrounded by balloons in Dad's office photo; and generations that follow.

Thinning the electrolyte

"A solid oxide fuel cell is a particular kind of fuel cell," he explains from his modest workspace, where the cement floor is unpainted and a water de-ionizer runs continuously. "In it, ions go through the solid oxide material, and electrons go through the circuit. Because this is a solid material, the ions need a high temperature to be able to diffuse through it with a low enough resistivity to be useful."

The high temperature sets up a demand for expensive materials throughout the fuel cell. If he can reduce the heat, he can scale back the expenses fuel cells now eat up. To lower the temperature, he's working on thinning down the electrolyte material the ions must pass through.

Dropping the temperature

"By making it thinner, we can reduce the resistance of the electrolyte portion of the cell by having the ions travel a shorter distance," Reding says.

"By making this electrolyte thinner, we can then accommmodate a higher material resistivity in the electrolyte when we lower the temperature of the cell. And because we're using a lower temperature, we can use cheaper materials in the rest of cell."

Steel would be ideal for connecting individual cells, for example, because of its cost, he says. But today's temperatures are too hot for steel.

"Currently, more expensive materials are used. The typical electrolyte material, yttria stabilized zirconia, needs to be less than 10 micrometers thick to allow for such a change."

Producing clean, affordable energy

Reding says he's long been interested in energy research, which makes his 10-hour days rewarding.

"Energy conservation was something I was always curious about, but I never saw that as the golden goose," he says. "It can help, but to really make progress in the energy industry, I think you need to develop new energy technologies, not just use the ones you have less. I think this research is a good means of striving toward a goal of improving energy technologies."

A bachelor's degree in ceramics engineering and master's in materials science engineering put him on his current path. "As a materials engineer, there are a lot of ways you can influence energy technology. Fuel cells are one of the technologies that has potential," he says.

Right now, he is concentrating his work on the fuel cell's electrolyte.

"I want to optimize the electrolyte. Then, if things go well there, we can start working with other parts of the cell that would would that would allow for better use of fuels other than hydrogen."

Ultimately, he hopes, "We could have a fuel cell that operates around 650 degrees Celcius and would cleanly and efficiently use hydrocarbon fuels." ■

—K.M.

Reinhardt Schuhmann, Jr. Professorship

Alum's Gift Makes It Happen—**Sharon Martin**

A rare individual

Reinhardt Schuhmann, Jr. was renowned around the world for his work in engineering. Early in his career, he discovered that a sound scientific basis was extremely useful in the practice of engineering, as demonstrated in his early studies on ore dressing. In the 1940s, his expertise was utilized in the Manhattan Project. He revolutionized the materials area in bringing thermodynamics to bear in the practical arena of extractive metallurgy. His patents with Paul Queneau led to some of the most important and significant changes in the extractive metallurgy field in the past century.

A young scholar, Schuhmann enrolled at the Missouri School of Mines at the age of 15. In 1938, he graduated with his doctorate degree from MIT. He began teaching at MIT at the age of 24. In 1954, he arrived at Purdue as a professor of metallurgical engineering. He founded the School of Materials Engineering, and served as its head for several years. In addition to his research and administrative duties, he also found his way into the classroom.

"I was fortunate to have one of the country's most renowned thinkers and researchers as a professor," says William Shropshire, Jr. (BSMetE, '59), who sat in his classroom as a sophomore and a senior. "He was quiet, scholarly, intense and demanding of his students."

Yet he was extremely approachable. "I played on the varsity tennis team, and was pretty good," says Shropshire. "After our last project was graded, Professor Schuhmann asked me to play. I thought, 'Well, OK.'"

They arrived at the clay courts where Professor Schuhmann produced his own key. "It was clear that he not only was a tennis player, but a fine player. He beat me!" laughs Shropshire.

Many years later at a symposium honoring Schuhmann, the then-80-year-old professor recalled the match with his former student. "He asked me if I brought my racquet. When I said, 'No,' he said, 'Good, I don't have to have a rematch.'"

It was that genuine manner that Shropshire admired. "He didn't have to tout his excellence," says Shropshire. "He had such a profound influence on the way I approached problems in metallurgy, and still do. I was fortunate to have a long-term relationship with him."

William W. Shropshire, Jr.

Honoring a mentor

In gratitude of all Schuhmann had done for him and others, Shropshire decided to provide a leadership gift for the Reinhardt Schuhmann, Jr. Professorship. An endowed professorship helps attract high-level, talented faculty, thus advancing the research efforts, creativity and prestige within the school. Discretionary funds generated for professorships lend more flexibility in the school's budget.

"A professorship in the name of Reinhardt Schuhmann, Jr., is a tribute to the many talents of the man, as well as his role in advancing the field of metallurgical engineering and the School of Materials Engineering at Purdue," says Keith J. Bowman, professor and interim head.

The professorship has been fully funded and the search has been initiated for the first holder of the chair.

"Purdue is an important institution," says Shropshire. "Anything that alumni can do to strengthen the university affects the future of engineering. It strengthens the school, as well as the state of Indiana and the nation.

"I am appreciative of all those who have joined in the creation of the Schuhmann professorship," he adds. "I suspect he'd be gratified, but a little embarrassed by the attention." ■

Catching Up with Tresa Pollock

Blazing Trails at Michigan—**Sharon Martin**

As a first-generation college student at Purdue, Tresa Pollock was introduced to metallurgical engineering. While exploring the field, she became interested in high-temperature materials. It's an interest that has led her to develop a distinguished career in the field.

"I originally became interested in high-temperature materials as an undergraduate at Purdue, through my co-op job at Allison [now Rolls Royce] and through working with professor John Radavich," says Pollock (BSMetE, '84). "The co-op program was a really great opportunity for me."

She built on that opportunity by earning her doctorate in 1989 from MIT. From there, she landed a job at General Electric Aircraft Engines developing new alloys for aircraft engines, which included nickel-based alloys and intermetallics.

"One single crystal alloy from the effort is now in service in several engines," says Pollock. "I really learned a great deal at GE; finding a new material with interesting properties is just the first step. Introducing new materials into aircraft engines is a complex process, not only due to the complicated manufacturing steps required but also due to the fact that safety is a critical issue."

From industry to the classroom

With a wide range of options available to her, Pollock opted to explore the academic life. She began teaching at Carnegie Mellon in 1991. From there she joined the faculty at the University of Michigan, where she's been teaching since 1999.

"Teaching is always a priority," says Pollock. "I teach MSE undergraduate and graduate students, and also occasionally teach mechanical engineering undergraduates."

She also has a fairly large research group, and spends a lot of time with her graduate students and postdoctoral researchers.

"My research is on high-temperature materials and coatings," explains Pollock. "These materials are unique in their ability to operate in severe environments, and have been essential to the development of aircraft engines, efficient power plants, and to space vehicles such as the shuttle and other hypersonic vehicles."

She and her researchers work on metallic materials (nickel, titanium, magnesium and platinum group metals), as well as intermetallic and ceramic coatings. Some current subjects of interest are ruthenium-containing single crystals, a new liquid tin-assisted directional solidification process, platinum group-based bond coatings and femtosecond lasers for microfabrication and "local" materials diagnostics.

"We are interested in the discovery of new high-temperature materials, definition of new processing approaches that enable those difficult materials to be fabricated," says Pollock. "Since all propulsion systems are more efficient when they operate at increasingly higher temperatures, the overall goal is to continue to drive materials forward as an enabling technology for a wide range of systems."

Pollock feels the future of this research will have an effect on energy efficiency.

"As carbon-based sources of fuel will become increasingly rare and expensive in the coming decades, materials that increase energy efficiency will become an even more important topic," says Pollock. "As always, progress in taking vehicles to space will rely on new materials developments."

In addition to her research, Pollock serves on several boards and groups. She is the current president of the Minerals, Metals and Materials Society (TMS), serves on the executive committee of the College of Engineering at Michigan, and is an associate editor of *Metallurgical and Materials Transactions*. She's also involved in activities related to Women Faculty in Engineering and Science.

In 2004, Pollock was elected to the National Academy of Engineering.

"In the past few decades, a wide variety of engineering-driven technological achievements have given the U.S. a healthy economy," says Pollock. "Continued health is now dependent on us remaining in a leadership position and maintaining our ability to define new "high technology" industries. Given the rapid pace of development in other areas of the world, we need to think carefully about our future; this is what motivates my service activities in the broader engineering community." ■

Tresa Pollock

Study Abroad Sends Students Packing

Forming True Global Engineers—**Phil Meeker**

Beth Herzog (Right)

Aaron Pedigo (Right)

With the rising numbers of international corporations, collaborations and outsourcing, students in engineering need a global education. To prepare students for this cross-cultural environment, the School of Materials Engineering offers opportunities for their students to globetrot, learn, and interact with the world.

"The school really encourages people to go abroad," says Kei Yamamoto, a senior in the school who traveled to Imperial College in London this summer. "I think it's a very enriching experience."

This last school year, five students in the materials school signed up to broaden their perspectives and to have some fun in a foreign land.

Nell Gamble, a senior in the school, fell in love with Ireland by only reading a brochure about the program. She had to see the County Cork and the green hills that seemed so alive with Irish legends.

"I like to get out away from my familiar surroundings to stay sharp, to stay focused. Then, when you come back, you can see everything from a different point of view and it looks more interesting," says the senior, who went this summer to the National University of Ireland in Galway with 15 other Purdue students.

Exposure to new viewpoints excited all these students. It made them stop and wonder how they can expand their horizons and take advantage of global opportunities.

"In the United States, you think there's a standard way for what you do," says Beth Herzog, a senior in MSE who went to Sydney, Australia.

"You go through engineering, you get an engineering job, and you retire six companies later. That's the average nowadays. Once you've been exposed to a bigger city not in a cornfield, other cultures and stuff like that, there's not one way to do things. There's a ton of ways to do things."

The students seemed inspired by their experiences.

Nell Gamble

Julie Sievers

Kei Yamamoto

Julie Sievers, a senior in MSE, says, "I gained a better understanding of myself in the sense that I can go anywhere and do anything."

Another senior, Kei Yamamoto, says that after he returned, he felt more capable of following whatever career path he could dream. He witnessed firsthand that an engineering education didn't equal a job with a technical focus.

"I like engineering, but I also like business and all those things. I met a friend in London who got his degree from aerospace engineering and he's working for Chase doing investment banking because that's what he wants to do," says Kei who's interested in becoming a business magnate or a professor.

"I thought that was pretty cool, you know? They hired him just because they want the problem solving skills that he learned in school—the critical thinking that he learned in engineering to solve problems."

Moreover, the students, including Kei, discovered added responsibility in their studies abroad.

"For me, a global engineer is more than an engineer who has been outside of his or her own country," says Aaron Pedigo, a senior in materials engineering who went abroad to study at Tohoku University in Japan.

"A global engineer is an engineer that not only recognizes that there is an entire world out there, but makes decisions to try and better it." ■

in my view

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of methane (CH_4). This makes the cost of hydrogen highly dependent on the cost of natural gas, and vice versa. As more natural gas is used to generate hydrogen to convert Canadian oil sands, one can expect natural gas prices in the U.S. to rise. The use of methane for hydrogen is unsustainable in a second way: Steam methane reforming produces carbon dioxide that exacerbates the climate change problem.

It's clear, then, that energy-efficient means of producing hydrogen without the production of greenhouse gases will have to be found. The best way would be through the cracking of water. Argonne National Laboratory, along with other laboratories and universities, is exploring a number of ways to do this. The simplest is to use a more sophisticated version of the water electrolysis experiments we all did in high school. Low-temperature water electrolysis, however, requires a lot of expensive electricity and currently relies on scarce catalyst materials such as platinum. Good research is taking place to make these systems more efficient and to find inexpensive alternatives to exotic catalysts. Other ways being explored to generate hydrogen include electrolysis of steam (rather than water) and using a series of thermochemical reactions that have the net effect of taking water as input and producing hydrogen and oxygen.

Direct solar production, though it still requires substantial research, may one day be the best source of hydrogen. Two ways are being pursued in laboratories. First, photo-electrochemical cells can use electron-hole pairs generated in photovoltaic cells to split water rather than to produce electrical current. Artificial or biomimetic photosynthesis is a second route that builds on our understanding of photosynthetic processes in nature.

Solar energy reaching the earth dwarfs other energy resources. In fact, the equivalent of the yearly world energy demand strikes the earth every 40 minutes. If this resource can be effectively harvested, hydrogen production may be its biggest contribution to our energy needs.

Meeting the world's energy needs in an environmentally sustainable way may be the biggest problem facing humanity over the rest of the 21st century. The solutions to this problem are not clear, especially when it comes to our growing thirst for transportation fuels. Hydrogen produced from nonpolluting sources will have an important role to play in the near future, even if the direct use of hydrogen to run cars and trucks is still many years away. ■

** Dr. Mark Petri received his bachelor's ('85) and master's ('86) degrees in nuclear engineering, and his Ph.D. ('95) in materials engineering, all from Purdue. In 1989, he joined Argonne National Laboratory, the nation's first multipurpose energy research center, where he manages the International Energy Resource Cooperation section and oversees the laboratory's hydrogen production research program.*