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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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A Light in the Darkness

While it's true, "the best laid schemes o' mice an' men gang aft agley," had poet Robert Burns known Patrick Delaney, a senior electrical and computer engineering student at the University of Minnesota, he might have added another line: "ere they grow to even better schemes."

Delaney visited Nicaragua in June 2004 as a volunteer for a Nicaraguan organization that helps rural Nicaraguans gain access to sustainable forms of economic development and with other issues. Delaney initially planned to explore the feasibility of developing micro-hydroelectric power systems that would enable villagers to harness the power of small mountain streams. A personal encounter with a Nicaraguan family however, left him traveling in quite a different direction.

The family, which was relatively wealthy by rural Nicaraguan standards, had purchased a solar panel to power four compact florescent lights. (Most families in the area rely on crude kerosene "lanterns" made from empty soda bottles; these homemade lanterns are a fire hazard, they yield a dingy yellow light, and they can pollute indoor air.) Unfortunately, the solar panel didn't work—or so they thought. Delaney, however, determined they had misinterpreted the wiring schematic and was able to get it to work. The first time the lights went on forever changed Delaney and set in motion a plan to change the world as well.

"Hundreds of people came from the surrounding countryside," said Delaney. "They gathered around the house simply to look at the lights. It was this amazing, magical moment."

Instead of hydroelectric power—which is impractical in many parts of Nicaragua—Delaney began looking to solar-powered solutions. When he returned to Minnesota, Delaney teamed up with fellow electrical engineering students (Lacey Nielsen, Adam Flink, Omkar Deodar, Valentina Michelson, and Ther Xiong) and ECE professor Bruce Wollenburg to develop a prototype lantern using LED—light emitting diode—bulbs as part of their senior project. Their original approach was to design a lantern that could be built on the spot out of materials such as a baby food jar with multiple LEDs mounted inside on a piece of plastic pipe. But as his interest grew, so did Delaney's understanding of what it would take to develop an approach that could really succeed over the long run.

Patrick Delaney, helping to install a solar panel.

"As we moved through this whole process, I began to understand that engineering isn't just about design," said Delaney. "Most engineering problems are also economic problems—and you have to take both under consideration to develop viable solutions."

Rather than attempt to raise enough capital to launch an initial manufacturing run of the prototype, Delaney decided to identify existing products that could meet the Nicaraguans needs and then figure out how to get them into their possession. He enlisted the help of University of Minnesota business and economics students Trisha Qualy, Mike Semeniuk, and Aleksandr Kladnitsky, and Mario Aleman, an electrical engineering graduate of the University of Nicaragua. They formed a non-profit organization called Bright New Ideas (BNI). After a good bit of research, they zeroed in on a lantern design that was affordable (less than $20), durable, and "earth friendly."

"A lot of the products out there use sealed, lead-acid batteries," Delaney explains. "That's what we used initially in our design project. But those kinds of batteries have so many disadvantages. If they get wet, they can crack—and they become an environmental hazard."

The BNI team found a lantern powered by rechargeable "double-A" batteries. They conducted a test run in August 2006, taking 60 of the solar powered lanterns to Nicaragua and distributing them amongst the rural people. The lanterns were a big hit. But 60 lanterns was just a drop in the bucket. The group returned to the U.S. and began formulating a plan that would maximize the impact of their efforts.

"We want to provide them with the best possible lanterns we can," Delaney said. "Currently we're trying to source a better lantern; one that's more durable and can function as either a flashlight or a lantern. At the same time, we want to incorporate an economic equation that will make this project sustainable in the long term."

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When Small is Big

In the world of nanotechnology, ECE Associate Professor Beth Stadler is making a big impact with small wonders.

There is no quick explanation or catch phrase to describe the breakthrough research being conducted within the University of Minnesota Electrical and Computer Engineering Department by Associate Professor Beth Stadler and her research group. No easy sound bites, no simple images that deliver the big picture. In fact, the work they are doing occurs at a scale that is almost incomprehensible. Their forte is growing nanowires; structures so miniscule that more than a thousand of them could be easily hidden behind a line no thicker than this: ———.

Although Stadler's group is still in the early stages of its research, their achievements to date have opened the door to the development of a fantastic new class of nanoscale sensors that "hear," "see," and "smell," much the way humans do. Such sensors may soon lead to the development of more powerful medical diagnostic tools and innovative sonar applications, and—perhaps a bit further in the future—enable scientists to create artificial sensors that could be used to supplement or substitute for defective human sensory organs. In fact, the inspiration for exploring the use of nanowires as acoustic sensors came from pictures of the cilia inside the cochlea within the human ear.

"In photographs, cilia from a human ear—which really function as a frequency filter—look a lot like our nanowires," said Stadler. "When sound enters the human ear, different sets of cilia resonate in response to different frequencies. When these cilia begin to resonate, they initiate a biological process that sends electrochemical signals to the brain. Our sensors work much the same way, except they rely on magnetic signals to detect their resonance."

Which leads us to the breakthroughs that have been bringing some serious attention to Stadler's research: hers is the first research group to figure out how to grow nanowires of Galfenol (a gallium/iron alloy) and the first to use nanowires as acoustic sensors. They have grown nanowires that have both magneto-strictive and magneto-resistive properties, which are the characteristics that enable them to be used as sensors. When the nanowires bend—as they resonate in response to sounds, for example—they generate magnetic fields that can be measured using giant magneto resistance (GMR) sensors, which are similar to an array of hard drive heads.

"These sensors could be used in a wide variety of applications ranging from hearing, to sonar, to medical imaging," said Stadler. "Because of their extremely small size, they may prove especially suitable in medical applications. For example, a nanowire sensor could be inserted into the human body with very few negative side effects and used to take an ultrasound image of an area of interest from a nearby blood vessel."

Stadler began her nanowire research in the fall of 2001 using her start-up funds which served as seed money to keep the project going while she sought more substantial funding from the National Science Foundation (NSF) and the Office of Naval Research (ONR). Her initial requests for funding received very positive responses from ONR—but no dollars—until she joined forces with Professor Alison Flatau from the University of Maryland who works in acoustics. Ultimately, some collaborative proposals were funded by NSF and ONR, which enabled Stadler's group to proceed with their research. Fabricating nanowires out of materials such as nickel and cobalt proved to be relatively straightforward, but working with Galfenol and magnetic-sensing layers turned out to be much more challenging.

"Electrochemically depositing gallium-iron alloys and GMR layers proved to be extremely difficult," said Stadler. "Two of the graduate students in our group, Patrick McGary and Liwen Tan, have worked very hard to get the electrochemistry just right. After that, we have been able to grow great Galfenol wires and magnetic sensors."

Much work remains to be done to move from cutting-edge research to the development of real-world applications. Next up for Stadler and her group is characterizing the acoustic response of the nanowires and integrating and optimizing the performance of the magnetic heads used to measure their responses. But she remains convinced the probability of developing successful applications is very high.

"Developing acoustic sensors that could be used as a cochlear implant to restore or enhance human hearing is still a bit of a stretch," said Stadler, who noted that a fully functioning human ear can "hear" a broad spectrum of frequencies. "To date, it appears our sensors will perform better at higher frequencies."

That's why the most likely applications to emerge in the near term are those that function at high frequencies, such as medical imaging and sonar. But Stadler isn't ruling out the possibility of someday developing nanowire sensors that could effectively detect lower frequencies. What's more, her research group has also demonstrated some success in the development of artificial "noses" if you will: gas sensors that rely on a different class of nanostructures to detect the presence and level of gases. These structures use optical properties that only occur at the nanoscale, and may one day lead to the development of sensors that could be used for homeland security, leak detection, and food safety. Stadler is currently seeking additional grant monies to fund that research.

By the look of things, finding new ways to turn the small mysteries of life at the nanoscale into big scientific breakthroughs may keep Stadler and her colleagues busy for many years to come.

IN BRIEF

Faculty

■ **Faculty promotions.** In May, Kia Bazargan, Heiko Jacobs, Beth Stadler, and Jian-ping Wang were promoted to Associate Professor, with tenure. Ramesh Harjani was promoted to Professor.

■ Professor **Georgios Giannakis** has been selected to serve as an Institute of Electrical and Electronics Engineers (IEEE) Signal Processing Society Distinguished Lecturer from January 1, 2007 through December 31, 2008. Distinguished lecturers are invited to lecture at local chapter meetings of the IEEE Signal Processing Society.

■ Assistant Professor **Chris Kim** received an IBM Faculty Partnership award to support his work on Analysis, Measurement, and Design Techniques for Negative Bias Temperature Instability (NBTI) Tolerance. NBTI is one of the primary aging mechanisms of nanoscale transistors and can lead to chip failure. This award is a competitive, worldwide program established to enhance collaboration between faculty members at leading universities and IBM researchers.

■ Professor **Zhi-Quan (Tom) Luo** has been elected a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) "for contributions to modern optimization and its applications in signal processing and digital communications." The grade of Fellow is awarded by the IEEE Board of Directors to recognize extraordinary accomplishment in one of the fields of interest of the IEEE. The total number of Fellows selected in any one year is limited to no more than one-tenth of one percent of the total IEEE membership.

■ Associate Professor **Beth Stadler** was named a University of Minnesota McKnight Presidential Fellow. The award—which provides research funds for three years—is part of a University-wide program that recognizes the most promising faculty who have been recently granted tenure and promotion to associate professor.

■ **Professor Randal Victora and Associate Professor Jian-ping Wang**, together with their graduate students Xiao Shen and Weikang Shen, won the 2006 Information Storage Industry Consortium Technical Achievement Award for "pioneering work in the conception and experimental confirmation of exchange-coupled composite recording media." The award includes a cash price of $1,500. This marks the third time the award has been won by the University of Minnesota ECE department, the only time one University has accomplished that feat. (Professor Jae Moon received the award in 1997, and Victora and Professor Jack Judy won the award in 2001.) Victora is only the second person to have won the award two times.

Alumni

■ **Peter Herczfeld** (Ph.D., 1967) received the Pioneer Award at the 2006 International Microwave Symposium by the Institute of Electrical and Electronics Engineers (IEEE) Microwave Theory and Techniques Society. Herczfeld is the Lester A. Kraus Professor of Electrical and Computer Engineering and Director of the Center for Microwave/Lightwave Engineering at Drexel University.

■ **Jar-Ferr (Kevin) Yang** (Ph.D., 1988) has been elected a Fellow of the Institute of Electrical and Electronics Engineers (IEEE). The grade of Fellow is awarded by the IEEE Board of Directors to recognize extraordinary accomplishment in one of the fields of interest of the IEEE. The total number of Fellows selected in any one year is limited to no more than one-tenth of one percent of the total IEEE membership. Yang is a Professor at National Cheng Kung University in Tainan, Taiwan, where he also serves the Director of the Institute of Computers and Communication in the College of Electrical Engineering and Computer Science.

■ **Xinmiao Zhang** (Ph.D., 2005) has been named the Timothy E. and Allison L. Schroeder Assistant Professor of Computer Engineering and Networking at Case Western University. Zhang's research interests include VLSI architecture design for communications, digital signal processing, medical instruments, and cryptosystems.

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To date, all of their efforts have been funded "out-of-pocket" by the students and their families and by donations from the student section of the Institute for Electrical and Electronic Engineers at the University of Minnesota. BNI has formulated a business plan (which was named a finalist in The Minnesota Cup Business Plan Competition) designed to help them take things to the next level and set in motion an ongoing, sustainable approach to getting their lanterns into the hands of those who need them. Part of that plan includes selling the lanterns from here on out for a reasonable price. Because the old style soda bottle lanterns burned nearly $70 worth of kerosene per family per year, in five years time solar lanterns can actually save them more than $300 (approximately one year's income).

Currently, BNI is attempting to negotiate a deal with a sponsor who would provide financing to purchase several thousand lanterns, which the BNI team would then sell in Nicaragua to pay off the financing. They are also pursuing both donations and grant monies to help sustain their efforts. Although their focus is on Nicaragua for now, the overall mission statement for BNI is "finding and bringing efficient, effective, and environmentally friendly energy solutions to the people in our world who need it most." Long-term, they plan to investigate improving lantern designs and even developing manufacturing facilities in the countries that need better rural lighting solutions.

"It's very challenging to raise the funds we need to keep moving forward," says Delaney, 'but we plan to find a way to keep growing and find and discover new energy solutions for the future."

For more information, visit the BNI website at: www.brightnewideas.org/ or contact Delaney directly at: patrick.del@gmail.com

To Be (an Engineer) or Not to Be!

New class helps students choose the right career path

The first semester of an engineering program is typically a real eye-opener. As is often the case with the population at large, many incoming students aren't exactly clear about what it means to be an engineer.

"Engineering isn't the same as science; it's not the same as technology; and it's certainly about a lot more than tinkering," said ECE Professor Paul Imbertson. "By the end of fall semester of their freshman year, a lot of engineering students feel like they've been thrown into the deep-end and left to fend for themselves."

It doesn't have to be that way anymore, thanks to a new class developed by Imbertson and offered for the first time last spring. Called simply "Engineering Basics," the two-credit class is open to both engineering and non-engineering majors. It is designed to give students a basic overview of what it means to be an engineer and help them determine—before it's too late—whether it's the right path for them.

"We want our students to know what they're getting in to and help them determine sooner rather than later if it's not for them," explained Imbertson. After a good deal of deliberation, Imbertson settled on a course structure that covers three main thrusts: the philosophy of engineering, the tools of an engineer, and the practice of engineering. When covering the philosophy of engineering, Imbertson relied on real engineers as guest speakers and tried to take students inside the mind of an engineer, as it were, to better understand what makes them tick.

"Research studies have shown that there is little or no correlation among career choices and personality types—except for when it comes to engineering," said Imbertson. "Engineers really are a different sort, and the best way for students to begin to figure out if they might fit, is to let them rub elbows with real engineers."

For the second thrust of the course—the tools of an engineer—Imbertson began exposing the students to some of the software tools upon which modern engineers rely.

"Today's software tools are so powerful and so intuitive to use, that even newcomers can hit the ground running and begin to model and analyze different processes without really needing to understand all of the math and science behind it," he explained.

Finally, as part of the third thrust of the course, the students were divided up into five-person teams, each with a faculty advisor, and were asked to tackle a design project.

"These were structured much the same as our senior design projects," said Imbertson. "Each team had to come up with a plan, then go through the entire design process."

Forty students took the class last spring and a number of advisors reported that the class was exactly what their advisees needed at this time. Imbertson expects to make some minor revisions before the course is offered for the second time in Spring 2007—and he hopes to attract more students from outside the Institute of Technology.

"Just as we know that some students who start out in engineering soon discover that it isn't the right career choice for them, we also hope to come across some non-engineering majors who were born to be engineers," Imberston said.

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