Momentum!

Fall 2015

Toward Creating a Better Future

Oregon State UNIVERSITY

Momentum!

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FRONT COVER
Kamesh Mullapudi prepares a flexible polyimide substrate for glucose sensor processing and fabrication.

BACK COVER
In 2012, OSU Engineers Without Borders worked with community members in Lela, Kenya, to build a well and rainwater catchment system that now supplies easily accessible drinking water for residents.

EDITOR
Thuy T. Tran

CONTRIBUTING WRITERS
Gregg Kleiner, Cathleen Hockman-Wert, Marie Oliver, and Thuy T. Tran

GRAPHIC DESIGNER
Jack Forkey

COPY EDITOR
Marie Oliver
(Clarity Writing & Editing)

PHOTOGRAPHERS
Hannah Gustin, Mitch Lea, Karl Maasdam, Hannah O'leary, and Justin Smith.
Photo of Engineers Without Borders is courtesy of OSU-EWB.

COLLEGE OF ENGINEERING
Oregon State University
101 Covell Hall
Corvallis, OR 97331
541-737-3101
engineering.oregonstate.edu

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Our new strategic plan in action

In June 2014, the College of Engineering began a collaborative process with our stakeholders to craft a new strategic plan that supports the university's *Strategic Plan* 3.0 2014–18 — *Focus on Excellence.* We were pleased to release the college's plan, *Creating a Better Future,* this spring. It will help us be responsive to the times and give our graduates the knowledge, skills, and professional values that tomorrow's truly exceptional engineering leaders will require.

The college is already recognized nationally for its applied approach to engineering education, and we are poised to build on that success. Our stories in this issue of *Momentum!* put the spotlight on three of our four strategic goals:

- **Provide a transformational educational experience that produces graduates who drive change throughout their lives.**
  For many years, we have provided an opportunity for our undergraduates to showcase their senior capstone projects at the Engineering Expo on campus. This year, we also hosted the first Graduate Engineering Research Expo at the Oregon Convention Center in Portland. More than 250 displays highlighted our graduate students' remarkable accomplishments, representing innovative research at the forefront of change. The event strongly communicated the impact of engineering research at Oregon State and gave our students the opportunity to discuss their ideas and findings with industry representatives and the general public.

- **Become a recognized model as an inclusive and collaborative community.**
  Our fledgling Humanitarian Engineering program is a great example of the ways we foster diversity and collaboration among our students and faculty. We created this program in response to the increasing number of engineering students who want their contributions to make a real difference in people's lives, here in the United States and in developing countries around the world. We are extremely grateful to Dick and Gretchen Evans for their original gifts that helped get the program off the ground and, more recently, created one of the nation's first endowed professorships in humanitarian engineering.

- **Lead research and innovation to drive breakthroughs that change the world.**
  Throughout the college, engineers are searching for economically, environmentally, and socially sustainable solutions to 21st century global problems. Our story about additive manufacturing provides a snapshot of several diverse research projects that are applying or eventually will apply printing technologies to dramatically reduce waste and achieve objectives that otherwise might not be possible. Some of these projects are getting close to commercialization. When they are unleashed upon the world, they promise to make a real impact on human lives and the economy while reducing our impact on the environment.

For more information about our new strategic plan, visit **engineering.oregonstate.edu/coe-strategic-plan.** I would love to have the opportunity to chat with you about how you can help support the college in creating a better future.

Go Beavs!

Scott A. Ashford, Ph.D.
Kearney Professor and Dean
Oregon State University
College of Engineering

First Graduate Engineering Research Expo makes a big splash in Portland

By Gregg Kleiner

The College of Engineering's emphasis on graduate student education and research was on full display at the inaugural Graduate Engineering Research Expo on March 4, 2015, at the Oregon Convention Center in Portland. Row after row of tables topped with more than 250 research posters and hands-on displays gave testament to the college's phenomenal growth over the past few years.

Hundreds of graduate students from what is now the fourteenth largest engineering school in the United States presented a rich diversity of research projects, many revealing innovative solutions to complex societal problems.

"Oregon State is the leading public research university in the state, and the College of Engineering is a critical component of that leadership, so we wanted to showcase our accomplishments at the forefront of new ideas, research, and innovation," said Scott Ashford, dean of the College of Engineering. "This event was a great way to communicate the impact of our research to a broader audience and to give our students the opportunity to discuss their research with industry and the public."

At one table, a team of students from the School of Chemical, Biological, and Environmental Engineering talked about their efforts to develop a method for capturing the methane that is often "flared off" into the atmosphere at fracking sites and oil wells. As a way of sequestering carbon, the team is working to convert methane into useful methanol-based products.

"We're looking at how to add an oxygen into the methane to make methanol directly, which is a liquid at room temperature," said Peter Kreider, a Ph.D. candidate. "You can then use the methanol in the chemical industry to make other chemicals."

Much of the research on display was clearly aimed at making the world a better place, including improving human health.

Jessica Armstrong, a Ph.D. candidate in the School of Mechanical, Industrial, and Manufacturing Engineering, is working to help companies design and develop "inclusive products" that meet the needs of all people, whether or not they have disabilities.

Armstrong's work in inclusive design involves a "disability simulation suit" that applies restrictions to the upper extremity joints to mimic disabilities such as arthritis or limited mobility. She and her team members developed the suit in the hope that manufacturers will use it early in the design process to ensure that products work for people with disabilities.

"That's one of the hurdles for inclusive design," she said. "Many companies don't have the ability to do this type of testing up front, which is why we want to offer our disability simulation suit — to move the testing to the front end of the design process, where it's more useful."

Armstrong came to Oregon State from Idaho as an undergraduate. She hadn't decided whether to major in engineering or physics, and Oregon State offered an engineering-physics degree. "The undergrad engineering program was super exciting, because it teaches you how to design," she said. "I enjoyed it so much that I came back for a master's in design, and now I'm sticking around for my Ph.D."

Andrew Strahler, a Ph.D. candidate in the School of Civil and Construction Engineering, describes how his work will help engineers better understand the two- and three-dimensional response of sandy gravel mixtures, which are commonly used as structural fill materials. Strahler is part of Associate Professor Armin Stuedlein's research group.

Benyamin Narin, also in the School of Mechanical, Industrial, and Manufacturing Engineering, is working to outfit wheelchairs with robotics that could take advantage of machine learning so a chair would "know" its way around a person's home or frequently visited buildings.

Some of the research on display tackled the impact of human activities on ecosystems.

Stacey Garrison, a master's candidate in the School of Civil and Construction Engineering, is studying the impacts of agricultural practices on river basins, specifically where flooding from the loss of natural water storage and nutrient runoff reduces available oxygen to organisms where rivers enter the sea.

Garrison's research addresses solutions that not only address flooding and runoff, but simultaneously create habitat. "A lot of studies look at just the flooding or just the nutrient runoff, and mainly from a cost-reduction viewpoint, but very few have included this ecology factor," she said. "So I'm looking at the measured, added benefit of this habitat factor to impact multiple goals or objectives. That's where I've found my little niche."

Nuclear Engineering students Jon Napier and Delvan Neville also found their niche looking at ecosystems. They are interested in how radioactive materials move through landscapes and the food web, including how they enter plants and animals.

Transportation was another research thread running through the expo.

As unmanned aerial vehicles — also called drones — become more commonplace, Carrie Rebhuhm, a Ph.D. candidate in robotics, is thinking ahead to when the sky might be abuzz with drones. "I feel that the traffic management aspect is really overlooked in robotics, because everyone is all about how do we avoid near collisions," she said. "But I want to address this before you get to that situation by looking at the big picture and patterns." She described how traffic management on roadways deals very differently with an ambulance versus a freight truck. Similar issues will apply to drone traffic, she said.

Scott Campbell, in the School of Mechanical, Industrial, and Manufacturing Engineering, designed a bicycle frame made of wood. Campbell returned to school after the economic downturn slowed his work as a cabinetmaker. "The economy was the motivating force, but I was wanting to do something different anyway," he said. "I was working at the craftsman level and wanted to know more about the engineering level." He will soon be testing the frame and performing a lifecycle analysis on the material.

More than 600 people attended the event, including engineers and managers from industry, alumni and friends of the college, students and faculty from other universities, and even a few families with kids in tow.

Among the attendees walking the aisles of research displays and talking with students was Oregon State alumnus Craig Peterson ('79, Mechanical Engineering), who works for the heater manufacturer Cadet in Vancouver, Washington. He came to the expo because he is intrigued by the research. "I'm curious about the scope of what's going on at OSU now, so I wanted to come see the diversity of the research," he said. His son recently earned a Ph.D. in engineering from Oregon State and is working for a Corvallis-based spinoff.

Mark Reed, an engineer who works on integrated circuits for HP printers at the company's Vancouver location and often recruits at Oregon State, attended the expo to scout for talent and see the diversity of the research. "I work in integrated circuits, so it's fun to see the whole breadth of the research on display here," he said. "Our work is infinitesimal, actually, so it's great to see people working on very large projects like power grids."

Oregon State electrical engineering alumnus Michael Matthews graduated eight years ago and now works for Panasonic in Salem. He brought his wife and kids to the expo. "I did my senior project in Corvallis years ago, before kids, so they didn't get to see that," said Matthews. "We thought it would be fun to come here so they could see what it might have been like."

As the sprawling, four-hour event wound down, one thing was clear: research by Oregon State graduate students is impressive and important, and impacts nearly every aspect of our lives. If the level of turnout and enthusiasm for this year's inaugural event is any indication, next year's expo is bound to be even bigger and better. **M!**

Mahyar Sharifi Mood, Janhavi Kulkarni, and Matt Viehdorfer were among the 250 College of Engineering graduate students who presented their research at the expo.

Investment in humanitarian engineering builds community

By Cathleen Hockman-Wert and Thuy T. Tran

Sonja Michelsen, Katherine Lanfri and James Teeter, finish the second of three well implementations in Lela, Kenya, with the help of local Paul O'lango in 2013.

Professor Kendra Sharp (center) shows Dick and Gretchen Evans a biosand filter for water purification built by Oregon State students.

Part of the College of Engineering's strategic vision is to become nationally recognized for modeling a diverse, inclusive, and collaborative academic community. As one step toward that vision, a recent $1.5 million gift from Richard ("Dick") ('69, Industrial Engineering) and Gretchen ('69, Elementary Education) Evans will create one of the nation's first endowed professorships in humanitarian engineering.

Earlier gifts from the Evans helped to launch Oregon State's Humanitarian Engineering program two years ago. The program was created in response to growing interest among engineering students to make a lasting, positive impact on the world. Humanitarian engineers seek science- and engineering-based solutions to improve the human condition by increasing access to resources like clean water and clean energy, enhancing quality of life, and improving community resilience, whether in face of natural disasters or economic turmoil. Although the greatest need often lies in developing countries, the program also focuses on disadvantaged communities in the Pacific Northwest.

The curriculum addresses what Dick Evans calls "human skills" in addition to the requisite technical skills.

"The technical skills of engineering are essential, but so are things we might call human skills, such as communication, problem solving, leadership, and the ability to work across cultures," said Dick, who was president and chief executive officer of Alcan, a Fortune-100 mining company and aluminum manufacturer based in Montreal.

"The humanitarian engineering curriculum is a structured way for engineers to practice those human skills in challenging real-world settings."

Dick's own education in these human skills was less structured. He recalls being sent to Ghana, West Africa, with Gretchen and their two young daughters in tow, to manage 2,500 employees at a troubled aluminum smelter. The smelter had been closed twice in two years due to power outages and political unrest. Among the many challenges — three coups in three years, no telephones, pirates in the harbor, and deteriorating infrastructure throughout the country — was a deeply divisive and dysfunctional workforce composed of members of four distinct ethnic groups — Ashanti, Fanti, Ewe, and Ga — who spoke four different dialects and did not trust each other.

Americans had founded the plant five years earlier based on a model of equally distributing jobs to all tribes across all departments, but over the years the tribes re-distributed themselves. When Dick arrived, the Ewe had taken over the operations units, the Ashanti were in charge of engineering and maintenance, the Fanti were running staff functions, and the Ga were in charge of support services.

Over the next four years, Dick successfully broke down the most counterproductive behaviors of this tribalism and developed a cohesive team that outperformed all similar plants in the company. In the years following that experience, he applied the lessons he learned to numerous other business situations.

"While Ghana was a case of overt tribalism — and relatively easy to spot — I was able to generalize and apply the lessons in dozens of much more subtle cases of tribalism, such as IBM-ers versus Apple-ites, engineers versus accountants, and lawyers versus just about everyone else," said Dick.

Today, Dick defines tribalism as the tendency of groups of humans to coalesce around common beliefs and behaviors perceived to be in their own self interest and survival, and to exclude and punish those ideas and behaviors perceived to threaten the group. He said that recognizing and understanding tribalism in this broader sense was one of the most valuable insights he gained in more than four decades in the metals industry.

The Evans hope to help create a new breed of engineers who consciously choose to push the edges and expand their perspective, gain work and life experience outside their home country, and seek and embrace diversity in their career and life. They envision these engineers helping to create a diverse, inclusive, and collaborative community while they are at Oregon State and gain the sensibility and sensitivity to recognize and combat tribalism wherever their careers take them.

"Humanitarian engineering is a unique and impactful way to enable talented students with a passion for making a better world do exactly that," said Gretchen, who is a visual artist and active community volunteer. "When I heard of the connection with the humanities, I perked up my ears. Sometimes there can be a very narrow technical focus in engineering education, but the addition of humanities can lead to a more rounded education and help engineers think outside the box... Humanitarian engineering means listening to the culture and employing a little humility to arrive at more creative and sustainable solutions."

The Humanitarian Engineering program reflects a campus-wide emphasis on engaged service, which springs from the university's historic land grant mission. Multiple student organizations, including Oregon State's award-winning Engineers Without Borders chapter and the American Society of Civil Engineering student chapter, have been working on water, energy, and other projects in the developing world.

The first Richard and Gretchen Evans Professor in Humanitarian Engineering is mechanical engineering professor Kendra Sharp, who directs the program. She points out that the program is capturing the interest of a more diverse group of prospective students than is typically attracted to engineering, including women.

"We are thrilled that the Evans' gift will help us channel students' passion for making a better world," said Sharp. "The stability provided by this endowment will make a huge difference as we move forward."

In contrast to humanitarian engineering programs that are primarily an extracurricular activity, Oregon State's program is one of a handful nationwide that are firmly rooted in an academic curriculum.

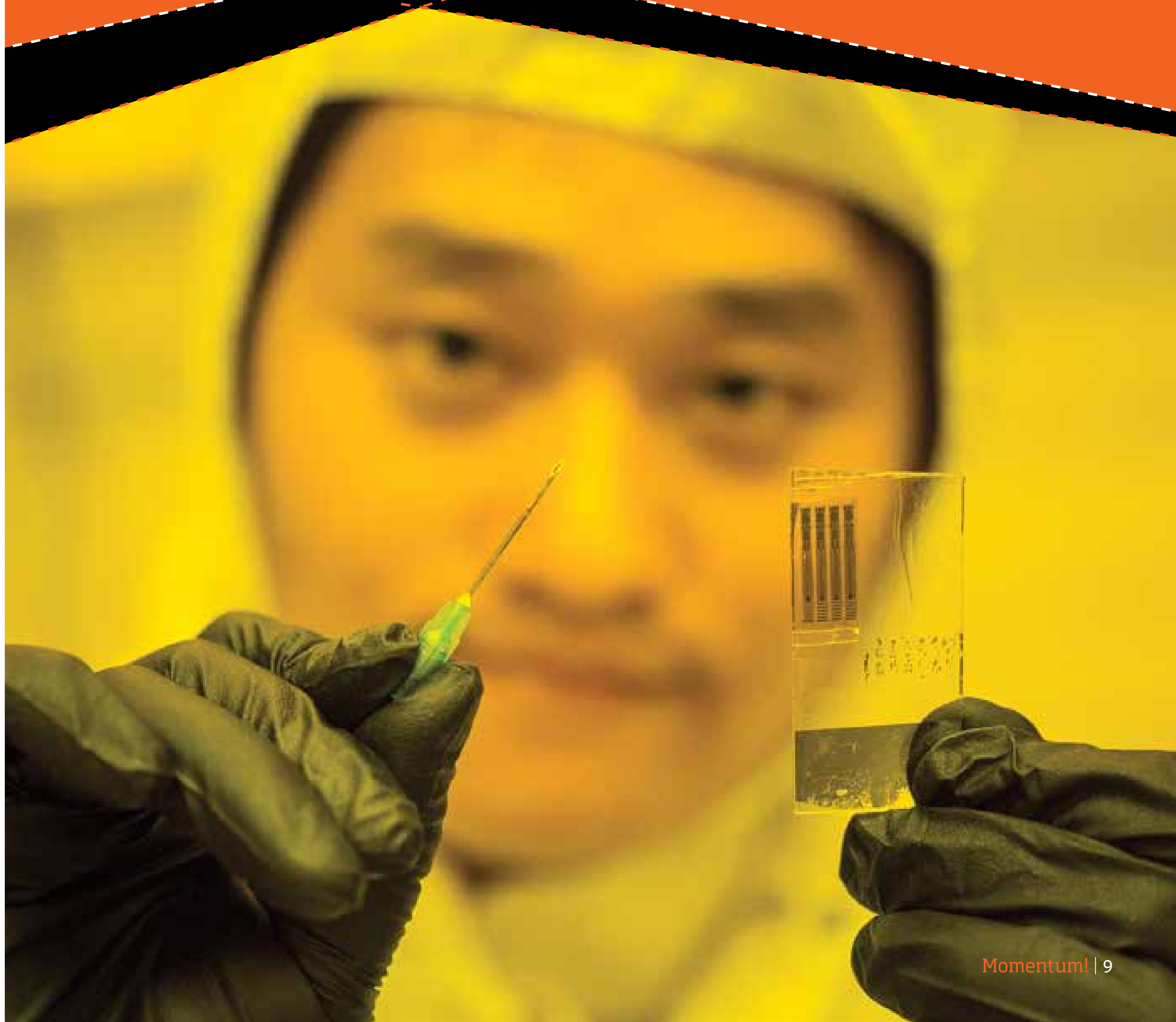
Oregon State's program also is one of the only such programs to reside in a university that also offers a Peace Corps Master's International program in engineering. The university was the first in Oregon to join this program, which allows graduate students in several disciplines to get a master's degree while doing a full 27-month term of service in the Peace Corps. Oregon State remains one of just 10 universities nationwide to offer this degree in engineering.

This fall, a new undergraduate minor in humanitarian engineering will be open for enrollment, with classes that emphasize the importance of context (socio-cultural, economic, environmental, resource), ethics and social justice, and cross-cultural communication. Students will be exposed to case studies of development projects, including learning from project failures as well as successes and a historical perspective on humanitarian interventions. **M!**

Additive manufacturing:

Addressing global challenges in product development

By Marie Oliver



As part of its newly adopted strategic plan, the College of Engineering strongly supports four signature research areas to address global challenges, and among them is advanced manufacturing. Several research projects are underway in the college that contribute to one particular form of advanced manufacturing: additive manufacturing.

Additive manufacturing refers to a process where materials are applied with spatial, compositional, and quantitative precision to create 3-D objects and the patterned thin-films used in electronics. Although additive manufacturing has been around in some form for nearly half a century, the movement toward economic, environmental, and social sustainability has led industry and the scientific community to explore new potentials for this revolutionary technology.

Researchers generally agree that the primary benefit to additive manufacturing is that it saves 90 percent or more in materials usage. In contrast to subtractive manufacturing, where manufacturers begin with a block or layer of material and remove what they don't want, additive manufacturing applies powders or liquid solutions only where they are needed. The process requires fewer natural resources and has the potential to vastly improve performance, enable distributed and just-in-time manufacturing for more products, and drastically reduce manufacturing and shipping costs.

Additionally, printing technologies allow functionality to be applied to all kinds of materials and in all shapes and sizes, enabling the creation of new designs and products that would not be possible using traditional methods.

"You can get to more organic shapes that aren't possible to produce using conventional manufacturing processes," said Karl Haapala, associate professor in the School of Mechanical, Industrial, and Manufacturing Engineering. "I've seen examples where manufacturing tooling is made using additive manufacturing that goes into production — let's say for a specialized geometry or a specially shaped part — that would be very difficult to produce using conventional manufacturing technology."

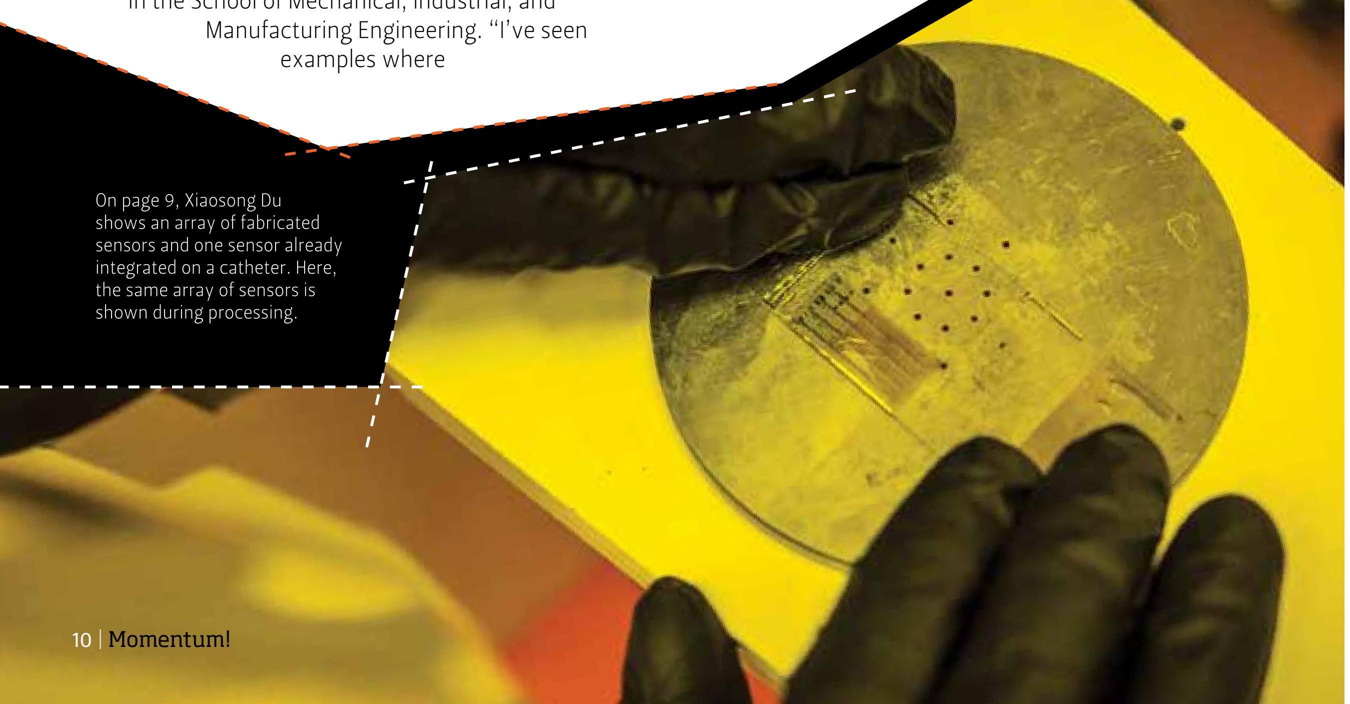
Several researchers in the College of Engineering are researching new and existing technologies that use or are excellent candidates for exploiting the potential of additive manufacturing: transistors, quantum dots, solar cells, and biosensors. Engineers are also exploring the possibilities for 3-D printing magnetic particles for various cutting-edge applications.

Transistors for computer displays

While working at HP, Greg Herman collaborated with Chih-Hung Chang, a professor in the School of Chemical, Biological, and Environmental Engineering, and colleagues to develop and patent indium gallium zinc-oxide (IGZO) thin-film transistors, which are now widely used in display technologies like Apple's iPad. Their collaboration broke new ground when they applied solution-based methods to create transparent amorphous oxide transistors, such as IGZO, using additive manufacturing. Now Herman is a professor in the same school at Oregon State and the engineers are continuing their collaboration.

"The idea with these methods is that we can reduce the amount of material that's used, but at the same time this is something we can do in our lab with a printer, under conditions that are much less energy intensive," said Herman.

"We're wasting less material, using less energy, and can ultimately make lower cost displays that perform better."



On page 9, Xiaosong Du shows an array of fabricated sensors and one sensor already integrated on a catheter. Here, the same array of sensors is shown during processing.

Kamesh Mullapudi examines patterned eclectrodes on a prepared polyimide substrate.

The precursors used in this process are also less toxic and much less flammable than those used for silicon-based devices. They use much less water to produce, and tests indicate that they may perform better. "Using our material, we can get about 30 times higher mobility than with amorphous silicon," said Chang. Mobility describes how quickly an electron moves through a material, and is an indication of performance.

Work remains to be done to improve certain other aspects of the technology before it is ready for commercialization.

Manufacturers could be slow to adopt additive manufacturing into their processes. "I think the biggest challenge is that even though the printed materials work really well, the industry standard is still the subtractive manufacturing approach," said Herman. "So it is a new method of manufacturing that needs to be further developed before a company decides to change their display fab to this new technology. It will more likely take hold when products begin to transition to flexible substrates (as opposed to glass), because they will end up building new manufacturing lines anyway. But there is a fair amount of interest from industry in terms of moving to this technology to reduce costs."

Quantum dots for solid state applications

Herman is also using copper indium disulfide to improve the photoluminescent properties of displays and other light sources.

Some technologies, such as Kindle Fire, are currently using quantum dots, which are semiconductor nanocrystals with unique properties. Quantum dots can give manufacturers much better control over the quality and color of emitted light, and improve efficiencies.

"Quantum dots produce very tight distribution of light," he said, "We can control how broad the emission is, allowing us to produce much sharper greens,blues, and reds. But to get high-quality quantum dots that efficiently emit a specific color can be fairly expensive, and manufacturers want to minimize the waste as much as they can. That's where additive manufacturing improves utilization of expensive materials."

Current technologies that use quantum dots are built using traditional subtractive manufacturing processes and incorporate quantum dots where they are not effectively being used. They also use quantum dots composed of cadmium compounds, which are relatively toxic. Herman is testing copper indium disulfide quantum dots, but is seeking a patent for a new material that might produce as good or better performance. He is working with two companies to develop an additive manufacturing process to improve the color spectrum of LED lighting and displays.

"The integration of quantum dots with additive manufacturing is still a couple years off, but could be much sooner depending on what we discover during the next several months," he said, regarding the timeline for commercialization.

Anti-reflective coating and printed solar cells

In addition to working on the display transistors, Chang is deeply involved in seeking solar energy solutions using additive manufacturing. He is director of the Oregon Process Innovation Center for Sustainable Solar Cell Manufacturing and founder of an Oregon State spin-off called CSD Nano. CSD Nano developed and patented the next generation of nanotech anti-reflective coatings for the solar industry.

The anti-reflective coating is made using nanoparticle inks that mimic the structure and antireflection properties of moth eyes. CSD Nano is in the market research phase, working with solar farms to determine the feasibility for commercializing the technology. A fair amount of international interest in this technology is evident.

Chang is also using additive manufacturing to print chalcopyrite (composed of copper, indium, gallium, and selenium) solar cells. The material is much more efficient than silicon, which is now used to manufacture solar panels.

"Most of the solar cells are manufactured using a vacuum process to make the film that captures sunlight, but the process is slower and the cost is higher," said Chang.

Although commercialization is on the horizon, the team is not quite ready yet. "We're at about eight percent efficiency for the ink, so we need to improve the efficiency before we consider commercialization. We're looking for 12 to 15 percent efficiency," said Chang. Silicon-based solar cells operate at about 18 percent efficiency, but that difference could be balanced out by the lower cost of the chalcopyrite-based version.

Biosensors for continuous glucose monitoring

John Conley, professor in the School of Electrical Engineering and Computer Science and co-director of the Materials Synthesis and Characterization facility at Oregon State, has been working closely with Pacific Diabetes Technologies to build the biosensors for what will eventually become an artificial pancreas. The research team is working on the second generation of the device, which is more robust and reliable than the first generation.

"We've helped them improve the adhesion of the biosensors to the substrates," said Conley. The technology is undergoing animal testing at Oregon Health and Sciences University in Portland and on campus in Corvallis. "Basically, the idea is to combine continuous glucose monitoring with controlled injection of hormones, and their ultimate goal is to make an artificial pancreas, but they're doing it one step at a time."

At this prototyping phase, the devices are built using subtractive manufacturing, but Conley, Herman, and their team recently published a paper that describes how additive manufacturing could reduce costs when moving into mass production. "The challenge will be to redevelop an already robust working sensor, developed with the subtractive manufacturing, to get it to work with additive manufacturing — basically reworking the process to make sure the layers adhere properly to each other," said Conley.

He describes the vision, which involves roll-to-roll printing: "Imagine a newspaper printing process, but instead you would run the film of our flexible substrate through a big printer. It would print the sensors as the film zooms through."

The challenges in moving to additive manufacturing will be finding the right materials and chemistry. "There's a lot of chemistry involved in the ink formulation, and that's where the chemical engineers and the chemists get involved," said Conley. "The chemistry has to be such that it flows well — doesn't clog up or corrode the printer. It has to adhere well and make a dense film."

Conley observes that materials research for additive manufacturing is still in the early stages. Many materials must be stored or handled under tightly controlled temperatures and humidity conditions. "You want to be able to do this at room temperature in normal atmospheric conditions, as opposed to needing either a vacuum system or very high temperatures to deposit high-quality films, said Conley. "Right now, there are only a few materials that can be printed under room temperature conditions and still give the same quality as vacuum deposited films, so there's a lot of opportunity for materials researchers."

Magnetic particles for computer memory and imaging

Pallavi Dhagat, associate professor in the School of Electrical Engineering and Computer Science, is investigating the potential for customizing additive manufacturing technologies to print magnetic materials composed of magnetic nanoparticles. These materials might be used in the future to 3-D print electronic components, nonvolatile memory elements, and even fully functional motors. Dhagat co-founded the Applied Magnetics laboratory at Oregon State — the only lab of its kind in Oregon.

The lab has been inkjet printing magnetic materials for about a year and is already breaking new ground. "We've shown some preliminary results indicating that there is something to be gained with the inkjet printing," said Dhagat. "The biggest advantage is that as you're dropping the ink containing the magnetic nanoparticles, you can apply a magnetic field to orient the nanoparticles, and you can do so drop by drop by drop, which means you can do it in any shape. This is something you cannot do with any other technology."

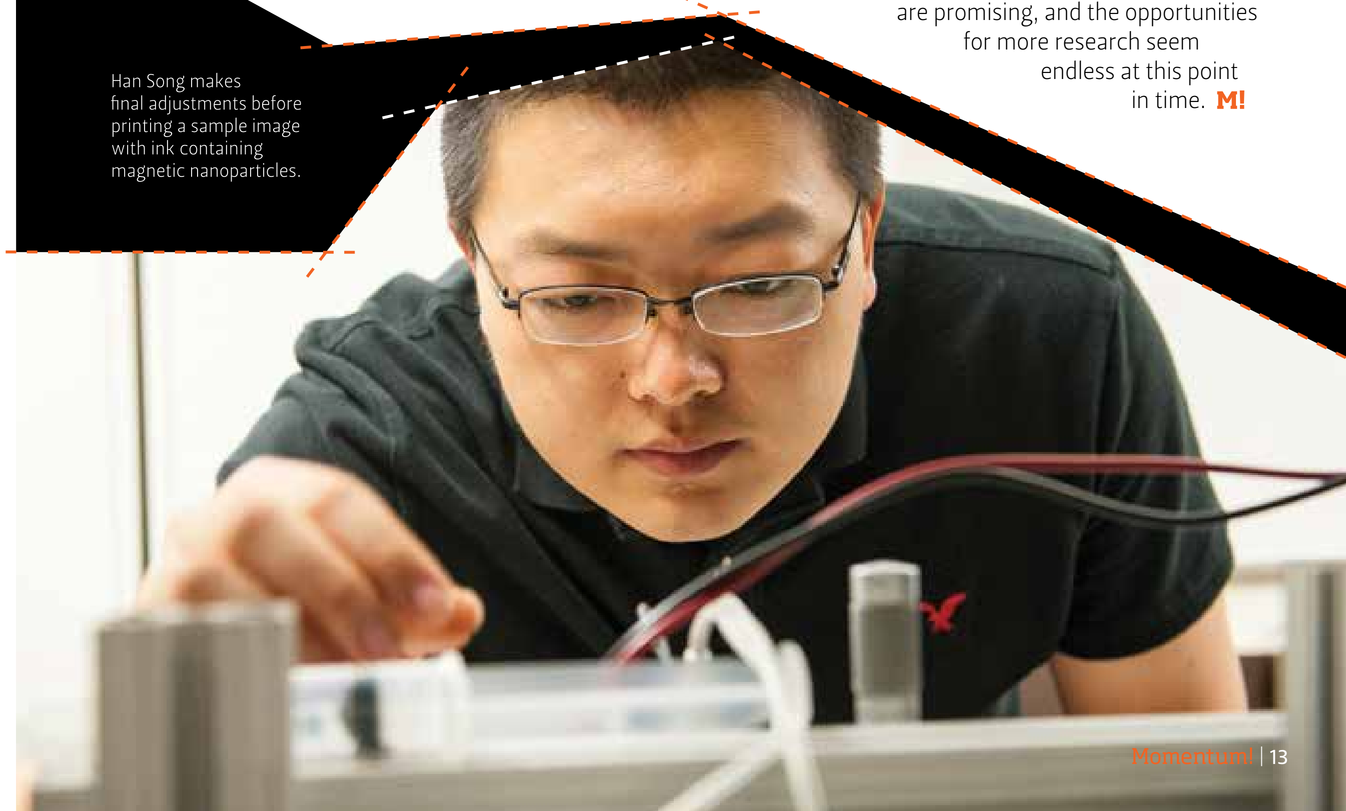
Dhagat envisions the day when three-dimensional devices will be built layer by layer using additive manufacturing. "You can have several jets: one for optical material, one for magnetic material, one to print the electronics, one to print something else," she said. "So the possibilities are limited only by one's imagination, if we can get the technology to be successful. We could print a robot that already has the electronics and the program to do what it's supposed to do. It walks off the platform and does its thing."

Applying technology to sustainability challenges

Haapala's goal as a researcher is to take a broad, system-level view of engineering problems by analyzing each particular challenge from an environmental, economic, and social sustainability perspective. Until recently, he was specifically focused on conventional manufacturing methods, but that is now changing.

"Over the past year, I've started to focus more on how the methods I'm exploring for conventional manufacturing can be applied to better understand the sustainability performance of additively manufactured products," he said. "It's really become a hot topic over the last five to 10 years."

The research on additive manufacturing in the College of Engineering is aligned with Oregon State University's strategic goal of actively promoting and supporting researchers whose work advances the science of sustainable ecosystems, improves human health, and promotes economic growth and social progress. This innovative technological solution could provide vastly improved functionality while drastically reducing the use of natural resources and lowering manufacturing costs. Early results are promising, and the opportunities for more research seem endless at this point in time. **M!**



Han Song makes final adjustments before printing a sample image with ink containing magnetic nanoparticles.

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