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ENERGYnotes

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NEWS FROM THE UNIVERSITY OF CALIFORNIA ENERGY INSTITUTE

Wireless Smart Lighting System

SAVES ENERGY, RESPONDS TO HUMAN PREFERENCES

Jessica Granderson tests the demonstration system with a remote control while Alice Agogino and Yao-Jung Wen watch.

Your mother always told you: "Turn off the lights!" And it turns out, that was sound advice. Turning off the lights when they are not in use is one of the best ways to save energy – especially in an office building. These days, many people don't even have to flip the switch to save energy. Automated lighting, which turns on when a person walks into a room and off when he or she leaves, is fairly common in many newer offices today. And opportunities to save even more energy with automated lighting are just around the corner.

UC Berkeley researchers are exploring new combinations of commercial lighting systems controlled by "smart" wireless sensor technology that can customize a room's lighting to meet a range of pre-established conditions, including the occupant's personal preference. Mechanical Engineering Professor Alice Agogino is leading a multi-year project funded in part by the California Energy Commission's Public Interest Energy Research (PIER) Program. Working with a team of students in her Berkeley Expert Systems Technology (BEST) laboratory, Agogino

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Energy-Saving LED Pioneer Seeks Even More Efficient Devices

Shuji Nakamura

Shuji Nakamura, a professor of materials and of electrical and computer engineering at UC Santa Barbara, received the 2006 Millenium Technology Prize for inventing blue, green, and white light-emitting diodes (LEDs) and the blue laser diode. These energy-saving light sources have revolutionized products ranging from flashlights to advertising signs.

The prize recognizes outstanding technological achievement aimed at promoting quality of life and sustainable development. The award selection committee described Nakamura's work as "the 'holy grail' of semiconductor research." The award comes with a cash prize of approximately $1.3 million (1 million Euros).

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UC DAVIS ENERGY EFFICIENCY CENTER:

ADVANCING TECHNOLOGY FROM THE LAB TO THE MARKET

The new UC Davis Energy Efficiency Center (EEC) has an ambitious mission: to advance commercialization of energy efficiency technologies in three of the largest energy-use sectors – transportation, agriculture and food processing, and buildings. It also has big plans to develop synergies among the 69 UC Davis faculty members who are working on energy across multiple departments, and to create an entrepreneurial culture that is motivated to seek and implement energy-efficiency solutions.

"Our success will not be measured by the number of papers published or research grants received. It will be based on the number of ventures launched or supported, and the demonstration projects that we can help make possible."
— Andrew Hargadon

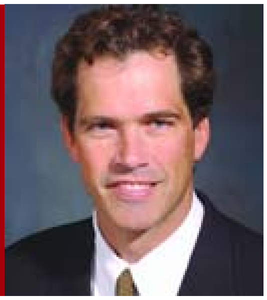
The center's approach—helping to push technology out of the lab and into the market—is quite different from most university research centers, acknowledges EEC Director Andrew Hargadon, a professor in the Graduate School of Management.

"Our success will not be measured by the number of papers published or research grants received. It will be based on the number of ventures launched or supported, and the demonstration projects that we can help make possible," he says.

The EEC's transportation projects will emphasize ways to reduce the fuel we use and the miles we travel in our vehicles. For example, the EEC is teaming with Innovative Mobility Research group, based at UC Berkeley's California Partners for Advanced Transit and Highways (PATH) and a Bay Area start-up company, ParkingCarma™, to help launch a "smart parking" garage in downtown Sacramento. ParkingCarma outfits parking spaces with sensors that transmit usage data to a central database. From that database, the system provides parking information and parking spot reservation or payment services to consumers via the Internet, cell phones, or in-vehicle navigation services. Smart parking can save gas, save time and reduce downtown traffic congestion by putting an end to drivers circling city blocks looking for elusive parking spaces.

"We're trying to take companies like ParkingCarma and give them a boost. They've got great technologies and this is a way to get it out in front of people," says Hargadon.

EEC is also funding business modeling and market analysis of a new infrared fruit and vegetable drying and blanching technology developed and tested at UC Davis. Processing fruits and vegetables is not only big business in California; it's a big energy sink. It's the third-largest energy user in California consuming about 300 – 400 million therms of natural gas and 600 – 800 million kWh of electricity each year. About a third of that energy use is for drying and heating.



"Previous research and field demonstrations show the technology has great promise," Hargadon explains. "So our role is to help identify an initial market, the right manufacturing partners, and potential funding streams to advance this product to commercialization."

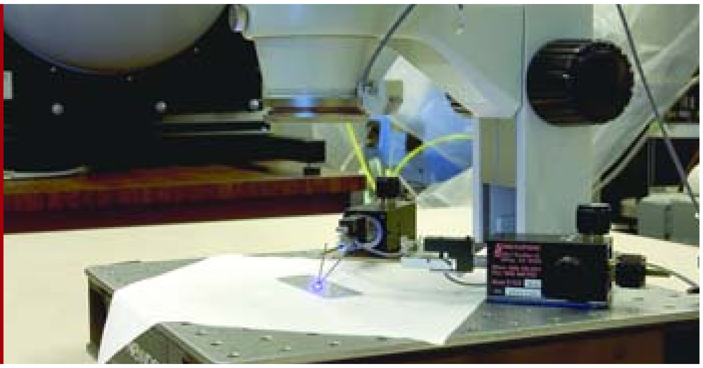
Hargadon believes the EEC can help university researchers develop an understanding of the path to market and the ultimate commercial viability of their creations. "They need to understand how the decisions they make in the early lab research stage may affect the product or invention's eventual commercialization success."

Taking this alternative research path makes sense for UC Davis, he adds, since the campus's roots, in agricultural extension, have always involved helping put science into practice. "We're returning to our roots, trying to resurrect ways universities can contribute to science."

The EEC was created through a $1 million challenge grant from the California Clean Energy Fund (CalCEF). The campus pledged $1.3 million to match the CalCEF grant in operating and research funds, faculty time, and office and laboratory space. In addition, PG&E Corp. pledged $500,000 over five years for academic fellowships, recruitment, and international energy conferences. CalCEF is a $30 million public benefit investment fund formed in 2005 as part of the Pacific Gas and Electric bankruptcy settlement.

Energy-Saving LED *continued from page 1*

"It's my dream to make LEDs more efficient. If efficiency could get to 100 percent, no heat would be generated."
— Shuji Nakamura



Blue laser.
Photo: Randall Lamb, UCSB

Nakamura has contributed a portion of the prize money to the UC Santa Barbara chapter of Engineering Without Borders and to Light-Up-The-World, which is installing lighting in parts of Africa, India, China, and Russia where electricity is scarce.

"They are using my invention, white LEDs, because they can be powered by solar cells coupled with batteries. White LEDs can operate with very low voltage, requiring very little energy."

Nakamura's breakthroughs have quality-of-life implications for millions. In addition to enabling energy-efficient, solid-state lighting, his innovations can be used in new printing technologies, improved optical data storage, and medical and public health applications such as sterilizing drinking water.

His discovery, which occurred more than ten years ago, launched him into the international limelight in semiconductor research after years of working in relative obscurity at Nichia Chemical, a small Japanese company. There, he was developing conventional red and infrared LEDs using an epitaxial wafer, or very thin layer of gallium aluminum arsenide. The race was on in the semiconductor industry to make blue and green LEDs, which, when combined with red LEDs, would create white light.

"I started thinking about this and knew I had to work to develop blue and green LEDs."

By 1989, scientists had zeroed in on two materials for making blue LEDs: zinc selenide (ZnSe) and gallium nitride (GaN). Nakamura chose to work with GaN precisely because it was the material most of his competitors were not using. He pioneered a new technique for metal organic chemical vapor deposition, the semiconductor manufacturing process that involves passing reactant gases over a substrate. Nakamura's technique involved passing the gases in two directions instead of one on a sapphire or silicon carbide substrate, and it resulted in a material with improved structural and electrical properties.

In 1993 he stunned the semiconductor world with the announcement that he had created and patented a bright-blue GaN LED. He created a green LED and a blue laser diode shortly thereafter.

Nakamura is still working to develop high-efficiency blue and white LEDs and blue laser diodes. One of his research goals is to improve the efficiency of blue LEDs. Currently, they are about 50 percent efficient, meaning, per unit of electric power, 50 percent becomes light and 50 percent becomes heat. In comparison, fluorescent lamps are about 10 percent efficient. Incandescent and halogen lamps are less than 3 percent efficient.

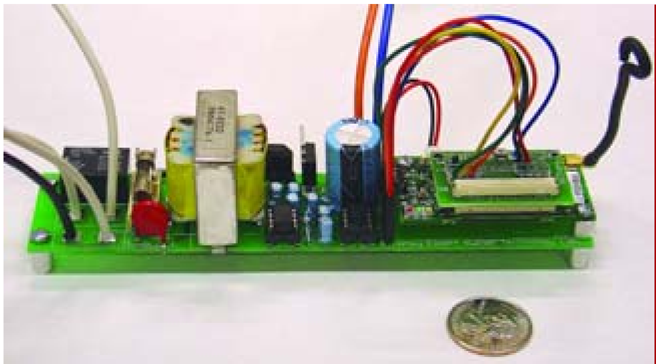
"It's my dream to make LEDs more efficient. If efficiency could get to 100 percent, no heat would be generated," he explains, acknowledging that while 100 percent efficiency may not feasible, 80 or 90 percent may be.

Nakamura pursues this goal using GaN-based materials and experimenting with different material structures. Each semiconductor wafer is comprised of multiple layers of material stacked in certain ways. Nakamura is changing the sequence or composition of each layer, and trying a totally different approach, such as adding more layers. He works with researchers at UC Santa Barbara's Solid State Lighting and Display Center, which he co-directs.

Nakamura believes mass production of LEDs will bring prices down in five to ten years, creating enormous potential.

"Just imagine this: If we replaced all conventional incandescent lighting with 50 percent efficient LEDs, by 2025 we could save enough energy to avoid having to build 150 power plants in the U.S."

Wireless Smart Lighting System *continued from page 1*



"To be able to fuse and validate sensor data altogether was our unique contribution."
— Alice Agogino

Smart lighting system actuation module components on circuit board.

has developed and tested a proof-of-concept wireless sensing and communications product for dimmable commercial fluorescent lighting systems. The BEST lab is an artificial intelligence, expert systems and information technologies lab.

"There are wonderful opportunities with intelligent micro-sensing," Agogino says. "And not just with micro-sensing but also with calibrating and interpreting what the sensors are saying, and then making decisions about what to do with that information." Her research is pursuing all of these opportunities.

The energy-saving potential is significant. Currently, commercial buildings consume about one-third of all electricity produced in the U.S. Lighting accounts for approximately 40 percent of electricity consumed in commercial buildings. If lighting energy could be reduced, even if only 20 percent to 30 percent—and Agogino's research indicates this is possible—then the savings could be significant.

MEETING MARKET DEMAND

Efficient lighting controls proven to save up to 40 percent in electricity consumption are commercially available but underutilized, according to Agogino. The market has not embraced these systems for three simple reasons: They are difficult to use, expensive to install in a building retrofit, and not tailored to the room in which they are installed or to the person using the space.

Working closely with Ph.D. students Jessica Granderson and Yao-Jung Wen, Agogino launched a project to overcome the market barriers. They designed and built a system that is easy to use and tailored to the space. Then they researched how people might use and respond to the system. They are now demonstrating it in an office on the Berkeley campus.

Agogino says the project was motivated by her concern over the wasted energy in her large research lab, which includes a section of small cubicles with desks and personalized spaces, as well as a shared space. There was only one light switch for the whole lab. "So even if only one person was working at their desk and the rest of the lab was empty, all the lights were on and it was wasting energy."

The system they designed can control individual fluorescent light fixtures, focusing the light where people are working. It can simultaneously dim the lighting in another part of the room if the space is not in use or if its use demands lower lighting, for example, during a presentation. The system can provide low background lighting and strong lighting at an individual's desk, and it can sense and take advantage of the amount of daylight in the room, adjusting the electric lighting accordingly.

To operate the system, a person "checks in" via his personal computer keyboard or a hand-held device like a television remote and directs the system to adjust the lighting to his preferences which have all been previously recorded in the computer. The team has also explored the possibility of using electronic key badges common today in many office settings to store an individual's lighting preferences. A less-invasive approach, she says, involves simple occupancy sensors that can detect occupancy in workspaces associated with specific individuals.

SYSTEM HARDWARE AND SOFTWARE

After considering the needs and designing the system, the team built the system around an off-the-shelf wireless sensor micro-sensor platform made by a company called Crossbow. The platform uses *Tiny OS* as an operating system and has a small radio antenna for wireless communication. The size of the system is defined by the two AA batteries it uses for power. They added to the platform other hardware and software components that they had developed. Agogino credits Wen, who is interested in mechatronics, control theory and design, for his work on this part of the project.

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"They don't want to feel like there's a robot running the room. So we need to work a trade-off between what's automatic and what they control, and we're setting experiments to see where they adjust from the default conditions."

— Alice Agogino

Final installation above office light fixture.

Building the prototype involved trial and error; Wen began the project using the default micro-sensor on the platform but switched to a different one mid-project because his calibration tests showed it was inadequate for the lighting precision desired. Wen even created his own printed circuit board and sent it out to be fabricated, Agogino says. "We came in thinking we could use off-the-shelf technology, but we learned we had to identify all the individual components and put it together ourselves."

The work paid off. They ended up with a completely integrated system for which they have a patent pending. They call their smart lighting product intelligent sensor fusion and validation. What sets it apart is its ability to combine information from different sensors and validate when a sensor goes bad. Other systems they tested were sporadic; if one sensor in a room failed, the system couldn't fuse information from different sensors collecting different data in different parts of room.

"To be able to fuse and validate sensor data altogether was our unique contribution," Agogino says. "In this way, we have increased the reliability of the system and have also been able to reduce artificial lighting levels when there is a significant amount of daylighting."

USER NEEDS AND BUILDING MANAGER NEEDS

The other key aspect of the project involved using human-centered design to model the lighting needs of both people who use the workspace and building managers. Granderson took the lead in this part of the project, which was funded in part by the UC Energy Institute. She interviewed eleven facilities managers from the City of Oakland, Government Services Agency, University of California campuses, and the private sector to determine how their needs to control energy consumption vary. She probed on issues such as demand response, when high energy prices during peak demand spur conservation or when there is a system-wide call for conservation during a brownout. Then she interviewed the people who use the work space to understand how their lighting needs might vary based on their age, activity such as reading or working at the computer, personal preferences, and willingness to respond to energy demand situations.

The resulting model showed a wide range of acceptability within occupants' personal preferences. "They were willing to adapt depending upon the degree of severity of the power or energy need," Agogino explains. "There was an 'ideal' or preferred setting, as well as an 'OK' setting and an 'unacceptable' setting. So, in an emergency situation, to save energy the building manager could adjust the system to favor the 'OK' setting rather than the ideal setting."

DEMONSTRATION AND NEXT STEPS

Now that Agogino and her students have designed and developed the system, and modeled the user response and interface, they are advancing to the implementation stage, testing the user interfaces with real people in an office on the UC Berkeley campus. Initial user response indicates that people want to be able to manually override the system if necessary.

"They don't want to feel like there's a robot running the room. So we need to work a trade-off between what's automatic and what they control, and we're setting experiments to see where they adjust from the default conditions."

Agogino has high hopes for the technology and the project, even though the current technology is not mature enough to meet the industry norm for payback in two to five years. A cost and energy-use analysis of the modeled smart lighting system saved about $40 annually, a 23 percent energy savings in a 150-square meter office space serving approximately 15 occupants. With improved design and mass production, however, Agogino notes, prices would drop, potentially making it a very desirable technology.

UCEI REQUEST FOR PROPOSALS

Proposals Due February 2, 2007

The University of California Energy Institute requests proposals for two grant programs:

- **California Energy Studies**
- **Energy Science and Technology**

The range of subjects appropriate for both programs includes energy production (resources and supply systems), efficient energy use, and environmental and health effects of energy production and use. California Energy Studies also includes the economics, politics, and regulation of energy systems. Energy relevance is a key criterion in the review process.

Those submitting proposals must be employed by the University of California and qualified to be principal investigators at a UC campus. Awards will be announced on or about May 18, 2007 for the period July 1, 2007 through June 30, 2008. Awards typically will be in the range of $10,000 to $35,000. Decisions on awards will be made competitively on the basis of a review process. Additional encouragement is offered to faculty early in their careers.

For more information, please visit:
http://www.ucei.berkeley.edu

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