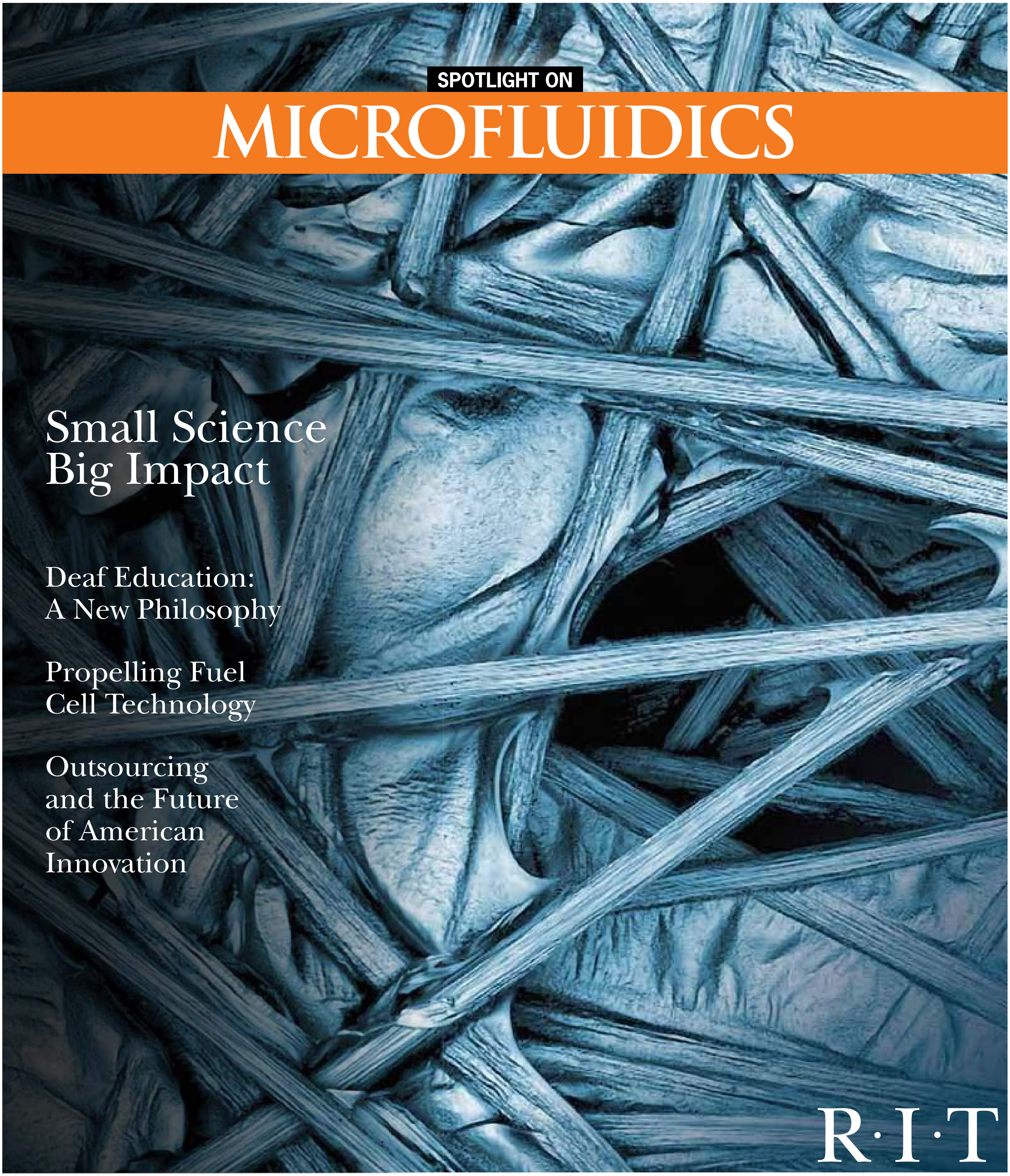
RESEARCH at RIT

The Rochester Institute of Technology Research Report

Fall/Winter 2011



SPOTLIGHT ON

MICROFLUIDICS

Small Science
Big Impact

Deaf Education:
A New Philosophy

Propelling Fuel
Cell Technology

Outsourcing
and the Future
of American
Innovation

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Donald Boyd,
Vice President for Research

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Contributing Writers
Michelle Cometa, Senior Communication
Specialist, University News Services

John Follaco, Senior Communication
Specialist, University News Services

Greg Livadas, Director of Media
Relations, NTID

Contributing Photographers
Elizabeth Lamark, Photographer,
ETC Production, The Wallace Center

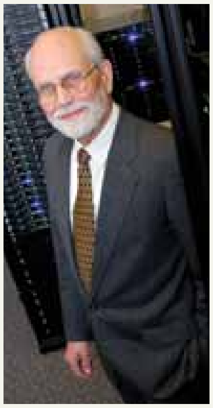
John Myers, Photographer

Office of Research Relations
74 Lomb Memorial Drive
Rochester, NY 14623
585-475-2167
E-mail: kmtpop@rit.edu

Vol. 4, No. 1
12M-P1032-10/10-PAL-JSA

Fueling the Future

Engineers, chemists, scientists, and policy experts at RIT are advancing the alternative energy technologies of the future.



The need for alternative energy solutions is not even a question. The vast majority of our energy comes from fossil fuels and is neither sustainable nor good for the environment. The debate is determining which alternative energy options are viable, creating the infrastructure to support them, and implementing policies that will encourage adoption.

At RIT, researchers across campus are developing a number of alternative energy technologies and analyzing societal factors that are critical to widespread adoption. In the NanoPower Research Laboratories chemical engineers are synthesizing novel nanomaterials and physicists are fabricating advanced photovoltaics. Our Clean Energy Incubator is now home to 10 startup companies, including Sweetwater Energy, whose patented cellulosic-based system creates concentrated feedstock for ethanol biorefineries.

In this issue we feature nearly a dozen laboratories that are focused on issues to help advance fuel cell technology. With a hydrogen fueling station on campus and a long-time partnership with General Motors, RIT is a destination for fuel cell technology. Dr. Satish Kandlikar, director of the Thermal Analysis, Microfluidics, and Fuel Cell Laboratory, is internationally recognized for his fundamental research in pool boiling. Today his laboratory is an integral part of General Motors' water management research for fuel cells.

At the Center for Sustainable Mobility, Matt Fronk, director of the center and former director of General Motor's Fuel Cell Research Laboratory, is leading an effort to create synergies among industry and academia and help accelerate the commercialization of fuel cell technology. Meanwhile, public policy experts are conducting analysis of alternative energy options and generating models to understand how policies might influence the market.

The answer to finding a viable alternative energy source may not be clear, but the good news is there are options. I invite you to learn about some of these options in this issue's feature articles.

We also highlight the National Technical Institute for the Deaf's Center for Education Research Partnership, where they are leading a movement to improve deaf education around the world. Our other feature focuses on Dr. Ron Hira, a public policy expert and national advocate for protecting America's work force.

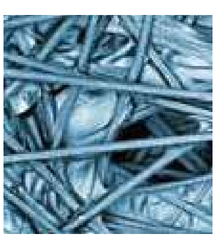
These features and more can also be found on our new website at www.rit.edu/research.

Best Regards,

Donald J. Boyd

Donald Boyd, Ph.D.
Vice President for Research

Inside this Issue



On the Cover
A confocal laser scanning microscope captures the three-dimensional microstructure of a gas diffusion layer used in proton exchange membrane (PEM) fuel cells. The Thermal Analysis, Microfluidics, and Fuel Cell Laboratory is conducting optical visualization studies to understand the fundamental mechanisms of water transport through a PEM fuel cell.

Water Management in PEM Fuel Cells: Dr. Satish Kandlikar, director of the Thermal Analysis, Microfluidics, and Fuel Cell Laboratory, and Jacqueline Sergi, mechanical engineering master's degree student, are conducting optical visualization studies on water management inside proton exchange membrane (PEM) fuel cells. The experiment uses a transparent fuel cell that represents actual automotive fuel cell geometry and allows for visualization of both the anode and cathode. The work is part of the lab's world-leading research portfolio that focuses on the fundamental phenomena of microfluidics and heat transfer.

Small Science Big Impact

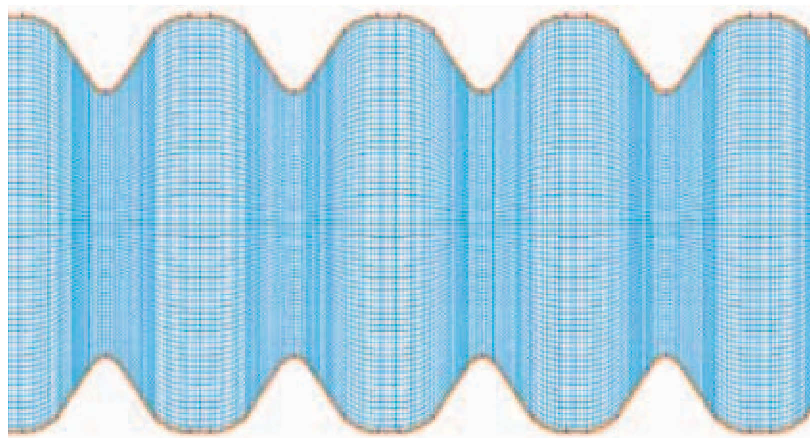
by Kara Teske

Researchers at RIT's Thermal Analysis, Microfluidics, and Fuel Cell Laboratory have gained international recognition for their fundamental research. With nearly two dozen student researchers, the laboratory immerses students in real-world research that establishes students within the industry long before graduation.

Fundamental Research Fuels Future Technologies

The saying goes, "Don't sweat the small stuff," but at RIT's Thermal Analysis, Microfluidics, and Fuel Cell Laboratory (TAμFL), it's the small stuff that has resulted in industry breakthroughs and earned the laboratory international recognition. Nearly 20 years ago, Dr. Satish Kandlikar, professor of mechanical engineering, founded the laboratory to focus on understanding the fundamentals of microfluidics and the phenomena of heat transfer. The research conducted is driven by actual industry challenges that allow students to learn at a level that will enable them to be innovators and influence future technologies.

The lab's early research focused on microscale fluid mechanics and heat transfer and positioned it as an international leader. Today, the lab has expanded to encompass a range of microfluidic applications, including pool boiling, heat transfer on a silicon chip, and water management of proton exchange membrane (PEM) fuel cells.



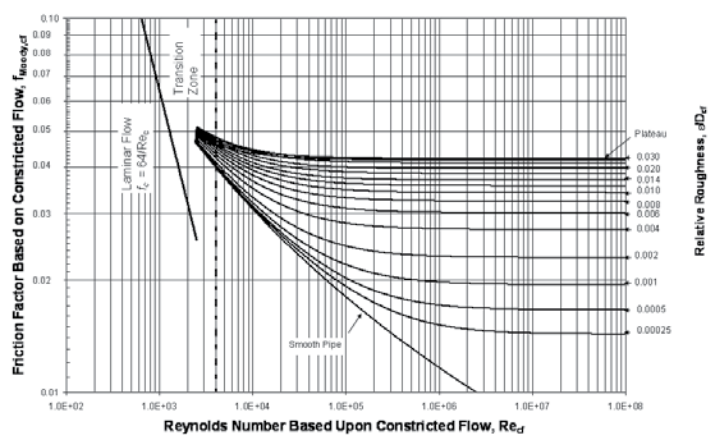
Roughness Effects Enhance Heat Transfer: Numerical and experimental studies show rougher microchannels have the ability to enhance heat transfer, but at the same time increase pressure drop. This is believed to be the first effort to systematically characterize the effect of structured roughness on fluid flow and heat transfer.

Revealing Roughness Effects in Microflows

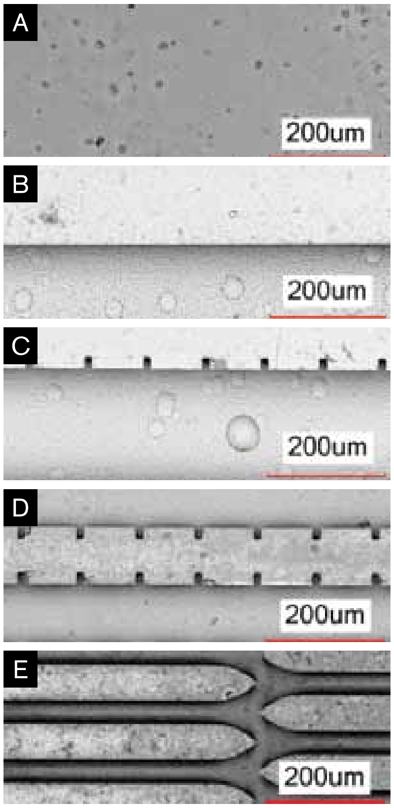
The effect of surface roughness on internal fluid flow has been apparent since 1933, but until recently the effect at the microscale was never fully characterized. In 2005, the lab opened a new area of study looking at the roughness effects on flow at the microscale. "Things are pretty well known for macroflows, but when you go down to microfluid flows—in channels smaller than a few hundred micrometers—things start to look different. By characterizing the microflow, it bridges the gap between macro and micro into one theory," explains Dwight Cooke, a master's degree student in mechanical engineering.

After carefully studying the literature published over 60 years, Kandlikar developed a modified Moody diagram that provides an accurate, yet very simple, way of calculating pressure drop in pipes at the macroscale, as well as at the microscale. Derek Schmidt and Tim Brackbill, master's degree graduates from the lab, confirmed the validity of the theory based on carefully conducted microscale experiments on rough tubes.

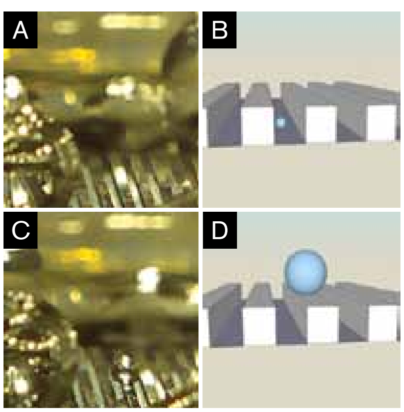
"Roughness inside the walls is on the order of micrometers—at the same size of the channels," says Viral Vinodray Dharaiya, a master's student who is building on to the research. "We



Modified Moody Diagram Developed by TAμFL: The Moody Diagram provides the friction factor inside a pipe based on the Reynolds number and relative roughness. It assumes that a surface can be defined by the average roughness. The lab developed a modified Moody Diagram that accounts for the roughness effects on flow at the microscale. The modified diagram is well accepted within industry and academia.



Understanding Pool Boiling to Enhance Performance: The lab is investigating the effects of five different geometries of chips on the pool boiling performance. Visualizations are captured at 1,000 frames per second and then analyzed to understand the bubble nucleation and growth in channels. The etched chips (b-e) all show increased performance compared to the plain chip (a).



Predicting Bubble Behavior: In-depth analysis of the pool boiling visualizations uncovered a bubble nucleating on the bottom surface (a-b), then moving to the top fin of the channel where it attaches itself and rapidly grows (c-d). The lab continues to investigate this finding to better predict bubble behavior and develop an optimal surface for heat transfer.

can't neglect how the roughness can affect the fluid flow and heat transfer."

Dharaiya is conducting numerical simulations for both smooth and triangular ribbed geometries and analyzing the resulting pressure drop through a National Science Foundation (NSF) sponsored project. The numerical simulation results are validated in an experimental investigation being conducted by graduate students Rebecca Wagner and Nicholas Schneider. The research shows rougher channels have enhanced heat transfer, but at the same time increased the pressure drop. This work is believed to be the first of its kind to systematically characterize the effect of structured roughness on fluid flow and heat transfer. The goal is to develop designer surfaces that will provide the desired thermohydraulic characteristics at microscale using roughness structures.

The modified Moody Diagram has positioned the group as leaders within the engineering community. Additionally, they are recognized for coining the industry- and academia-accepted definitions for microchannels, which are 200 micrometers and smaller in diameter; minichannels, which range from 200 micrometers to 3 millimeters; and nanochannels, which are below 1 micrometer.

Understanding Bubbles

Another key area of research the lab focuses on is boiling heat transfer and chip cooling. Recently, the lab partnered with IBM through a sequence of three (maximum possible) IBM Faculty Awards to conduct fundamental research that aided in the development of a proprietary chip design capable of cooling chips at approximately 700 watts per square centimeter. This work builds on some of the lab's pioneering research in the fundamental understanding of the boiling phenomena. More recently the research focuses on enhancing heat transfer on chips through the analysis of fundamental mechanisms of pool boiling and critical heat flux using high-speed cameras and microscopes.

"In pool boiling there is a stagnant liquid that is heated up, as opposed to flow boiling, which requires a more active system," explains Cooke. "This approach has the potential to remove a large amount of heat resulting from the evaporation of liquid into vapor phase with little pressure drop penalty."

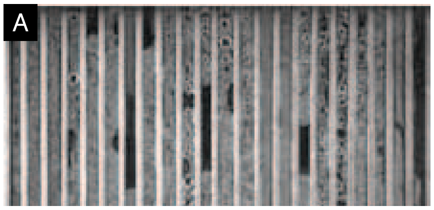
Using high-speed video imagery, as well as quantitative data, the lab is investigating the effects of different geometries on the pool boiling performance. "Studies have been conducted on roughening up the channels to promote bubble growth, but it's not understood how the bubbles emerge, how they interact, and what actually makes it better," says Cooke.

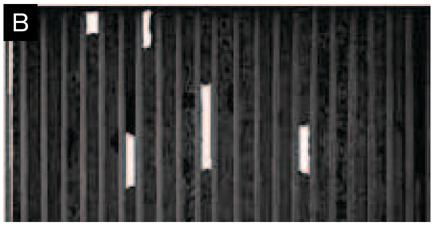
Five particular chips are being investigated, each having overall dimensions of 20 mm x 20 mm with a heated micromachined area of 10 mm x 10 mm and either 200 or 100 micrometer channels. The visualizations are captured at 1,000 frames per second, then closely analyzed to understand the bubble nucleation and growth in microchannels. All of the chips show an increase in performance compared to a plain chip, which may be explained by the increased surface area of the etched chips that allows for more heat transfer. Additionally, the structure of the chips affects the fundamental mechanics of bubble dynamics in pool boiling.

After watching countless hours of footage, Cooke also began to notice an extraordinary pattern. "I discovered a bubble nucleate on the bottom surface, then remarkably move to the fin—or top—of the channel, where it attaches itself and rapidly grows," Cooke explains. The group is taking a closer look at these findings to develop an optimal setup and better predict the bubble behavior. The work is also being extended to the application of nanotubes to enhance heat transfer during boiling on a silicon chip in collaboration with Dr. Yen-Wen Lu at the National Taiwan University under another National Science Foundation grant.

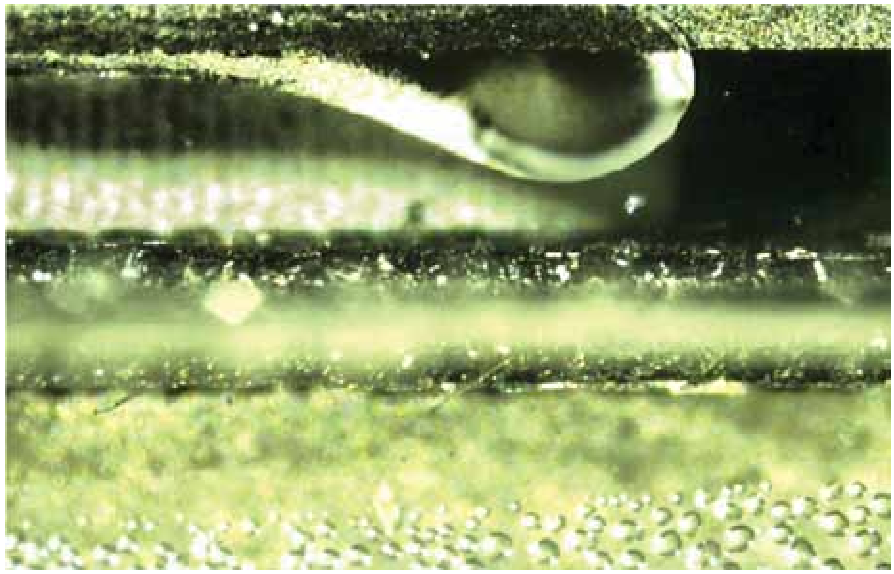
An Industry Partnership to Advance Water Management in PEM Fuel Cells

One of the lab's most successful areas of research deals with water management in PEM fuel cells. Through a series of Department of Energy (DOE) and New York State Energy Research and Development Authority grants, the lab works





Optical Visualization: A transparent fuel cell designed at the lab represents actual automotive geometry and allows for simultaneous visualization of the anode and cathode. High-speed imaging is used to analyze the two-phase flow and water structures inside the cell's microchannels (A). A MATLAB algorithm developed by Jacqueline Sergi, a mechanical engineering master's degree student, allows the water inside the microchannels to be automatically detected and quantified (B).



Cross-sectional View: A digital microscope image of an operating transparent PEM fuel cell reveals the anode and cathode gas channels, as well as the GDL cross-sections. Liquid droplets are routinely observed emerging from the cathode GDL and wick onto the top of the channel (top). Condensation in the anode channels is present under various operating conditions without the use of external humidification in the gas streams–indicating anode GDL water transport is primarily in the vapor phase.

intimately with General Motors to obtain a fundamental understanding of transport phenomena, which helps optimize material selection and product design.

Water management within a PEM fuel cell is critical to optimizing the cell's performance and longevity, especially under cold weather and freezing conditions. Without sufficient hydration, proton conductivity of the membrane cannot be maintained, but an excess amount of water can lead to flooding, which blocks reaction sites and hinders the flow of reactants. The lab is conducting visualization studies to provide a fundamental understanding of water transport within the fuel cell and identify the optimal balance of water. The process can be investigated at any level of the cell. At TAμFL, one group is looking at the channel level two-phase flow, while another group focuses on the gas diffusion layer (GDL).

Due to the complexity of a fuel cell, there are limited techniques available for characterizing the flow inside the cell. In the RIT lab, researchers are using optical imaging, which requires the development of a modified cell with transparent components. Jacqueline Sergi, currently a mechanical engineering master's degree student, helped to design a transparent fuel cell while on co-op at General Motors.

Using high-speed cameras, optical visualization studies are conducted at TAμFL to analyze the flow right down to the structure of the water. The fuel cell is transparent on both sides, which allows the anode and cathode flow channels to be viewed simultaneously. During operation, two-phase flow within the cell is captured using high-speed cameras. The flow is then characterized, and the frequency of different flow types is identified.

Sergi also developed an image-processing algorithm in MATLAB, which automatically detects pixels in the videos that represent liquid water. This processing technique enables the quantification of water inside the microchannels.

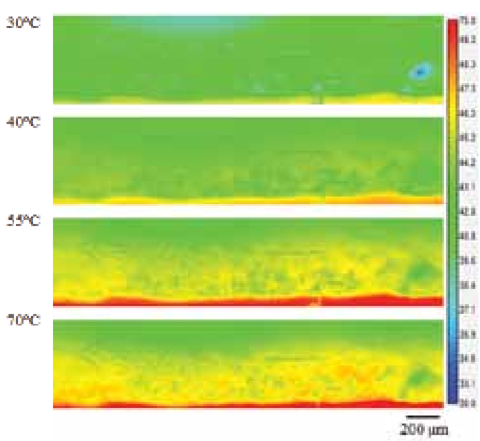
"Satish is internationally recognized for his expertise in this area. By partnering with his lab, we are able to gain fundamental knowledge to understand why something works and receive accurate parameters to help optimize our designs," says Jon Owejan, senior research engineer at General Motors.

Complementary work is conducted by General Motors using neutron imaging, which allows a fuel cell to be imaged without any modification to the standard cell materials. Because neutrons are able to pass through fuel cell materials with little attenuation but are heavily scattered by hydrogen, liquid water accumulation inside an operating fuel cell can be probed without modification to the design or materials. The capability was developed jointly by General Motors and the National Institute of Standards and Technology (NIST), led by Owejan and Thomas Trabold, former laboratory group manager at General Motors and now associate research professor at the Golisano Institute for Sustainability.

Michael Daino, a microsystems doctoral student, is investigating the GDL, a porous carbon fiber paper critical to water management. The GDL distributes the reactants throughout the cell and transports product water from the reaction sites into the gas channels. In recent years, advancements to this fibrous mate-

Thermal Analysis, Microfluidics, and Fuel Cell Laboratory: Led by Dr. Satish Kandlikar, TAμFL provides students with real-world research challenges that prepare them to be leaders in their industry. Students use the most sophisticated experimental techniques and are making significant contributions to industry long before graduation.

rial have improved water transport dramatically. However, the transport mechanisms continue to be debated because of the inability to probe the opaque material with high spatial resolution. Daino's research utilizes a confocal laser scanning microscope to examine the 3-dimensional microstructure of the GDL and reveal pore-scale properties that affect water transport. He also observes the GDL cross-section in an operating fuel cell using a digital microscope and high-resolution infrared camera.



Infrared Imaging: Infrared images of the GDL cross-section at various constant temperature boundary conditions are applied to the bottom of the GDL with color scale in degrees Celsius. The temperature gradient across the GDL affects the water transport from the catalyst layer to the gas channels.

The high-resolution cross-sectional imagery reveals anode GDL water transport is dominantly in the vapor phase as opposed to the cathode GDL where liquid water is routinely observed. The infrared imaging is utilized to determine the temperature gradient across the 200-micrometer-thick material, which affects the water transport through the GDL. This novel study allows for the direct comparison of GDL thermal properties to fuel cell performance.

"This partnership with General Motors provides an invaluable experience for our students," says Kandlikar. "They are able to participate in research using the most sophisticated experimental techniques and have a direct influence on industry even before they graduate."

Research Experience Provides a World of Opportunities

"Students are the centerpiece of the research at TAμFL. It is amazing to witness the dramatic transformation as students unravel a new dimension of their talent and are contributing at the cutting edge of the technology. They are on their way to become the top researchers in their chosen field with an unparalleled combination of fundamental and applied science perspective," says Kandlikar.

Every student in the lab publishes at least one journal paper before graduation—many become top-cited in his or her particular field of research. Dr. Mark Steinke, the university's first microsystems engineering doctoral graduate and now a thermal engineer at IBM, published over 12 conference and journal papers.

This summer Kandlikar hosted the 8th annual International Conference on Nanochannels, Microchannels, and Minichannels in Montreal. Kandlikar is also regularly invited to give keynote and plenary lectures around the world, including engagements in Montreal, Washington, D.C., La Grande-Motte, Moscow, and Fukuoka.

Under Kandlikar's leadership his students are immersed early on into the global research community. "This experience has allowed me to see that my research is relevant on a global level and has exposed me to a whole world of opportunities," says Sergi.

On the Web

For more information about these labs, visit www.rit.edu/kgcoe/mechanical/taleme/.

Smart Building Technologies

Robert Garrick

The RIT campus is undergoing a transformation that has gained it recognition as a Campus Sustainability Leader, according to the Sustainability Endowment Institute. Dr. Robert Garrick, associate professor in the College for Applied Science and Technology (CAST), along with his students, is embracing the movement and working with RIT's Facilities Management Services (FMS) and external companies to integrate and evaluate smart building technologies throughout the RIT campus.

From the new Global Village complex to Leadership in Energy and Environmental Design (LEED) gold and platinum certified buildings, the campus provides a perfect test bed for students to apply the knowledge they gain in the classroom. In partnership with FMS and external companies, students examine the building systems to assess efficiencies and look for opportunities to better integrate building sub-systems. By understanding how the systems operate and their efficiency, students strive to improve building performance and human comfort.

For example, the team of students and FMS staff has deployed solar sensors in Engineering Technology Hall and University Services Center to enable better building control by understanding solar exposure. By knowing the solar energy, the team strives to improve the control of the heating and air conditioning systems.

"One of the challenges of the LEED certified buildings is maintaining human comfort while maintaining energy efficiency," explains Garrick, who is also the recipient of the 2009-10 Richard and Virginia Eisenhart Provost's Award for Excellence in Teaching. "If we can improve building sub-systems integration the efficiency will be even greater."

The students are also developing an experiment with the new residence halls at RIT's Global Village. The team proposes that smart energy performance meters be installed in each dormitory and provide real-time energy consumption data. The research results would uncover the human interaction issues that must be addressed to allow smart energy meters to achieve their intent.

Controls to Enhance Building Efficiencies: Student researchers are working toward collecting dynamic occupancy information and linking building sub-systems that allow for better control and further enhance efficiency. The team deployed solar sensors (denoted in red) in two LEED certified buildings on campus to enhance better building control by understanding solar exposure.

Geopolymers—a Resource for the Mobile Military

Ben Varela

Geopolymers, inorganic compounds with better compressive strength and flexibility than reinforced cement, have the potential to replace traditional cement for military, commercial, and domestic applications—from buildings to roads and airport runways.

Dr. Ben Varela, associate professor in the department of mechanical engineering in the Kate Gleason College of Engineering, is working with the United States Air Force Office of Scientific Research to test the feasibility of using geopolymer materials for military applications. Varela visited Wright-Patterson Air Force Base in Ohio to complete a series of tests on the development of the composite material.

Geopolymers are inorganic materials, synthesized from kaolins or fly ash, prepared with alkaline solutions and soluble silicates. The formula has the consistency of a dense paste that starts to solidify in a matter of hours, compared to days needed for traditional cement.

"Depending on the composition, you can have a solid block within a couple of hours, with strength measuring 3,000 psi," Varela explains. PSI, or pounds per square inch, is a measurement of pressure on the structural block. Comparatively, cement may reach that level of strength, but it takes 28 days.

"That is what the Air Force was interested in. If we can cast a runway, we can potentially have airplanes landing in less than a day," says Varela. "We use concrete for many applications, but concrete is not as stable at high temperatures. It deteriorates at 450 degrees Celsius. In fires, that is the cause of the collapse of the structure. In the case of geopolymers, my experiments show they are stable up to 1,000 degrees Celsius and we are looking to raise that level even higher."

The process to manufacture geopolymers also requires less energy because it is done at a lower temperature than cement, 65 degrees Celsius, saving energy in the overall process. "The production of cement and concrete produces a large amount of carbon emissions. It is estimated that for every ton of cement we produce, we also produce one ton of carbon dioxide," says Varela. Cement manufacturing is one of the largest emissions producers of carbon dioxide to the atmosphere. Geopolymers may be an alternative to the use and manufacture of structural materials.

"We are finally realizing the potential of geopolymers and we are catching up with the research being done in Australia and Europe very, very fast. We are only one of a few research groups in the U.S. but interest is picking up and there is a potential now to retrofit some structures such as roads and bridges," adds Varela.

K-PSS Geopolymer: The K-PSS Geopolymer was exposed to 1100 degrees Celsius for four hours. The sample showed some minor cracks on the surface but remains remarkably stable, shrinking only 3 percent.

Deaf Education: A New Philosophy

by Greg Livadas

Research at NTID is shifting the way deaf students are being educated. Recent research suggests that even with qualified interpreters in the mainstreamed classroom, educators need to understand deaf children learn differently, are more visual, and often process information differently than their hearing peers.

Research Findings at NTID

A popular assumption in education for many years was that deaf students are the same as hearing students except that they simply don't hear. But research at RIT's National Technical Institute for the Deaf is contradicting that belief, and consequently altering the way deaf students are being taught.

"We're changing the face of deaf education around the world," says Dr. Marc Marschark, professor and director of NTID's Center for Education Research Partnerships (CERP). "You can't teach deaf kids as though they are hearing kids who can't hear. It's not about ears and it's not about speech versus sign language. It's about finding their strengths and needs. The historical approach to deaf education simply doesn't work well enough to get deaf students where they need to be."

Center for Education Research Partnerships: Established in 2002 at RIT's National Institute for the Deaf, the Center for Education Research Partnerships explores how deaf students learn. The center, led by Dr. Marc Marschark, is working to improve deaf education around the world.

Through the center's research, thousands of deaf and hard-of-hearing students—from children as young as five to college students—have been tested in Australia, the Netherlands, England, Scotland, and on the RIT campus in Rochester, N.Y., to determine how they acquire new knowledge and how that knowledge is organized, understood, and communicated to others. Studies involve everything from tracking eye movements and performing memory tasks to attending experimental "classes" taught by deaf and hearing teachers.

For hearing children, a flood of information arrives constantly from background noises, ambient conversations, even words heard on the television. Deaf children may not have the same opportunities to learn through hearing, but they have different opportunities, Marschark points out.

Understanding How Students Learn: The center's research focuses on deaf and hearing children from 5-11 years old, as well as college-age students. The mathematics project, sponsored by the National Institutes of Health, is helping to uncover the differences in how deaf and hearing individuals process information.

Ambassador for Deaf Education: Dr. Marc Marschark and his colleagues present their research findings at dozens of conferences and workshops around the world annually.

But does it matter whether the child has deaf or hearing parents? Whether the child uses sign language or his or her voice? Whether the child uses a cochlear implant?

Recent research findings show:

- The deaf students who perform best academically usually are the ones whose parents have effectively communicated with them from an early age.
- Children who sign early on generally outperform those who do not sign during their early school years.
- Early language skills—both American Sign Language and spoken language—correlate with reading ability, with no evidence that one is necessarily better than the other.
- Most deaf students' difficulties in reading are mirrored by difficulties in understanding sign language.
- Deaf and hard-of-hearing children entering school often are lagging behind hearing children in their knowledge of the world, number concepts, and problem-solving skills, not just in language.
- Deaf students do not always learn, think, or know in the same ways as hearing children.

CERP's Origins

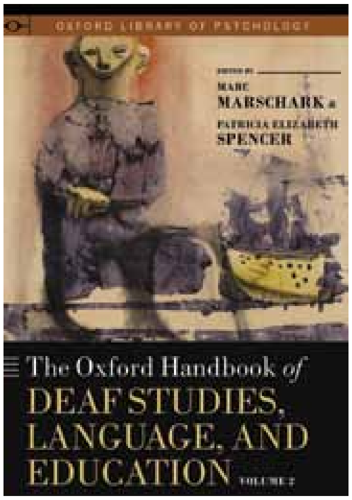
CERP occupies much of the north wing of the first floor of the Mark Ellingson Residence Hall and has a laboratory and office area in Peterson Hall. Five of the 10 staff members are graduates of NTID's master of science program in secondary education; five are nationally certified sign language interpreters. All of its funding—more than $6 million so far—is from grants from the National Science Foundation, the National Institutes of Health, and contracts or gifts from foundations, U.S. organizations, and foreign governments.

CERP has roots as early as 2002, when it was awarded its first NSF grant to study factors thought to influence deaf students' learning through sign language and barriers that hinder classroom learning. The following year, a second NSF grant was awarded for research to study communication and technological barriers to STEM (Science, Technology, Engineering, and Mathematics) education for deaf and hard-of-hearing students.

"One thing we found in our early studies is that despite what some people claim, deaf students' difficulties in mainstreamed classrooms could not be blamed on interpreters," says Marschark. "We started realizing some differences between deaf and hearing students: how their memory works, the organization of their knowledge, and their learning strategies are simply different. So for mainstream teachers, you can't assume the deaf students coming into your class know the same things or learn the same way as your hearing students. For example, deaf people's visual-spatial memories are better than hearing people's. But sequential memory isn't as good."

For decades, expectations of education for deaf students have been lower than for their hearing peers. Fifty percent of deaf and hard-of-hearing students graduating high school in the U.S. read at or below fourth-grade levels.

But research by Marschark and others shows that how much hearing one has doesn't predict how much they'll learn, either as children or adults. "Whether you use a hearing aid or a cochlear implant or are a native signer who uses ASL, they each have advantages," he says. "But by the time they're in college, all of that is washed out. Their experience has leveled it out."



A Handbook to Deaf Studies: Dr. Marc Marschark and Dr. Patricia Elizabeth Spencer have recently authored *The Oxford Handbook of Deaf Studies, Language, and Education.* The book provides a comprehensive review of the current state of deaf studies.

Raising and Educating a Deaf Child: More than 50,000 visitors have come to www.educatingdeafchildren.org since its inception in 2009. It remains a popular resource where parents can ask questions about their deaf or hard-of-hearing children.

History of Deaf Education

Deaf children for centuries have not been educated as well as their hearing peers. Still today, there are no schools or provisions for teaching deaf children in many countries.

Prior to the advent of television and wireless pagers, deaf people in the U.S. used to gather at clubs or on street corners to share the latest news in sign language. Then a movement grew to educate deaf children orally and encouraged (or forced) them to use their voices.

In 1960, linguist William C. Stokoe recognized American Sign Language as a bona fide language, complete with its own syntax and linguistic features. More schools started to utilize American Sign Language as the language of instruction.

The Americans with Disabilities Act, signed into law in 1990, also marked a change in education for deaf and hard-of-hearing children. More parents of deaf children were sending them to mainstreamed schools, which are required to provide necessary accommodations to ensure their education. That could include interpreters in the classroom, but qualified interpreters weren't always found, especially in rural areas.

Today, Marschark says 86 percent of deaf students in the U.S. are in mainstreamed programs all or part of the day. In many cases, they are the only deaf or hard-of-hearing student in their school.

"Mainstreamed teachers think that if they remove the communication barriers they can teach their deaf kids as though they are hearing kids. Now that we've discovered some of the differences in how deaf and hard-of-hearing students learn, we want to know how to turn that knowledge into more effective teaching strategies. We're in a position to educate parents and mainstream teachers about how these kids are different. Using the memory example, given their difficulties of retaining sequences, if you arrange material visually and spatially, deaf kids would do better."

Hidden Figures Test: This common children's activity tests the visual-spatial strengths of deaf and hard-of-hearing students.

Marschark is taking his research out of the laboratory and into classrooms and lecture halls around the world. He gives invited presentations to parents, teachers, and other professionals more than 20 times a year and has written several books on the subject. Marschark and his colleagues gave nine presentations in July 2010 describing various aspects of their findings at the International Congress on the Education of the Deaf (ICED) in Vancouver, B.C.

In 2009, CERP launched a website (www.educatingdeafchildren.org) intended as a clearinghouse for objective answers to questions about raising and educating a deaf child. To date, dozens of

Overseas Successes

NTID's Center for Education Research Partnerships has earned an international reputation. Its staff was asked to continue work that began in 2000 to study the achievements of the 2,122 deaf students in Scotland—from preschool through high school. Extensive data was collected on virtually every deaf child in that country.

The project, based at The University of Edinburgh, continued until 2005, when Mary Brennan, a noted researcher involved with deaf education in Scotland, died. CERP obtained a grant in 2009 with collaborators at Edinburgh to continue her work and is now studying how academic outcomes of the students is related to early social, language, and educational predictors.

Dr. Marc Marschark—director of CERP at RIT, and who has appointments with The Moray House School of Education at the University of Edinburgh and in the School of Psychology at the University of Aberdeen—is also studying mathematic achievements of deaf students, from ages 5 to 25, in the U.S. and Scotland.

"Despite the frequent focus on reading comprehension, deaf students historically lag behind their hearing peers in mathematics, which has implications for all of their schooling and subsequent employment," Marschark says.

That project is made possible by a $1.65 million grant in 2008 from the National Institute for Child Health and Human Development. The project's co-investigator is Dr. Rebecca Bull, of Aberdeen, who is an internationally recognized expert in young children's mathematics abilities, Marschark says.

questions have been asked and answered on the site, which has had more than 50,000 visitors from around the world.

Many of his findings today about deaf students' learning would not have been politically correct to utter just a few years ago, he says.

"Five years ago we thought the same thing, but we didn't have the evidence. Now we know it's true," he says. "In the past, saying things like this upset people. But the climate has changed. People are accepting that differences don't mean deficiencies. Now people better accept their strengths and weaknesses."

Today, fewer schools specializing in education for deaf students exist. And several have been eyed for closure in the near future due, in large part, to dwindling enrollments.

"Rather than closing them, we need more programs that understand how to educate deaf kids," Marschark says. "The mainstream as it exists now is not necessarily the best place for many deaf students. Sure, a kid doing OK in the mainstream will stay there. But he could be a star in another setting. The status quo is not good enough."

Changing Attitudes

A lot of parents think that if their deaf child learns sign language, it will interfere with learning to speak.

"Not true," says Marschark. "Early sign language actually can support later spoken language for children with or without cochlear implants."

And his research shows that if a deaf child knows English as well as sign language, he or she tends to do better academically, socially, and with language development.

"Literacy is a big challenge," Marschark says. "For 100 years, we've made very little progress at improving deaf kids' reading. Current research suggests that we've been looking in the wrong place. The reading problem is not about reading. It's about comprehension. They learn just as much from what they read as what is signed or spoken. It's counterintuitive for many people, I know, but the evidence is very clear."

Just as there were varying opinions on whether deaf students should sign or speak, more recent controversy existed with the improvement of technological advances and cochlear implants (CI). More than 275 students at RIT/NTID currently have CIs, which enable them to hear some sounds. For years, implants were controversial in the Deaf (the uppercase D denotes those who see themselves as part of a linguistic-cultural minority) community, especially for young children with hearing parents. Many were afraid those children would never be exposed to sign language or their rich cultural history.

"We're not interested in the political or the philosophical. We're sensitive to those issues, but we're trying to figure out how we can best support learning in the classroom for students of all ages," Marschark says.

Dr. Louis Abbate, president and CEO of the Willie Ross School for the Deaf in Longmeadow, Mass., said CERP's research was looked at when the school rewrote its mission five years ago. The school, founded in 1967, used to stress only oral communication for its students. Now, with an integrated campus, they need the flexibility to teach students orally or in sign language or both.

"We needed the flexibility to respond to the needs of each student," Abbate said. "Marc was the first person we went to when we wanted to look at our communication model." Abbate has often referred parents to CERP's website: "The answers are very balanced and very reasonable. We use that all the time. So many parents are faced with either/or decisions early on, and they usually get pushed in one direction. Marc's work is balanced. It talks about the value of different approaches and how they can be integrated with one another."

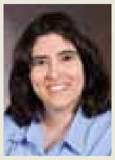
Dr. James DeCaro, interim president of NTID, says CERP's work is an asset to the field of education of the deaf and to RIT/NTID.

"Marc continues to build the preeminent research center in our field addressing these important teaching and learning issues," DeCaro said. "We are lucky to have him here at RIT."

On the Web

Learn more about the Center for Education Research Partnerships at www.rit.edu/ntid/cerp.

Making Computing Accessible for Visually Impaired



Stephanie Ludi

Tom Reichlmayr

Research conducted in RIT's B. Thomas Golisano College of Computing and Information Sciences is making computing more accessible for the visually impaired.

Software engineering associate professors Dr. Stephanie Ludi and Tom Reichlmayr have been awarded two National Science Foundation grants to expand the Accessible Computing Educaiton Project (ACE), which strives to increase participation in computing among students with visual impairments through outreach, class material preparation, support, and teacher development.

"The computing world needs new perspectives," says Ludi, the principal investigator of the grants. "We're not going to move forward and really innovate until we include all points of view. Right now women and people with disabilities are really in the minority. We need to bring those people to the table."

Ludi and Reichlmayr led a summer-long Research Experience for Undergraduates program to continue to develop activities that engage visually impaired students in computing using robotics.

Robotics Engage Visually Impaired: Researchers at RIT are developing activities that engage visually impaired students in computing through the use of robotics.

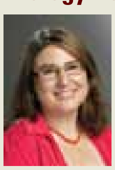
Those activities are then tested during computing workshops for visually impaired students. These sessions, dubbed ImagineIT, have taken place at RIT, as well as in San Diego and New York City.

"It's really rewarding to see how excited the students get," says Reichlmayr, a co-principal investigator. "These students are a very small minority in their schools and they have limited opportunities to collaborate with other students who are just like them."

Ludi hopes to soon expand the project's online resources, making it easier for teachers to access their lesson plans. She is also teaming with students to make "Alice," a popular computer programming software tool that was developed by researchers at Carnegie Mellon University, more accessible.

"It's one thing to bring visually impaired students into the world of computing—that's very important," says Ludi. "But once they're here, we need to keep them here. They need to be supported."

Biology Research Develops Students



Dina Newman

Hyla Sweet

Alicia Wooten

Faculty members in the College of Science are helping to prepare deaf and hard-of-hearing students for graduate school by making the research experience more accessible. The program, Undergraduate Research and Mentoring for Deaf Students in Biology, is led by Dr. Hyla Sweet and Dr. Dina Newman, faculty members in the School of Biological and Medical Sciences, through a National Science Foundation Undergraduate Research and Mentoring (NSF-URM) grant.

"Historically, deaf and hard-of-hearing students have not been involved in undergraduate research—an important part of the education experience," says Sweet. "This program makes the undergraduate research experience accessible to these students and provides them with the skills to be successful in graduate school."

Students who are selected for the NSF-URM Fellowship are matched with a research mentor and work side-by-side for two years, conducting research and gaining exposure to the research community. "I am learning how to communicate scientifically," says Alicia Wooten, a 4th year undergraduate student in biomedical sciences and a NSF-URM Fellow paired with Sweet. "Presenting my research at the Undergraduate Research and Innovation Symposium has given me confidence in my research."

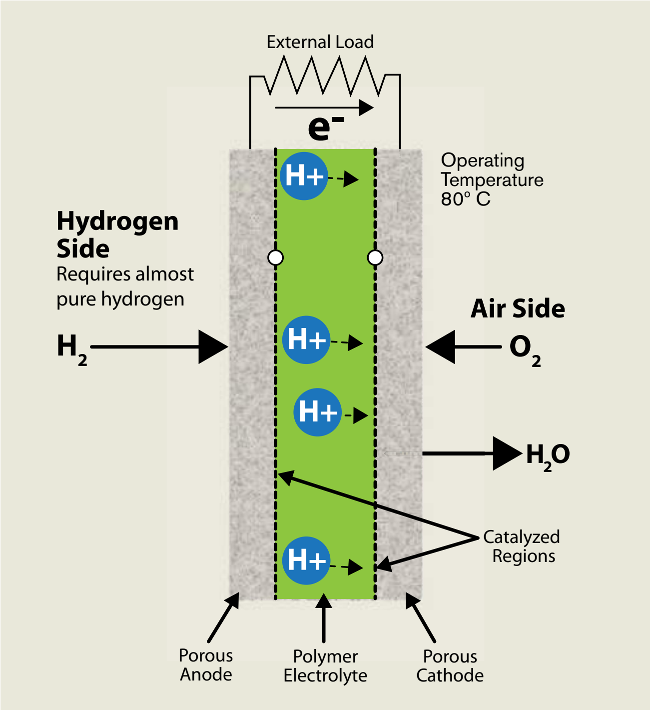
The pair is expanding on Sweet's research in developmental biology that examines the evolution of development and development changes through time that result in different body plans in animals. Using sea urchins as a model, the research team has been studying the expression patterns and function of certain developmental genes.

"Sea urchins provide a good model for studying evolution," explains Wooten. "They have an extensive fossil background that provides us with significant data to accurately compare our findings to."

Their studies have already uncovered significant differences in both expression and function. As they continue to examine more genes they are building a more complete picture to better understand how the genes are interacting to affect the expression, function, and overall differences.

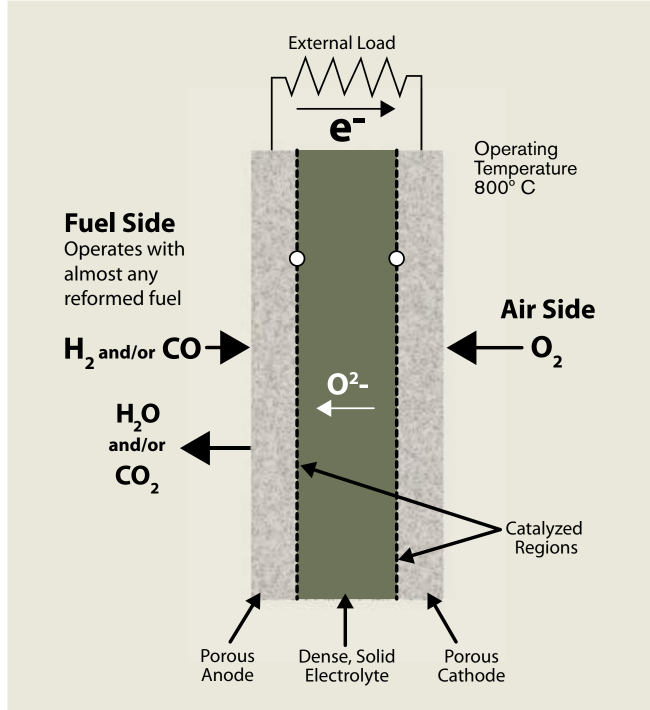
Research Experience Builds Confidence: Alicia Wooten (right), with mentor Dr. Hyla Sweet (left), present their research results at the Undergraduate Research and Innovation Symposium.

The program has already successfully graduated its first cohort in May 2010. Kevin Keller, one of the program's first fellows was accepted into the Ph.D. program at Michigan State University in ecology, evolutionary biology, and behavior. Another one of the Fellows, Jeff Barnette, is enrolled in the environmental science graduate program at RIT.



Proton Exchange Membrane Fuel Cells

PEM fuel cells are typically used in automotive applications and operate at lower temperatures, allowing lower cost materials and components, but require almost pure hydrogen.



Solid Oxide Fuel Cells

Solid oxide fuel cells are used for stationary and auxillary power unit applications and require more costly materials and components, but can operate with nearly any reformed fuel.

Propelling Fuel Cell Technology

by Kara Teske

RIT researchers across campus are conducting a wide array of fuel cell research to advance the widespread adoption of this clean and efficient green technology.

Fundamental Research to Commercialization

When man stepped foot on the moon more than 40 years ago, fuel cell technology was there electrifying the journey. Why, then, has this emission-free, clean technology not been widely adapted here on earth? There are three main challenges researchers at RIT and around the world are addressing to enable the widespread adoption of fuel cell technology: cost, durability, and hydrogen infrastructure.

Driven by industry and with support from local, state, and federal government, RIT researchers from across campus are addressing these challenges in a number of ways:

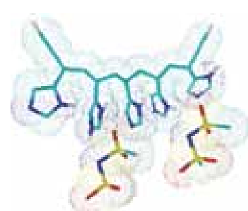
- Polymer chemists are synthesizing new materials to enable better performance of proton exchange membrane fuel cell membranes at high temperature (greater than 100°C) and low relative humidity;
- Mechanical engineers are conducting fundamental analysis on the water management inside proton exchange membrane fuel cells;
- Another group of mechanical engineers is creating models and conducting real-time simulation to improve cell performance;
- Chemical engineers are developing processes to integrate new materials;
- Industrial engineers are developing novel manufacturing processes to enhance durability and manufacturability;
- Researchers at the Golisano Institute for Sustainability are testing complete fuel cell systems to accelerate commercialization; and
- Public policy experts are analyzing the policy mechanisms to push the market, the development of the necessary infrastructure, and environmental impacts of hydrogen fuel cell technology.

"Together, the researchers create a wealth of knowledge from fundamental understandings to testing and simulation that will help to accelerate the commercialization and introduction of fuel cell technology," says Matt Fronk, director of the Center for Sustainable Mobility at the Golisano Institute for Sustainability and former director of General Motor's Fuel Cell Research Laboratory. "When adopted, fuel cell technology, along with other alternative fuel and propulsion technologies, will help us achieve the national goal of reducing our CO2 emissions 80 percent by 2050."

Fuel Cell Chemistry

Novel Polymers to Improve Performance and Economic Viability: Dr. Thomas Smith, professor of chemistry, and Fan Yang, a master's degree chemistry student, are synthesizing a novel polymer to help address the high- temperature membrane problem and trying to identify alternative catalysts to replace platinum and improve affordability of hydrogen fuel cells.

As discussed in the article "Small Science Big Impact" beginning on page two, one of the critical challenges of proton exchange membrane fuel cells is managing the water inside the cell. Dr. Thomas Smith, professor of chemistry and interim academic director of the Golisano Institute for Sustainability, is also examining a related issue described as the high-temperature membrane problem. An essential constituent of the proton exchange fuel cell is the proton exchange membrane (PEM). The PEM is typically a sulfonic acid fluoropolymer that needs to be hydrated to function well. When the temperature is elevated, above 100°C, the humidity drops and the proton conductivity in the PEM decreases dramatically. Smith has been leading an effort to explore the ability of a PEM comprised of a nanocomposite of a fluoropolymer and a novel protonated imidazole polymer to transport protons at high temperature and low humidity.



Imidazole Polymer: Dr. Thomas Smith, professor of chemistry, is synthesizing a unique polymer–imidazole–to improve performance at high temperatures and low humidity.

These unique polymers are synthesized at RIT and have been provided to Dr. Timothy Fuller at General Motors for evaluation of proton conductivity. Smith and Fuller have been collaborating since 2004. Jinhang Wu and Jingjing Pan, graduates of the chemistry MS program, both completed thesis research that focused on the elucidation nature of the nanocomposite membranes. Joel Walker, an undergraduate chemistry student, is continuing to synthesize imidazole polymers for proton conductivity studies at GM. While proton conductivity results to date at temperatures below 100°C have been promising, measurements at higher temperatures are needed in order to assess the viability of imidazole polymer composites as a solution to the high-temperature membrane problem.

"When we are educating students we look at a critical technology problem and say, 'What's the need? What's the critical problem?' Working on this problem allows our students to learn and see what issues need to be addressed, and that it takes time to find the answers. From this perspective this research has been an excellent learning vehicle," says Smith.

The other aspect of hydrogen fuel cells the chemists are working to address is identifying a membrane electrode system with a base metal catalyst to replace platinum. "If we can catalyze oxidation of H_2 and reduction of O_2 with metals that are cheaper and more ubiquitous in the environment, the economic viability of hydrogen fuels cell will be greatly enhanced," adds Smith.

A Career in Alternative Fuels

RIT offers a variety of academic programs that examine fuel cell technology and prepare students for a career related to alternative fuels. The New York State Energy Research and Development Authority (NYSERDA), along with RIT's College of Applied Science and Technology and the Monroe Community College, has established the Rochester Clean Energy Education Partnership. Through this collaboration new courses were created that focus on alternative energy technology and clean energy development. RIT's programs include:

Ph.D. Programs
- Sustainability
- Microsystems Engineering

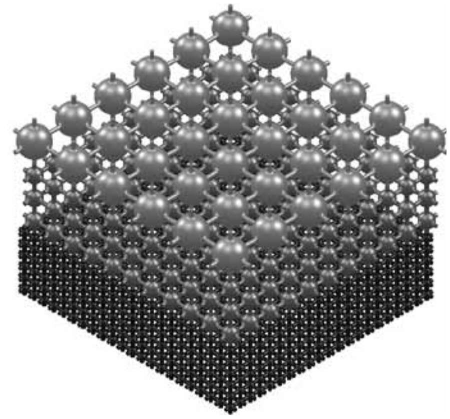
Master's Degree Programs
- Science, Technology, and Public Policy
- Sustainable Engineering
- Sustainable Systems (pending NYS approval)

Bachelor's Degree Programs
- Chemistry (environmental chemistry track)
- Chemical Engineering (alternative energy and environmental tracks)
- Mechanical Engineering (alternative energy and environmental tracks)
- Polymer Chemistry
- Public Policy (environmental policy track)

Learning about Fuel Cells: Dr. Clark Hochgraf, associate professor in the College of Applied Science and Technology, leads fuel cell course work that teaches students how to make use of fuel cell technology and the societal impact.

Advanced Manufacturing Processes

Novel Approach to Fuel Cell Manufacturing: Dr. Denis Cormier, associate professor of industrial and systems engineering, is developing additive manufacturing processes, which will allow the materials to be graded by porosity and improve the overall durability of the cell.



Grading Porosity of a Fuel Cell: The three layers of a fuel cell each consist of different materials and fuses at different temperatures. By using additive manufacturing processes developed at RIT, the materials can be fused at temperatures specific to the material and graded to improve durability.

Dr. Denis Cormier, Earl W. Brinkman Professor and associate professor of industrial and systems engineering, is part of a multi-university collaboration with the University of South Carolina's Hetero-FoaM Energy Frontier Research Center that is sponsored by the Department of Energy's Office of Science. The center is focused on bridging the gap between making nano-structured materials and understanding how they function in energy applications. The group Cormier leads is developing new processes to synthesize and fabricate novel materials for solid oxide fuel cells (SOFC), specifically for the anode and cathode.

Using models developed by the center's analysis and simulation groups, Cormier is synthesizing materials using novel additive manufacturing techniques. "The design of porous layers in a fuel cell involves making tradeoffs. Large pores are desired to allow hydrogen fuel to easily flow into the cell. At the same time, small pores with high surface area are preferred for increased electrochemical activity," explains Cormier. By using additive manufacturing, sometimes referred to as 3-D printing, the group hopes to be able to grade the porosity of the material from large down to fine pores, similar to that of the human vascular system.

The machine used to create the material operates similar to an inkjet printer, where each cartridge has a different color or pigment. In this case, the pigment is replaced by nano-sized particles used to make fuel cells. In the first phase of the project, Cormier is using three material print heads to mix the "inks" and grade from one material composition to another. Building on to this approach, a second piece of equipment with two material heads and a built-in laser allows for particles to be fused as the material is printed. Because each material fuses at a different temperature, the laser power can be adjusted to address the dissimilar materials.

A fuel cell consists of three layers, each made from a different material. Because virtually all materials expand when they are heated, dissimilar expansion rates between the layers can lead to cracking and degradation of the cell. "By gradually blending the composition of the material between layers, issues of durability can be addressed. At the same time, we can control the porosity of the material," explains Cormier.

The printed fuel cells are provided to the characterization and validation group based at the University of South Carolina to test and determine how well the models predict the performance of the fuel cells.

"The work Dr. Cormier is doing is very important, especially in a new technology area like fuel cells. Many times the manufacturing process of integrating materials is not addressed upfront to insure that the effects of various process parameters on ultimate system performance and durability are taken into consideration," adds Fronk.

Real-time Simulation, Modeling, and Control

Research at the Hybrid Sustainable Energy Systems (HySES) Laboratory, based in RIT's department of mechanical engineering, is focused on model development, real-time simulation, and control design for solid oxide fuel cell systems. The lab's research is supported by the National Science Foundation and the Office of Naval Research. Led by Dr. Tuhin Das, assistant professor of mechanical engineering, the laboratory has developed models for a number of SOFC configurations, reformer types, and fuel types. The models capture the primary physical phenomena of SOFC systems, such as thermodynamics, heat transfer, reaction kinetics, pressure dynamics, and electrochemical phenomena.

"Fuel cells are complicated systems with numerous interconnected physical phenomena. The challenges involved in these model development efforts lie in model management and in reducing computational burden while capturing the essential system characteristics," explains Das. "The use of modular modeling practice and hierarchical model architecture that we have developed at HySES is instrumental in addressing these challenges."

The laboratory also focuses on system characterization, which gives a clearer understanding of the transient and steady-state behavior of SOFC systems. The research provides insight into the different and varied time-scales involved in the overall functioning of SOFC systems. The time-scales arise due to both the presence of varied physical phenomena and the interaction of balance-of-plant components with each other and the fuel cell. "Understanding of the system characteristics helps us to develop control strategies that lead to optimal performance," adds Das.

Controlling the transient behavior of SOFC systems is critical for preventing fuel starvation, a phenomenon that SOFCs are susceptible to, especially when exposed to power transients. Difficulty in sensing the internal conditions of the SOFC makes this issue particularly challenging.

Traditional approaches require many extra sensors that significantly increase cost and also pose reliability issues. Alternately, detailed models may dramatically increase computational burden on the controller. Das and his team of researchers have developed an innovative approach using a fundamental property of the SOFC system obtained through characterization studies. The approach not only reduces sensing requirement, but also reduces the reliance on a computer model and specific knowledge of the system.

Simultaneously, the laboratory is also exploring ways to improve the responsiveness of SOFC systems to fluctuations in power demand. Addressing this issue would expand the use of SOFC systems from uniform power applications to rapid-response scenarios. However, for SOFCs, improving responsiveness and preventing fuel starvation are conflicting control objectives. The laboratory's research handles this limitation by augmenting the SOFCs with energy storage elements, such as batteries or ultra-capacitors, and other energy storage concepts. Such hybridization leads to a spectrum of control problems where control of the storage element and power-split algorithms must be developed that effectively handle system and sensing uncertainties. The research team is exploring the use of robust nonlinear control strategies to address these control problems.

Hybrid Sustainable Energy Systems (HySES) Laboratory: Dr. Tuhin Das and a team of mechanical engineering students are developing models that capture the primary physical phenomena of solid oxide fuel cell systems. The models provide a better understanding of the system characteristics that will enable the development of control strategies that lead to optimal performance.

Testing and Commercialization

Bringing Together Industry and Academia to Advance Fuel Cell Technology: Dr. Thomas Trabold, Daniel Smith, and Matt Fronk, researchers at the Center for Sustainability Mobility, are leading an effort to bring together industry and academic expertise and accelerate fuel cell technology.

The Golisano Institute for Sustainability (GIS) is home to a suite of full-scale testing and simulation capabilities for fuel cell systems. In 2009, the Center for Sustainable Mobility, based at GIS, constructed a facility to conduct system-level testing onsite for solid oxide fuel cells. The first-class facility is equipped with three test stations and hook-ups to alternative fuels, including natural gas, hydrogen gas blends, bio-diesel blends, and US07 ultra low sulfur diesel. In partnership with Delphi, researchers at the Center for Sustainable Mobility are conducting tests to identify options to further develop the product durability and reliability, as well as develop cost-effective manufacturing processes of solid oxide fuel cells. This joint project is sponsored in part by the U.S. Office of Naval Research and the Army Tank Automotive Research, Development, and Engineering Center.

"This lab plays a key role in the overall product development cycle by working on the connection of materials research into first scale up products or systems. We provide some of the early durability work or development testing at small scale, while our industry partner's work on the larger scale issues. Ultimately this will help to accelerate the whole process toward commercialization," adds Fronk.

Until now, minimal investigation has been done on the life cycle and failure analysis of fuel cell systems. Researchers at the center are conducting accelerated durability testing based on failure modes identified through failure mode and effects analysis (FMEA) evaluations. Once these failure modes are understood, environments are created to accelerate them and further analyze how they affect performance and durability trends, as well to begin building a database for future products to assist in predicting failures before they occur. For example, carbon formation has been identified as one of the key performance issues, so carbon formation

Testing to Improve Durability: The Center for Sustainable Mobility is partnering with Delphi to conduct tests of their solid oxide fuel cell system to further develop the product durability and reliability, as well as develop cost-effective manufacturing processes of solid oxide fuel cells.

is accelerated to understand the key operating signals and trends that could be used in forecasting future failures.

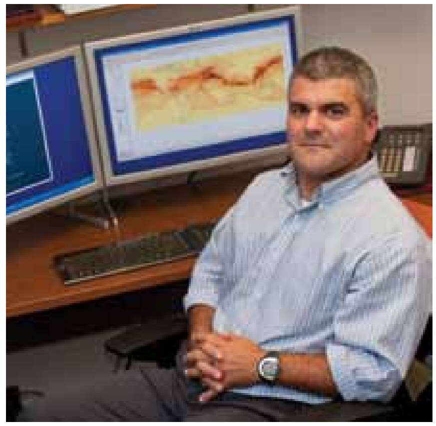
Dr. Thomas Trabold, associate research professor at GIS, is also conducting fundamental parametric studies to identify parts of the operating envelope where carbon formation occurs and providing recommendations to mitigate the problem. The studies show that temperature changes, which occur during SOFC startup, result in excessive carbon formation, leading to the degradation of system performance and durability. By simulating the temperature gradients at startup, the operating protocols can be customized to allow the system to reach higher temperature before supplying the fuel and air to the fuel reformer.

"This research directly supports industrial partners like Delphi, and provides an understanding of the fundamental underpinnings to their commercialization process," says Trabold.

One of the cornerstones of the Center for Integrated Manufacturing Studies, from which GIS emerged, is built on remanufacturing strategies. In solid oxide fuel cells, the materials must withstand extreme temperatures up to 800°C, and as a result are typically expensive. The group is also identifying key component areas of this fuel cell technology that are ripe for remanufacturing. "If you could reuse one or more of these high-value subsystems nearing the end of its useful life by harvesting the valuable raw materials or components within them, they could be utilized for three to four lifetimes," explains Daniel Smith, senior program manager at CIMS. "By incorporating these considerations into the design upfront we will be able to maximize the system value."

"'Reman,' as the term is commonly used in industry, is not always applied to new technology programs. We believe that by involving the concepts around design for remanufacturing that the early commercialization and technology insertion plans can more easily and more cost effectively be executed," says Fronk.

Policies to Drive Adoption



Building the Infrastructure: Dr. James Winebrake is developing models to understand how subsidies might pull the market forward and how simulations that show the evolution of the market and the impact of changes in the market or policy affect the trajectory of the technology.

While scientists and engineers work to advance fuel cell technology to reach mass commercialization, public policy experts are analyzing the policy mechanisms and how they affect market penetration.

Dr. James Winebrake, professor and chair of the department of science, technology, and society/public policy, and a team of master's degree students have been analyzing how different levels of subsidies might pull a market forward and how mandates at either the state or federal level might allow for the penetration of hydrogen fuel cell vehicles. "The role of the public sector is critical in moving fuel cells into the market," says Winebrake. "Policies and programs at the federal, state, and local levels that help reduce the upfront costs of fuel cell vehicles are important, as well as programs that encourage the development of hydrogen refueling stations."

The group is also conducting dynamic systems modeling to simulate the evolution of the fuel cell vehicle market and the role policies play in affecting market trajectories. The simulations help to explain the dynamics between vehicles and the infrastructure needed to refuel those vehicles.

The models show that "clustering" hydrogen refueling stations at a higher density in fewer locations is more effective in creating sustainable hydrogen vehicle markets than spreading these stations out at lower density in more locations. For example, building 30 stations in each of 10 areas is a more effective strategy than building 10 stations in 30 areas. "The modeling and simulation affirms this approach. Hydrogen station density is a key factor in fuel cell market development, and a critical mass of stations is needed for fuel cell vehicles to obtain market traction," explains Winebrake. "Rochester is one area where clustering could be successful."

The city is home to research and development for fuel cell technology, with three fueling stations already in place: the GM Facility in Honeoye Falls, N.Y.; the Monroe County Green Fuel Station near the airport; and on campus at RIT. "This network has supported our demonstration of the viability of fuel cell vehicles in five years. It's an important point of confidence for developing public awareness that you can deal with hydrogen in a safe way and fueling can occur quickly. RIT's participation is just another way they are supporting our program and helping to advance the technology," adds Dr. Mark Mathias, lab director for fuel cells and batteries at GM.

To get the technology and the infrastructure to a point where consumers are able to enjoy the benefits of fuel cell technology, Winebrake believes there is a need for early involvement from the public sector by continuing to support companies and universities with research and development; encouraging consumers with tax incentives; and facilitating the infrastructure development to ensure the technology and infrastructure move forward simultaneously.

New York state is taking the lead in developing real plans to reduce their carbon footprint by 2050, and both Winebrake and Fronk have been asked to participate in the New York Climate Action Council focused on important policy and planning programs.

Outsourcing and the Future of American Innovation

by William Dube

The transfer of domestic jobs to cheaper overseas locations, known as offshore outsourcing, has been an issue for manufacturing jobs for decades; now it is impacting white-collar jobs as well.

A Three-Decade-Old Problem

Some estimates suggest that by 2015, as many as 3.5 million white-collar jobs in high-wage fields like engineering, computer programming, and research and development could be moved to lower cost locations in India, China, and Eastern Europe. Dr. Ron Hira, an associate professor of public policy at RIT, believes that this trend is having severe short-term and long-term repercussions for American workers and inhibits our ability to compete in an increasingly innovative and high-tech world.

"Outsourcing is not a new problem," Hira says. "There have been serious concerns surrounding the movement of domestic jobs to lower cost locations for close to three decades, particularly in the manufacturing sector. However, the current trend involves not only a new class of employees—middle class,

Protecting Our Future Work Force: The movement of American jobs overseas has been a three-decade-old issue impacting American, foreign, economic, and trade policy. Dr. Ron Hira, associate professor of public policy at RIT, is a strong advocate for greater government attention and reforms to protect America's next generation of highly skilled workers.

white-collar workers—but also the movement of laboratories, R&D centers, and intellectual capacity to foreign countries. These areas have historically been America's competitive advantages, but we are now outsourcing our capacity to innovate."

Princeton University economist Dr. Alan Blinder estimates that approximately 30 percent of American jobs are vulnerable to offshoring. In addition, the U.S. now runs trade deficits in high-tech products (those products that require a large amount of R&D to produce), many corporate research and development facilities are moving overseas, and a number of U.S. universities are training America's international competitors. In addition, significant domestic production capacity in computer hardware, electronics, and high-tech manufacturing—and the high-skilled workers that go with these sectors—have been outsourced.

"If corporations are not doing basic research and complex work in the United States, the nation ultimately loses the capability to develop cutting-edge products, concepts, and companies," notes Dr. William Lazonick, author of *Sustainable Prosperity in the New Economy: Business Organization and High-Tech Employment in the United States* and director of the Center for Industrial Competitiveness at the University of Massachusetts Lowell. "Ron Hira is a leader in analyzing how the globalization of the high-tech labor force is affecting sustainable employment opportunities in the United States."

Leading the Discussion

For close to a decade, Hira has been at the forefront of the effort to analyze the impact of outsourcing, identify its causes, and advocate for policy reforms that will better protect U.S. workers and improve our overall innovation capacity. His 2005 book, *Outsourcing America*, coauthored with his brother Dr. Anil Hira, a professor of political science at Simon Fraser University, was one of the first comprehensive analyses of high-skill outsourcing and the corporate and government decisions that have increased its development. The book was a finalist for the Independent Book Publishers Association's Benjamin Franklin award for best business book in 2006, and a second edition was released in 2008.

"Current government practices, including U.S. high-skill immigration regulations, taxation laws, and corporate

A Look at the International Skilled Labor Force: Highly skilled jobs in the United States are in increasing danger of being outsourced to lower wage countries. Dr. Alan Blinder, economist at Princeton University and former vice chair of the Federal Reserve, has developed an *offshorability index* rating the vulnerability of occupations to being outsourced. The scale goes from 25-100, with 100 being the most vulnerable to being offshored. Any rating above 50 indicates an occupation that is offshorable, and above 75 is highly offshorable. Blinder bases the index on the interpersonal demands of the occupation, the ability of other countries to perform the job more efficiently, and employers' ability to compensate foreign workers at reduced rates compared to American workers.

Computer Programmer	
Offshorability Index	100
# of Jobs in U.S.	367,880
Average Annual Wage in U.S.*	$74,700
Average Annual Wage in India#	$10,200
Average Annual Wage in China§	$9,300
Average Annual Wage in Phillipines†	$5,900

Mechanical Engineer	
Offshorability Index	70
# of Jobs in U.S.	232,660
Average Annual Wage in U.S.*	$80,600
Average Annual Wage in India#	$9,700
Average Annual Wage in China§	$24,700
Average Annual Wage in Phillipines†	$5,000

* Estimates based on United States Department of Labor, Bureau of Labor Statistics Occupational Employment and Wages for May 2009

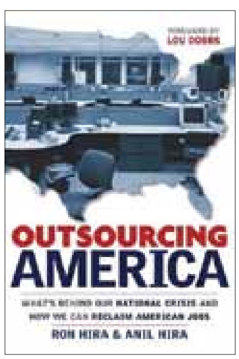
Estimates based on PayScale.com data

§ Estimates based on J.M. Gemini's Guide to China Markets

† Estimates based on Phillipines Department of Labor Statistics for July 2006 and August 2008

offshoring policies, are accelerating in the movement of U.S. jobs overseas and reducing our overall research and development capacity," Hira says. "Through my research, advocacy, and organizing efforts I have worked to trigger stronger action to improve trade, manufacturing, and immigration policies and enhance the American economy as a whole."

Hira has testified before Congress on the impact of outsourcing on American workers, helped develop a series of congressional hearings on national innovation policy, and served on the working group for the Council on Competitiveness' National Innovation Initiative. In addition, he serves as a research associate for the Economic Policy Institute, a Washington, D.C.- based think tank, where he has authored a number of national offshoring reports and assisted in putting together a series of panels on the current state of economic development in the United States. He has also worked to increase the overall profile of the outsourcing debate through a host of national and international speaking engagements and frequent appearances on national television, including CNN, CNBC, PBS, and NBC.



Outsouring America: The 2005 book was one of the first comprehensive analyses of high-skill outsourcing and the corporate and government decisions that have increased its development. A second edition was released in 2008.

In addition to his national efforts, Hira has worked to assist the Rochester region in publicizing the impact outsourcing has had on the local economy and improving its high-tech business environment. He hosted a regional hearing at RIT of the U.S. China Economic and Security Review Commission, a congressional advisory committee focused on U.S. trade policy that featured local business, labor, and government leaders. The hearing investigated the impact of trade with China on the western New York economy.

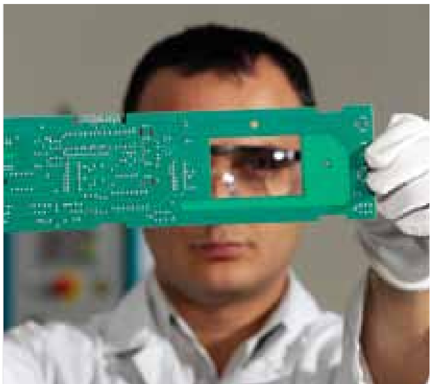
He also co-leads, with New York State Assemblyman Joseph Morelle, development of *Rochester and the Innovation Economy*, a speaker series that brings national innovation experts to Rochester to meet with local leaders and discuss best practices and opportunities for expansion.

"Having witnessed the devastating impact of outsourcing on the people I represent, I'm encouraged to see Ron Hira out there on the battlefield, asking the tough questions," says Congressman Donald Manzullo (R-IL) who held one of the first national hearings on offshoring in 2003. "He provides solid, thoughtful policy recommendations for government and business leaders, and his work should be required reading for every corporate manager and political leader in America."

Reforming High-Skill Immigration

A key focus of Hira's recent research efforts has been on high-skill immigration, particularly current government policies related to H-1B and L-1 temporary worker visas for skilled foreign labor.

The H-1B is a three-year, non-immigrant visa, created under the 1965 Immigration and Nationality Act, which can be renewed once for an additional three years. The visa provides employers with the opportunity to temporarily employ foreign workers who possess



Electronic Engineer	
Offshorability Index	70
# of Jobs in U.S.	135,990
Average Annual Wage in U.S.[*]	$91,500
Average Annual Wage in India[#]	$13,200
Average Annual Wage in China[§]	$26,000
Average Annual Wage in Phillipines[†]	$7,000

Computer and Information Scientist (Research)	
Offshorability Index	96
# of Jobs in U.S.	26,130
Average Annual Wage in U.S.[*]	$105,400
Average Annual Wage in India[#]	$26,300
Average Annual Wage in China[§]	$75,000
Average Annual Wage in Phillipines[†]	No Data

Accountants & Auditors	
Offshorability Index	72
# of Jobs in U.S.	1,106,980
Average Annual Wage in U.S.[*]	$67,400
Average Annual Wage in India[#]	$14,200
Average Annual Wage in China[§]	$23,400
Average Annual Wage in Phillipines[†]	$8,300

at least a bachelor's degree. Employers can sponsor applications for permanent residence for their workers. The L-1 visa is a non-immigrant visa that allows for intra-company transfers within multinational corporations. Unlike the H-1B, L-1 workers must only possess specialized knowledge regarding the general company operations; no higher educational degree is necessary.

However, despite claims from employers that they use skilled guest worker visa programs to attract talented foreign workers and help them remain permanently in the United States, evidence shows the visa programs to be increasingly a means to help outsource U.S. jobs or recruit cheap temporary labor.

"Some companies are gaining an unfair advantage by using the H-1B and L-1 visa categories to pay substandard salaries and suppress benefits and working conditions for foreign and domestic workers," says Dr. Ray Marshall, professor emeritus of economics and public affairs at the University of Texas at Austin and a founder of the Economic Policy Institute.

Hira authored a 2010 EPI report, "Path to Skilled Permanent Immigrants or Cheap Temporary Labor," which examined the 20 U.S. employers receiving the most H-1B skilled worker visas and the 20 receiving the most L-1 visas. The results indicate that, despite claims to the contrary, on average, employers actually apply for permanent residence status on behalf of just 13 percent of their H-1B workers and 7 percent of their L-1 employees. In both visa programs, it is the sponsoring employer—not the worker—who is permitted to file for permanent residency on behalf of the worker.

"Proponents of expanding these visa programs argue that it's in our national interest to attract the best and brightest workers from around the world and to keep them here permanently," says Hira. "But these employers are saying one thing and doing quite another. They are spinning these workers through a revolving door in order to drive down wages and help send more jobs overseas."

The analysis shows that in practice many employers use guest worker visa programs simply for temporary labor mobility and reduced labor costs, not to bring needed skilled foreign workers permanently to the United States. For example, according to U.S. Department of Labor records, an international computing firm, which ranked 10th in H-1B use and 14th in L-1 use in 2008, applied for permanent residence for none of its H-1B or L-1 workers.

Hira argues that in some cases foreign workers are brought to the United States for job training by American workers, then after the training, foreign workers return home and do the same work for less pay, while the American workers may be laid off. In other cases, foreign workers are brought to the country temporarily to coordinate operations between the U.S. and workers in their home countries often because they can be hired to do the job more cheaply.

Hira calls for a series of reforms to current U.S. policy to reduce misuse of the visa programs and more properly protect both American and foreign workers. These changes include:

- Instituting workable, effective labor market tests and giving U.S. workers an enforceable opportunity to compete for jobs they are qualified for before admitting temporary foreign workers.
- Toughen rules and enforcement to ensure the nondisplacement of American workers, ensure guest workers are paid at least market wages, and audit

A National Advocate: Dr. Ron Hira has twice testified before Congress and has appeared frequently on national television, including CNN, CNBC, PBS, and NBC.

employers regularly for compliance.

- A clear and speedy path for the best and brightest to stay here permanently.
- The rules that tether H-1B employees to the employer that sponsored them should be changed to allow workers freedom to seek other employment after a short period, no more than one year.

"If the goal of our skilled-immigration policy is to capture the best and brightest, then we ought to align our policies to meet those goals," Hira says. "When skilled foreign workers are needed we should rely primarily on permanent immigration to supply them.

"Several reform measures to the program have been proposed and are now working their way through Congress, and it is my hope that guest worker visas can be overhauled to ensure that foreign workers cannot be exploited and American workers are not undercut," he continues.

Enhancing our Economic Future

Outsourcing might be good for American corporations, but it's not necessarily good for American workers, and it's likely to be bad for the American economy in the long run. Instead of American companies competing against foreign rivals—which was the case in the 1980s when American semiconductor, auto, and steel manufacturers lost market share to Japanese manufacturers—companies are now pitting their American workers against their overseas counterparts. This changes the political dynamics and often leads to American companies advocating for policies that are harmful for American workers and the economy.

"Substantial reforms are needed to numerous areas of government policy because much of what outsourcing companies do to damage American labor, product, and service markets is perfectly legal," adds Dr. Ray Marshall, who served as U.S. Secretary of Labor under President Jimmy Carter when outsourcing first began to impact the American economy.

Hira does believe that the current national economic and political environment makes it more likely that real reforms can be implemented, but sustained action will be needed to affect real change.

"There is more attention to offshore outsourcing now due to enhanced media coverage, the 2008 economic collapse, and the persistent unemployment problem," Hira adds. "Sensible reform is being fought by those benefiting from outsourcing. Only through an active public, and more attention by policymakers to these complex problems, will we be able to craft the right solutions. The alternative is that America will continue to lose high-wage jobs and its capacity to innovate."

Leading the Way in Innovation and Entrepreneurship

RIT is committed to promoting innovation and technological development to meet the needs of an increasingly complex and competitive world. A key component of this effort is the Center for Student Innovation (CSI), a 10,000-square-foot circular glass structure that serves as a nexus of creativity and technology, where teams of students from all corners of the university can develop and showcase innovative and entrepreneurial projects.

"The center is a signature structure that brings RIT closer to the vision of becoming America's 'Innovation and Creativity University,'" says RIT President Bill Destler.

The center serves as a resource and management hub for RIT's developing innovation curriculum, undergraduate research, and design programs, which require students to incorporate real-world planning and project development into their course work. It also sponsors the CSI summer fellows program, which gives students the opportunity to develop new inventions, technologies, or designs with monetary support and faculty assistance. This fall, RIT opened the doors to Entrepreneurs Hall, a holistic program that combines a residential community, cohort entrepreneurship courses, mentoring, and access to the university's student incubator.

RIT is also home to the Albert J. Simone Center for Innovation and Entrepreneurship, which encourages and develops budding entrepreneurs, and the Venture Creations Business Incubator, which assists startups in business planning, product development, and commercialization.

Inc. magazine recently recognized RIT among the top 20 incubators in the feature "Incubator Nation: Where Great Ideas are Born."

Passion for Innovation

Jon Schull

RIT's annual Undergraduate Research and Innovation Symposium is evidence of the innovation and creativity alive on the RIT campus. This year's symposium, held August 13, drew more than 150 student presentations across all disciplines. Their ideas, passion, and inspiration are the future of American innovation.

"You could have the next FaceBooker, Dean Kamen, or Thomas Edison for all I know," says Dr. Jon Schull, interim director of the Center for Student Innovation.

Corey Mack, a mechanical engineering technology major, presented his idea to convert intermodal shipping containers into low-cost disaster relief housing powered with solar arrays. Another psychology student, Rachel Lorenz, presented her research on the psychology of nicotine addiction. Meanwhile, Abbey Burns and Benjamin Jilson, industrial and systems engineering students, offered a new approach to optimize the layout of a wind farm. These are just a sample of the dozens of innovative ideas and research presented.

A panel of distinguished business leaders and alumni served as judges for the symposium. "We were blown away by the intellectual curiosity, passion, and level of difficulty that students pursued these projects with," says Dr. Kenneth Reed, graduate of the College of Science and 2008 Outstanding Alum. For these reasons the judges agreed it was impossible to declare just a few winners. Instead, the center agreed to establish the RIT Student Research and Innovation Grants program. The program will be administered by and for the students who participated in the symposium.

The program was initiated by a contribution from the center and an additional commitment by Reed. The grants will be awarded to students to help advance their innovations.

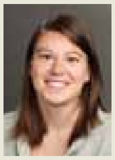
"For students it's about pursuing a dream, for society it's about incubating new technologies, and for the university it's part of the process of becoming an innovation university," adds Schull.

Photo courtesy of Lau Li Qian Yi.

Idea Factory: The Center for Student Innovation hosted its first-ever Summer Research Fellows program, bringing together students from across campus to foster innovation and creativity. The program culminated with presentations and demonstrations at the Undergraduate Research and Innovation Symposium.

Determination Drives Innovation for Power Wheelchair

Devin Hamilton



Beth Kiefer

For Devin Hamilton assistive technologies are second nature. Diagnosed with cerebral palsy at a young age, Hamilton's determination and innovative mindset has allowed him to overcome everyday challenges throughout his life. This summer, Hamilton and Beth Kiefer, both 5th year mechanical engineering technology students, embarked on a research project that could change the lives of thousands who suffer from the disability.

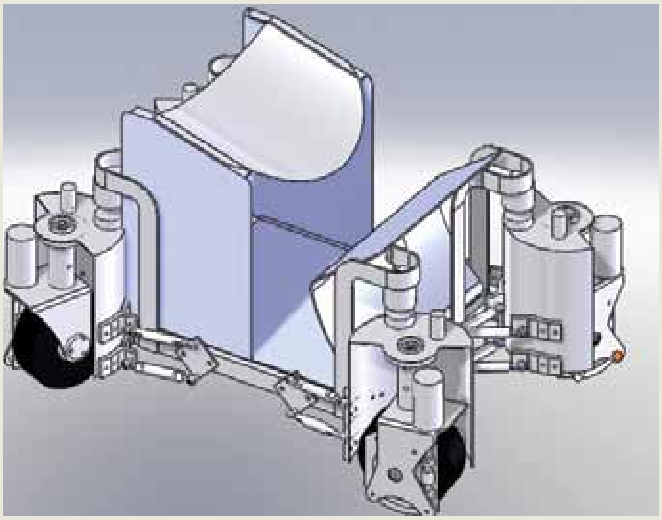
The vision was to design a power wheelchair that addressed some of the limitations of current systems for people with disabilities like cerebral palsy. The research team started by conducting a comprehensive analysis of wheelchair standards; steering, driving, and seating systems; and current developments in the wheelchair market.

There are a few features that make the power wheelchair unique; most obvious is the kneeling position of the chair. For people with cerebral palsy, this position helps to minimize spasticity and allows for more muscle control. "Depending on what position you are sitting in, it can be uncomfortable, which makes your muscles work more," explains Hamilton.

"We learned from an orthopedic surgeon and physical therapist at Rochester General Hospital that this position can save energy, too," adds Kiefer. "A person like Devin is working twice as much to sit here because his muscles are constantly moving."

Hamilton and Kiefer designed a 3-D model of the novel chair using SolidWorks and are now machining a prototype with aluminum and fiberglass. The chair is believed to be the first electronic kneeling chair in development and a patent is in the process of being issued.

"I've dealt with assistive technologies my whole life," says Hamilton. "I see a problem and I automatically know I can fix it." For Kiefer it is the joy of taking an idea from design to fabrication, she says. The pair hope to continue development of the power chair and other assistive technologies.



Power Kneeling Chair: Devin Hamilton and Beth Kiefer, 5th year mechanical engineering technology students, have designed a kneeling power wheelchair. The novel chair provides improved comfort and functionality to individuals with disabilities like cerebral palsy.

Research Awards and Honors

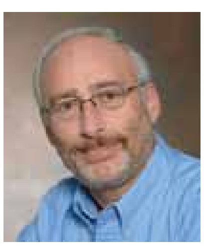
by William Dube

RIT values the contributions of its faculty, staff, and students across all colleges and centers. Below we highlight members of the RIT community who have received significant RIT, national, or international recognition this year.

Trustees Scholarship Awards

The Education Core Committee of the RIT Board of Trustees awards up to three Trustees Scholarship awards each year to RIT faculty who demonstrate outstanding academic scholarship.

Joseph Hornak, professor of imaging science and chemistry, is the director of RIT's Magnetic Resonance Laboratory and editor-in-chief of the *Encyclopedia of Imaging Science and Technology*. His area of specialization is magnetic resonance, specifically imaging, spectroscopy, spin relaxation, and diffusion.



Marc Marschark, a professor at the National Technical Institute for the Deaf, directs the Center for Education Research Partnerships. His primary research interest lies in relations among language, learning, and development.

James Winebrake, professor and chair of the department of science, technology, and society/public policy, is a nationally recognized expert on the environmental impacts of transportation and energy use in society.

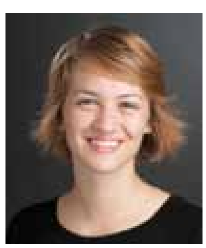
Fulbright Scholars

The Fulbright program is sponsored by the U.S. Department of State and is the largest U.S. international exchange program offering research and teaching opportunities for students and scholars.

Samir Nazir, a master's student in the science, technology, and public policy program, will spend a year serving as a visiting scientist at the National University of Singapore. Nazir will help analyze the economic and environmental benefits and costs of electric vehicles.

Barry M. Goldwater Scholarships

The Goldwater program was established by Congress to promote research excellence in mathematics, engineering, and the natural sciences and to assist students pursuing careers in these fields.



Summer Saraf, a third-year physics major, is working to analyze the molecular origins of cataract disease.

Photo courtesy of Susan Tontarski.

Sebastian Ramirez, a third-year biochemistry major, is working on the development of novel antibiotics using X-ray crystallography.

National and International Recognition

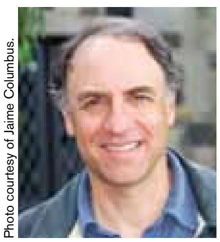
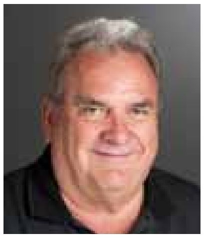


Photo courtesy of Jaime Columbus.

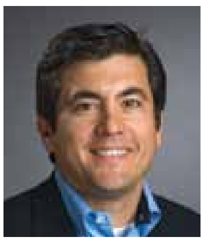
The book *In the Neighborhood,* by **Peter Lovenheim**, an adjunct professor of English, was selected as a Discover Great New Writers Summer Selection by Barnes & Noble. Julia Roberts' production company, Red Om Films, has also optioned it and a movie version is currently in development.

Hui Mien Lee, a visiting scientist with the Golisano Institute for Sustainability, was appointed as a delegate to the 2010 United Nations Global Compact Leaders Summit. The conference brought together more than 1,000 business, government, and community leaders to enhance the sustainability parameters of the U.N. Global Compact.

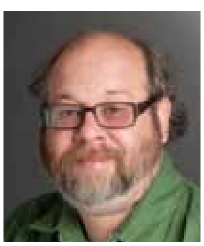
Michael Ruhling, associate professor of music and director of the Rochester Institute of Technology Orchestra, has been appointed as a member of the Haydn Society of Great Britain's Committee of Honour. He will assist with program development, performances, and research related to Joseph Haydn, classical composer.



Alan Nye, professor of mechanical engineering and faculty adviser for RIT's Formula Racecar Team, received the 2010 Faculty Advising Award from the Society of Automotive Engineers. The award is presented for outstanding mentorship and support of undergraduate engineering students.

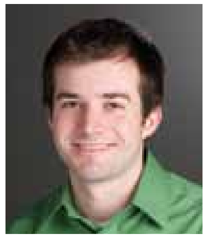


Andres Carrano, an associate professor, and **John Kaemmerlen**, a lecturer, both in the department of industrial engineering, received a 2010 Award of Excellence from the Institute of Industrial Engineers. Carrano and Kaemmerlen were recognized for their development of unique research and education efforts in lean concepts.



Stephen Jacobs, associate professor of interactive games and media, has been appointed a visiting scholar at the International Center for the History of Electronic Games. Jacobs will advise and assist the center, housed at the Strong National Museum of Play, in the development of *eGameRevolution*, an original exhibit on the history of electronic games.

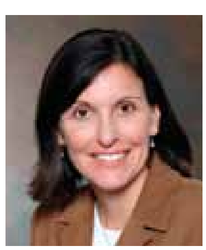
Elizabeth Kmiecinski, associate professor and co-director of the nutrition management program in the School of International Hospitality and Service Innovation, received the 2010 Outstanding Educator Award from the American Dietetic Association.



Christopher Tomkins-Tinch, a fourth year bioinformatics major, has been named a 2010 Department of Homeland Security Scholar. The program for undergraduate students promotes scientific and technical advancements in research fields related to homeland security and national defense. Tomkins-Tinch served as a research intern with Oak Ridge National Laboratory, where he worked to improve collective intelligence technologies through the DHS' Sensorpedia project.

Nabil Nasr, director of the Golisano Institute for Sustainability, has been appointed by the government of Singapore to serve on its International Science and Technology Advisory Board. The expert working group focuses on promoting technical development in Singapore's industrial sector and higher education system.

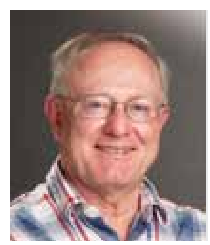
Michael Rogers, a professor in the School of American Crafts, was selected for Art on the Edge 2010, an international juried exhibition of art and glasswork presented by the New Mexico Museum of Art.



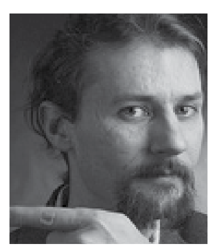
Margaret Bailey, the Kate Gleason Endowed Chair in the department of mechanical engineering, received the 2010 Denise Denton Award from the American Society for Engineering Education. The award goes to outstanding research focusing on women in engineering.

Richard Newman, professor of history, has been named a Distinguished Lecturer by the Organization of American Historians. In that role, he will conduct a series of presentations on the Civil Rights Movement and Colonial America.

Geoffrey Alan Rhodes, professor of film and animation, premiered his latest feature film, *Buried Land,* at the 2010 Tribeca Film Festival. The film was shot on location in Visoko, Bosnia, and chronicles the potential discovery of a valley of ancient pyramids in central Bosnia.



Robert Barbato, professor of management, received the 2010 Best Empirical Research award presented by the Small Business Institute. Barbato was sited for his analysis of small business development and entrepreneurship in Kosovo.



Jeffrey Wagner, associate professor of economics, has been elected president of the New York State Economics Association. The research society was founded in 1948.

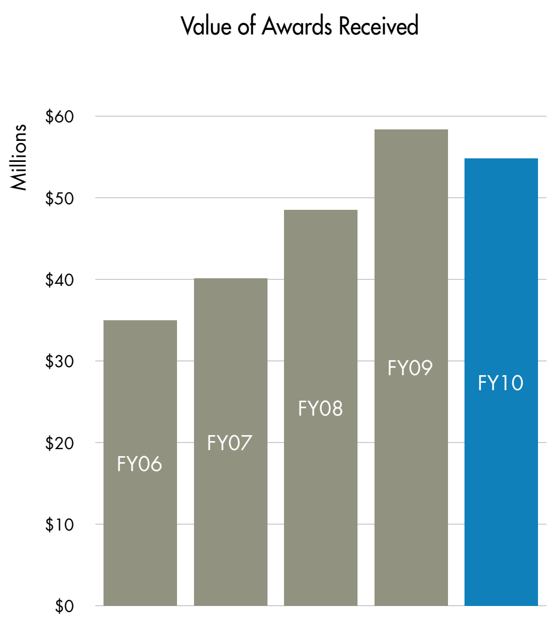
About This Section

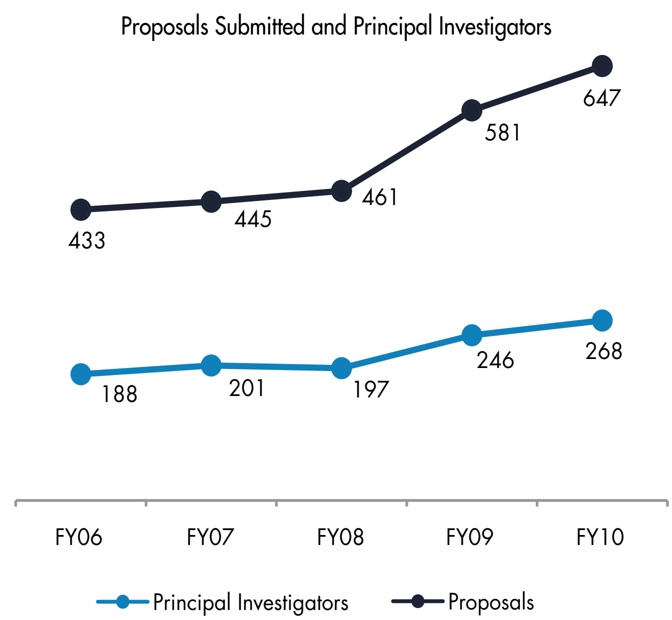
This listing is a sample of awards and honors that have been received by RIT faculty and staff over the past year. For more information, please visit www.rit.edu/news.

By the Numbers

by David Bond

In fiscal year 2010, a record number of investigators and proposals helped to secure nearly $55 million in new research awards.





RIT received $54.8 million in new research awards for the fiscal year ending June 30, 2010, including grants and contracts purposed for research, instruction, outreach, and facilities; direct federal support for research at the National Technical Institute for the Deaf; and gifts in support of research. In fiscal year 2010, researchers at RIT were more prolific than ever. In total, 268 principal investigators submitted 647 proposals for external research funding to a variety of federal, state, corporate, and foundation sponsors. This is a significant increase in the number of investigators—8 percent—and the number of proposals—10 percent.

Funding Sources

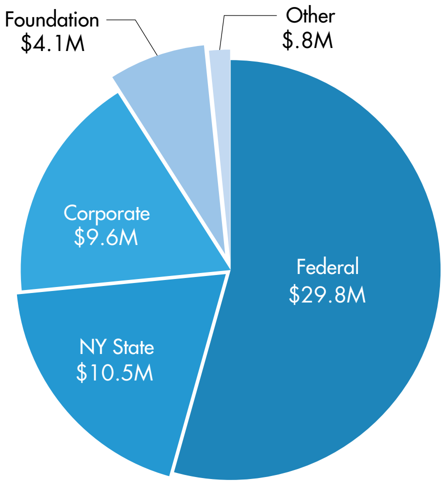
While the pursuit of research funding has become increasingly competitive across all types of sponsors during our nation's economic recovery, RIT investigators continue to enjoy significant support for world-class research from all types of sponsors.

Various federal agencies funded just over half of new research awards this fiscal year. Support from the National Science Foundation and the U.S. Department of Energy in particular continues to increase. NSF was RIT's largest federal sponsor, providing $6.9 million of the $29.2 million in new federal funding. Awards from the DOE this year amounted to $4.2 million and supported research in multiple areas, including solar cells, fuel cell performance, and image analysis.

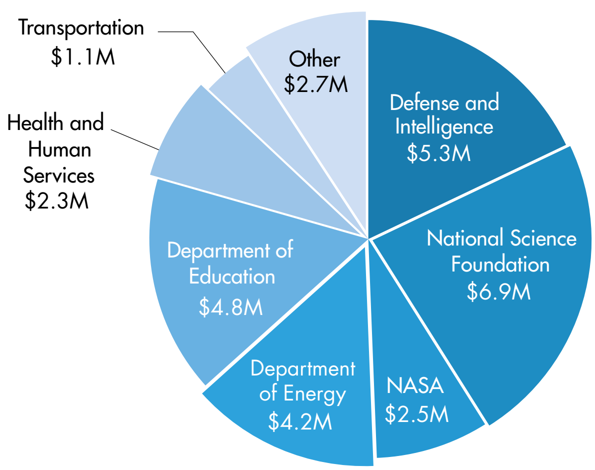
Foundations made new awards of $4.1 million to RIT last year in support of research. The most significant supporter was the Andrew Mellon Foundation, which provided funding for the Munsell Color Science Laboratory to improve artwork reproduction techniques, and for the Image Permanence Institute for photo conservation research with the George Eastman House.

Over 100 different companies funded research at RIT in the last fiscal year. Some companies funded multiple projects, including Carestream Health (4 projects), Harris RF (3), Impact Technologies (7), and Procter & Gamble (5). RIT also renewed long-term master agreements for conducting research with Corning, Kodak, and Procter & Gamble.

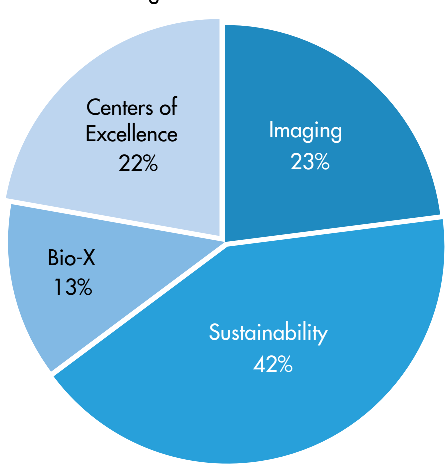
FY10 Awards by Funding Source Type



FY10 Awards from Federal Sponsors



Strategic Research Domains



Strategic Research Domains

Research at RIT continues to focus on three key research areas: Imaging, Sustainability, and Bio-X. A multidisciplinary collaboration with the B. Thomas Golisano College of Computing and Information Sciences and the Chester F. Carlson Center for Imaging Science has resulted in awards from the National Institutes of Health and the National Science Foundation. The research, led by Anne Haake, supports the development of a biomedical-image database with input from physicians and eyetracking data to assist in teaching and diagnostics.

The NanoPower Research Laboratories continue to receive strong support for their photovoltaic and advanced battery research. Brian Landi, researcher at NPRL and assistant professor of chemical engineering, received support from Lockheed Martin for third-generation lithium ion battery research.

American Recovery and Reinvestment Act

The American Recovery and Reinvestment Act of 2009 included funding for research to assist the nation's economic turnaround. RIT investigators have received awards in diverse areas with recovery act funding from the National Science Foundation, National Institutes of Health, and other federal agencies.

Recovery Act Awards from the National Science Foundation include:

Stefi Baum, imaging science, Science Master's Program: Decision Support Technologies for Environmental Forecasting and Disaster Response

Manuela Campanelli, Center for Computational Relativity and Gravitation, Community Infrastructure for General Relativistic Magnetohydrodynamics (CIGAR)

Stefan Preble, microsystems engineering, MRI: Acquisition of a Scanning Probe Microscopy System for Nanoscale Probing, Manipulation, and Fabrication

Yosef Zlochower, Center for Computational Relativity and Gravitation, Next Generation Parallel Computing Infrastructure for Numerical Relativity

Five RIT investigators received Recovery Act awards through the National Institutes of Health. **Steve Zilora** (information technology), **Vicente Reyes** (biology), and **Robert Osgood** (biology) received support to work with Rochester General Hospital on research involving ear infections in children. **Peter Hauser** (NTID) received support to work with the University of Rochester Medical Center on visual functioning in deaf children, and **Dina Newman** (biology) received support for her research in the genetics of age-related hearing loss.

Other Recovery Act awards include Department of Justice funding for **John McCluskey** (criminal justice) to work with the University of Texas at San Antonio to develop a crime analysis consortium in Bexar County, Texas. Recovery Act funding has also supported tuition assistance and facilities improvements at RIT.

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RIT is one of the largest private universities in the world. With a unique blend of rigor and imagination, of specialization and perspective, of intellect and practice, RIT is a vibrant community of ambitious and creative students from nearly 100 countries.

Photo courtesy of Bill Barley.

Rochester Institute of Technology is internationally recognized for academic leadership in computing, engineering, imaging technology, sustainability, and fine and applied arts, in addition to unparalleled support services for deaf and hard-of-hearing students. RIT enrolls 17,000 full- and part-time students in more than 200 career-oriented and professional programs, and its cooperative education program is one of the oldest and largest in the nation.

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ContactInformation

We conduct research to advance the body of knowledge, enhance student and faculty learning, and build our reputation in the scientific and technical communities while providing positive returns to our sponsoring partners. Please send your feedback directly or through the RIT research website at **www.rit.edu/research**.

Donald L. Boyd, Ph.D.

Vice President for Research
(585) 475-7844
donald.boyd@rit.edu

Michael E. Dwyer

Director, Research Relations Office
(585) 475-2698
mike.dwyer@rit.edu

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