VOLUME III, 2015

impact

THE NEXT 100

We celebrated our centenary in 2013. Here are some of our people, ideas and new innovations that will propel us into the future.

Materials Science & Engineering
UNIVERSITY OF TORONTO

PUBLISHER'S LETTER

PUBLISHER
Jun Nogami, EngSci 8T0
Professor & Chair

ASSOCIATE PUBLISHER
Benjamin D. Hatton, MSE PhD 0T5
Assistant Professor

EDITOR-IN-CHIEF
Luke Y. H. Ng, ChemE 0T7
External Relations & Student Life Officer

ASSOCIATE EDITOR
RJ Taylor
Communications & Media Relations Strategist (APSC)

DESIGN
Mark Neil Balson

PHOTOGRAPHY
Roberta Baker
Jason H. T. Tam

WITH THANKS TO
Salvatore A. Boccia
Peter M. Brodersen
Matthew Daly
Han Gao
Laura Hoch
Geoffrey Ozin
Janet Rowe
Fanny Strumas-Manousos

Canada's Wonderland
St. Michael's Hospital

PRINTING
Somerset Graphics

CONTACT THE EDITOR-IN-CHIEF
+1 416.946.3211
mse.impact@utoronto.ca

GENERAL INQUIRIES
+1 416.978.3012
materials.engineering@utoronto.ca

ISSN 2368-8661

I recently broke my collarbone in an accident—I slipped on black ice while riding my bicycle. An x-ray on my shoulder revealed a fracture that necessitated a titanium plate to be surgically inserted on my right-side clavicle to hold it in place while it heals.

This incident reminded me of past and present biomaterials research in our department: the past being the development of improved titanium hip implants by Professor Emeritus Robert Pilliar, the ongoing work of Associate Professor Eli Sone on bio-adhesion and Assistant Professor Benjamin Hatton's exploration of anti-microbial and non-wetting surfaces to improve surgery and hospital care. These are just some examples of how far materials development has progressed, and its impact on almost every facet of human advancement. Faster healing, smarter computing and safer cars are just some of the achievements we are making because of smaller, stronger, lighter and generally more capable materials.

And so, in this issue, I am privileged to share with you our next leap forward in materials innovation.

Last summer, after ten years in the making, Professor Doug Perovic and his collaborators unveiled the **Ontario Centre for the Characterization of Advanced Materials (OCCAM)** at the University of Toronto. Supported primarily by the Canada Foundation for Innovation (CFI), the Ontario Ministry of Research & Innovation and in partnership with Hitachi High-Technologies Canada, our part of the OCCAM facility houses some of the most powerful electron microscopes in the country. These specialized tools will allow us to better understand and manipulate matter at the atomic scale. But more importantly, our advanced research capabilities will open the door for multidisciplinary collaborations from both academia and industry, paving the way for new opportunities that will benefit our students for years to come.

Jun Nogami, PhD, FAAAS, PEng
Professor & Chair

A One-Hundredth Birthday

Photos by Jason H.T. Tam

October 23 & 24, 2013—
A 100th birthday is quite the milestone. Established in 1913 as Department Eight: Metallurgical Engineering, we've made great leaps forward to become one of the top-ranked materials science and engineering departments in North America.

Materials selection pioneer and Cambridge University professor Michael Ashby gave two talks on sustainable technology and industrial design as part of the 3rd annual Winegard Visiting Lectureship in New Materials Engineering, while two alumni panels provided guests with leadership-level and recent perspectives on how we are making an impact today.

The two-day event topped off with a snazzy gala at Hart House, where 300 alumni, students, industry partners, faculty and staff filled the Great Hall.

100
Years of Materials Innovation
1913–2013

Thank you to our event supporters: Bereskin & Parr LLP / Celestica Inc / CIM MetSoc / Electrovaya Inc / Hatch Ltd / Hitachi High-Technologies Canada Inc / Integran Technologies Inc / Process Research Ortech Inc


01


02


03


04


05


06


07


08


09


10


11


12


13


14

01. The Honourable Dr. William C. Winegard

02. Graduates of the Last Decade (GOLD) Panel

03. Centennial steering committee alumni co-chairs Mary Ruggiero and Betty Lin

04. PhD candidate Abdolkarim Danaei demonstrating the x-ray diffractometer in the Walter Curlook Materials Characterization Laboratory to Professor Emeritus Bangalore Ramaswami

05. Student Siyao Jasmine Wu seeks insight from the GOLD panel

06. Alumnus Dr. Walter Curlook

07. L to R: Professor Emeritus Alexander McLean, ASM International president Professor C. Ravi Ravindran, Cambridge University Professor Michael Ashby, Professor Doug Perovic, and Professor Jun Nogami, Chair

08. Alumna Betty Lin (centre) with colleagues from Hatch

09. Alumnus David Neudorf and Professor Emeritus Alexander McLean

10. Two generations of U of T MMS alumni: Jamie and Frederick (Ted) Gerson

11. Faculty and students with industry partners from Process Research Ortech

12. Alumnus and Canadian Solar Inc CEO Dr. Shawn Xiaohua Qu and Celestica Inc chief metallurgist Dr. Polina Snugovsky

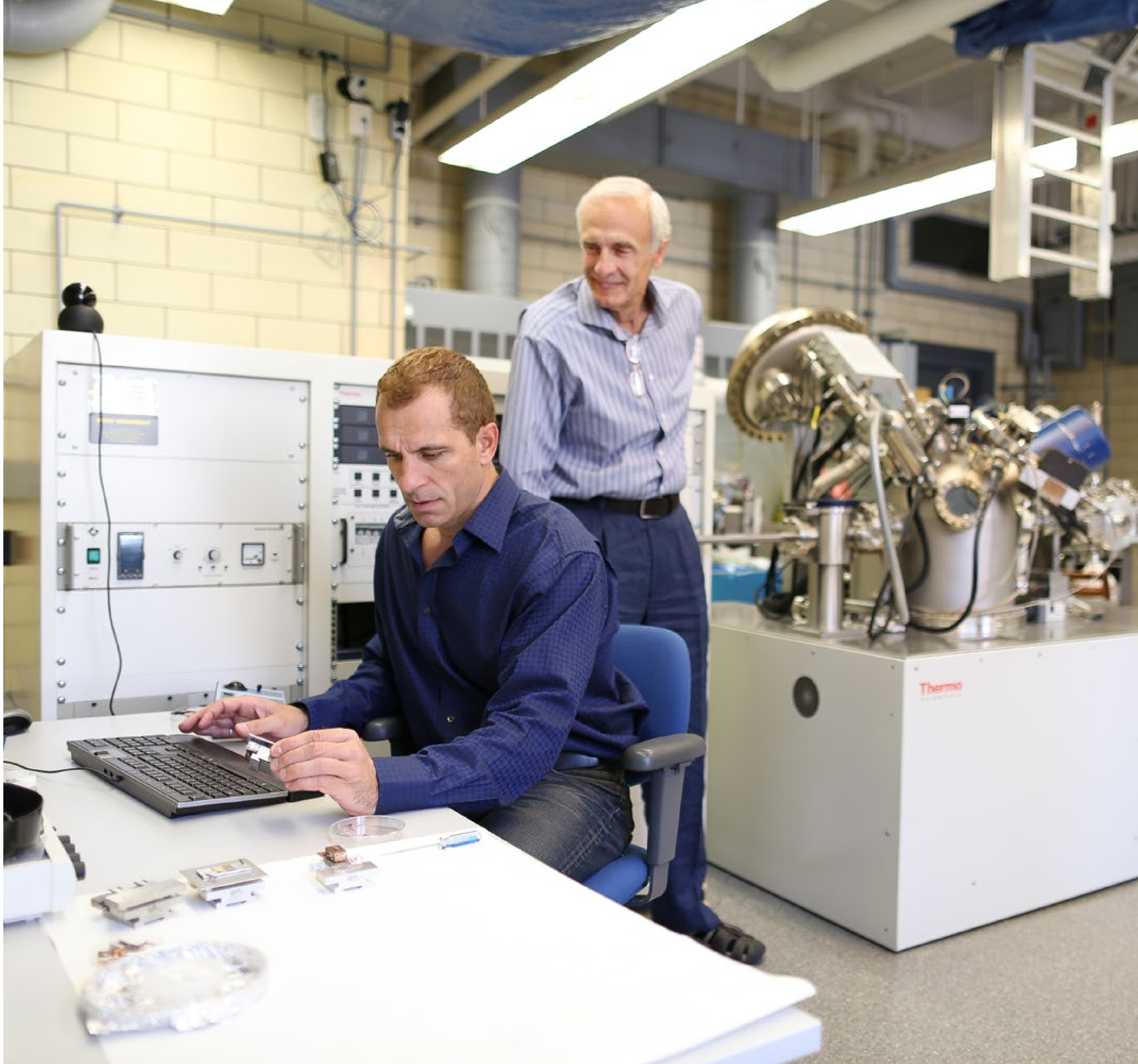
13. Alumni academia heavyweights: McMaster University provost David Wilkinson and MIT professor Donald Sadoway

14. U of T MSE community abound at the centennial celebrations

NAVIGATING ATOMS TO DRIVE INNOVATION

New materials characterization facility enables over 350 multidisciplinary projects

By Sydney Goodfellow, Benjamin Hatton, Naomi Matsuura & RJ Taylor
Photos by Roberta Baker



“THESE NOVEL CAPABILITIES WILL ALLOW US TO CHART NEW PATHS IN ENGINEERING DESIGN.”

A light-weight, aerodynamic car speeds around the corner of a country road. The car’s metallic paint is composed of super strong nano-metals that—combined with high-impact, standard safety equipment—keep the passengers inside perfectly safe. That same paint is bonded with microscopic particles that use photosynthesis to manufacture fuel from sunlight—similar to plants—to keep the tanks full, all while cleaning harmful carbon dioxide from the air.

It sounds too good to be true, but innovative materials like these ones are currently in development at U of T’s new advanced materials lab, the **Ontario Centre for the Characterization of Advanced Materials** (OCCAM).

Unveiled on July 17, 2014, the facility features state-of-the-art electron microscopes that allow researchers in energy, transportation, health care and more to develop safer, cleaner and more sustainable materials for a brighter future.

Supported by the Canada Foundation for Innovation (CFI) and the Ontario Ministry of Research & Innovation (MRI) in partnership with Hitachi High-Technologies Canada (HHTC), OCCAM offers highly specialized tools to understand and manipulate matter at the atomic scale. The centre also emphasizes collaborative and multidisciplinary projects, anticipating over 350 different research programs annually involving engineers and scientists from academia and the private sector. The Faculty-wide facility is a joint initiative between the Department of Materials Science & Engineering (MSE) and the Department of Chemical Engineering & Applied Chemistry (ChemE).

“These novel capabilities will allow us to peer deeper into the inner space of materials and chart new paths for engineering design,” says Professor **Doug Perovic** (MMS 8T6, MASc 8T8, PhD 9T0), co-principal investigator for OCCAM alongside Professor **Charles Mims** (ChemE).

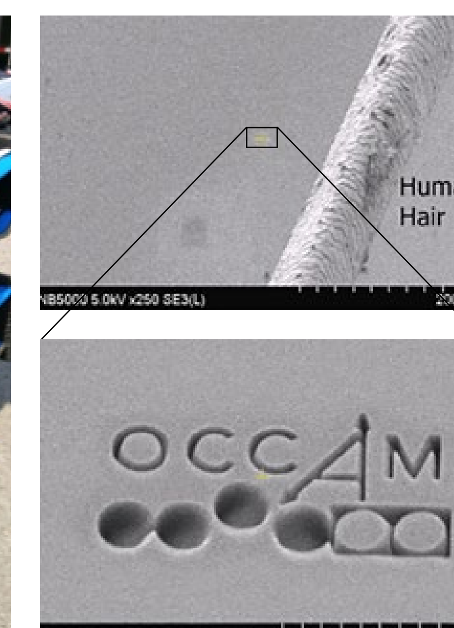
“OCCAM is a shining example of how U of T Engineering, in partnership with industry and government, is pursuing innovative solutions to some of world’s greatest challenges in health, city life and energy,” says Dean **Cristina Amon**. “We are profoundly grateful to CFI, MRI and Hitachi for their contribution to the creation of this unique world-class facility.”

Opening Spread
OCCAM co-principal investigators Professor Doug Perovic (MSE) and Professor Charles Mims (ChemE)

Right
Indy 500 champ Hélio Castroneves and Professor Doug Perovic use one of the electron microscopes to carve the OCCAM wordmark on a nano-scale ribbon at the July 17 unveiling event

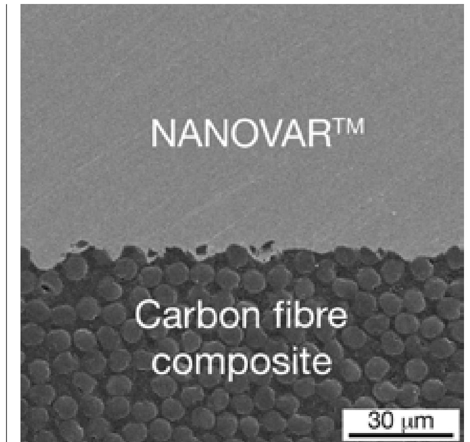
Below Left
U of T Materials Science & Engineering logo printed on Hélio Castroneves’ Hitachi-sponsored Penske Team race car for the 2014 Toronto Honda Indy, celebrating the partnership between U of T MSE and HHTC that led to the establishment of OCCAM (Photo by Khuong Doan)

Below Right
OCCAM wordmark carved into a nano-scale ribbon 1,000 times smaller than a human hair

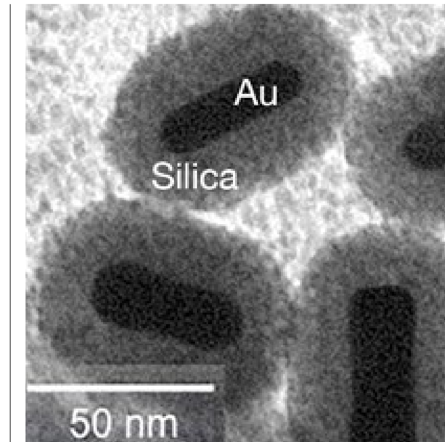


THREE BIG & SMALL IDEAS ENABLED BY OCCAM

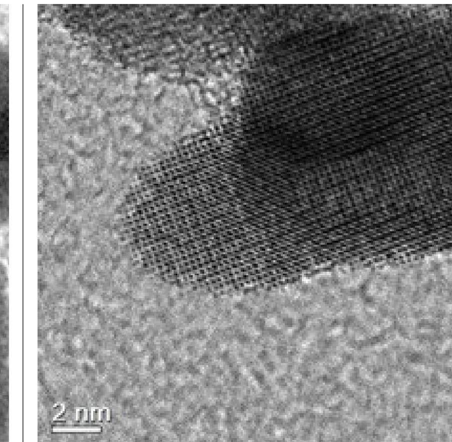
> "OCCAM's microscopes will help us design better technologies for tumour imaging and hopefully—treatment."



Integran's nanometal coating technology
(Photo: Integran Technologies Inc)



Gold rod core nanoparticles with nanoporous silica glass shells for anti-cancer drug delivery
(Photo: Naomi Matsuura)



Indium Oxide (In_2O_3) nanoparticle—a new generation of photocatalysts for solar fuels
(Photo: Laura Hoch, Geoffrey Ozin)

Car accidents that no longer kill people

"We have the technology today to make vehicles so safe that car accidents no longer kill people," shares Professor Perovic. But if we have the means, why aren't we using them? According to Perovic, the answer is cost—cost of materials and cost of manufacturing. That's why, through OCCAM, he has partnered with Toronto-based Integran Technologies to develop newer, inexpensive methods of boosting vehicle safety and efficiency.

Integran is the only company in the world that can coat plastic and carbon fibre with nano-metals, allowing them to make virtually any material significantly stronger with one coating. While they are continuing to find ways of reducing cost, Integran's technology has the potential for impact beyond the auto industry, from better spacecraft to lighter and more durable bicycles.

"The availability of OCCAM's resources will significantly enhance our product development capabilities," says Integran's president and CEO, Dr. **Gino Palumbo** (MMS 8T3, MASc 8T5, PhD 8T9). "The added merit is that it's located at U of T, an institution we've been in partnership with for many years and one of the main pipelines for our people talent."

Nano-devices for imaging & treating cancer

Cancer is a fickle beast. Recent results show that patients with the same cancer type and tumour size can have highly variable patient-specific responses to cancer drugs, and that personalized therapy may lead to better outcomes and increased patient survival. However, despite decades of intense research and billions of dollars of investment in new, targeted therapies to help cure cancer, patient survival rates have not substantially improved.

Assistant Professor **Naomi Matsuura** (MSE PhD 0T3) is leading a group at U of T's Department of Medical Imaging to develop new injectable, nanoscale agents that will increase the effectiveness of existing personalized cancer drugs. As part of this initiative, her team synthesizes 'model' nanoparticles to help guide the design of new generation nanoscale agents for cancer imaging and therapy. These nanoparticles have a gold rod core and a nanoporous silica glass shell to contain anti-cancer drugs. When the gold is heated with imaging radiation, the drug can be released locally to target cancer cells.

"OCCAM's high-resolution microscopes will allow us to see structures at the nanoscale and help us design better technologies for tumour imaging and hopefully—treatment," says Matsuura.

Solar fuels—if trees can do it, we can do it

A group of multidisciplinary researchers led by University Professor **Geoffrey Ozin** (Chemistry) is using OCCAM's advanced equipment to design nanomaterials that mimic the photosynthetic processes of plants. While plant photosynthesis uses the sun's rays to produce sugars and carbohydrates, the researchers are hoping to make materials that produce natural fuels such as methane and other gases.

This technology could be used to power vehicles, houses and more—and to store energy we aren't using for later consumption. In doing so, they could reduce, and even reverse, the detrimental impacts of fossil fuels. "We're still in early development stages," explains Assistant Professor **Benjamin Hatton** (MSE PhD 0T5), one of several faculty members working with Professor Ozin on this project. "But we're excited by the advances and resources that OCCAM will provide, and we look forward to making our technology better and more efficient."

"If trees can do it," he says, "we can do it."

OCCAM
FACTS & FIGURES

TOTAL PROJECT COST

Principle supporters:
Canadian Foundation for Innovation (CFI)
and Ontario Research Fund (ORF)

$16 Million

FIRST OF ITS KIND

First environmental transmission electron microscope (E-TEM) at a Canadian university

1st

MULTIDISCIPLINARY PROJECTS FROM ACADEMIA & INDUSTRY

350+

FACILITY SIZE ACROSS TWO LABS

450m^2

MAXIMUM MAGNIFICATION

1.0 x 10^{-10}m or approximately the size of a single carbon-hydrogen bond—size resolution of the new Hitachi environmental transmission electron microscope (E-TEM)

1 Angstrom

BLOCKING OUT THE NOISE

Cost of field cancellation system to shield magnetic interference on electron microscopes from an average of 172 streetcars passing the Wallberg Building on College Street in a workday

$250,000

INDUSTRY SUPPORTERS

20

MAJOR INSTRUMENTS

4 electron microscopes
6 surface characterization tools
1 advanced sample preparation system

11

By Mark Witten
Photos by Jason H.T. Tam

FOR YOUR SAFETY

THEIR CAREERS ARE ABOUT YOU

MEET THE ENGINEERS WHOSE JOBS ARE TO MITIGATE RISKS AND HELP KEEP US SAFE

Katherine Allan (MSE 0T2, MASc 0T5) helps save lives. According to the *Canadian Journal of Cardiology*, more than 90% of Canadians who suffer a sudden cardiac arrest outside of a hospital do not survive.

As a clinical research coordinator at St. Michael's Hospital, Allan is contributing to a national registry study, called CASPER (cardiac arrest survivors with preserved ejection fraction registry), aimed at preventing these tragic and often unexplained deaths from happening. "We want to prevent some of these cardiac arrests by identifying and treating individuals and family members with undetected genetic heart conditions before the event occurs," says Allan, who manages research studies for the hospital's Cardiac Arrhythmia Service unit.

She vividly recalls one of the first heart patients she encountered in the study, who was lucky to survive. "He was a young father who had a cardiac arrest while gardening. A bystander performed CPR, shock was delivered by emergency medical services (EMS) personnel, and therapeutic hypothermia was used in hospital to cool and protect his brain," she says.

The young dad and his family were understandably alarmed about his and their future health. "His daughter was very anxious about her own heart and his heart," says Allan, explaining that the girl's father was diagnosed with long QT syndrome, a serious heart rhythm condition. An implantable cardioverter defibrillator (ICD) was placed in his chest to treat irregular heartbeats and prevent sudden cardiac arrest (a condition in which the heart suddenly stops beating due to a problem with its electrical system). His children were also referred to a pediatric cardiologist for testing to detect or rule out inherited heart conditions. She saw the patient a few months later and he expressed his gratitude for the guidance, treatment and support that he and his family had received. "You want to help people and it's really nice to hear that you made a big difference," says Allan, who is also doing research on sudden cardiac arrest in young adults and their families as a PhD candidate in the Institute of Medical Sciences at U of T and the Department of Electrophysiology Research at St. Michael's Hospital.

Allan chose to pursue a career in medical research after she completed a Master of Applied Science (MASc) in Materials Science & Engineering at U of T under the co-supervision of Professor Emeritus **Robert Pilliar** and Professor **Rita Kandel** (Laboratory Medicine & Pathobiology), where her thesis involved tissue engineering bovine cartilage on synthetic bone material. Her interest in medical research dates back to high school when she volunteered in the pathology department at Sunnybrook. "Clinical research appeals to me because you're working with patients and seeing research having an impact in real-time rather than in the future. It's a big advantage having the engineering education. Research is about solving problems, whether medical or engineering. The engineering training gives you that mindset of knowing how to solve problems and do it efficiently," she says.

Allan also uses her technology skills to exploit the rich data capabilities of advanced medical devices, such as smart defibrillators, to improve outcomes for patients suffering cardiac arrest in hospital. "A large part of how we do what we do is through technology. It's very beneficial to have the technical knowledge and project management skills that I acquired in engineering at U of T," says Allan, who helped develop and test an innovative CPR training method for hospital staff.

Alumna Katherine Allan—clinical research coordinator at St. Michael's Hospital in a basic life support training classroom

In Allan's study at St. Michael's Hospital, performed in collaboration with George Brown College, medical and nursing students were given training in basic life support (BLS) that incorporated real-time, audiovisual feedback from a defibrillator during a simulated cardiac arrest, with a post-scenario debriefing using quantitative data obtained from the defibrillator. The results showed that teams trained with this method performed deeper chest compressions and higher quality CPR, and retained the skills better than those who received standard training. "It's vital that first responders know what to do when a patient arrests. We've rolled out this training to all our allied health staff, which has led to improvements in CPR quality and faster response times," says Allan.

> "Clinical research appeals to me because you're working with patients and seeing its impact in real-time."

Joelle Javier (MSE 1T0) wants you to experience the thrill of adventure without the danger. Her job is to help ensure that children and adults can ride monster roller coasters, shoot down water slides or fly on zip lines in Ontario safely. "I find it very satisfying to use my engineering knowledge and skills to prevent harmful incidents from happening," says Javier, a device review associate with the Technical Standards and Safety Authority (TSSA), a not-for-profit organization that enforces safety regulations and delivers public safety services on behalf of the Ontario government.

Protecting the public and preventing serious injuries or fatalities from occurring on amusement rides is an important responsibility. That is becoming more challenging for regulators as new amusement devices and activities—such as zip lining over lakes and zorbing (rolling down a slope inside a large hollow ball)—rapidly evolve to ramp up the thrill factor in North America and globally. But it's a role for which Javier is perfectly suited professionally, as a materials engineer, and personally, as an avid consumer. "I've always loved amusement rides and adrenalin-filled adventures. I get to think as a crazy, adventure and thrill-seeking person and imagine the worst thing a person could do to make the experience more fun. I try to push the boundaries of the design by seeing myself as the user and then testing the design for safety," she says.

Javier reviews design submissions for new installations and alterations of amusement devices and elevators, for the safety of the general public and compliance with Ontario codes and regulations. She also inspects existing rides at places like the Canadian National Exhibition (CNE) and Canada's Wonderland throughout the province. "I use my knowledge in materials science and engineering to review non-destructive testing of devices. You don't have to break a material to understand its properties or its strength. With roller coasters, for example, you look for cracks and corrosion," says Javier, noting that for aging rides the problems often result from the wear and tear of travelling from one exhibition to another.

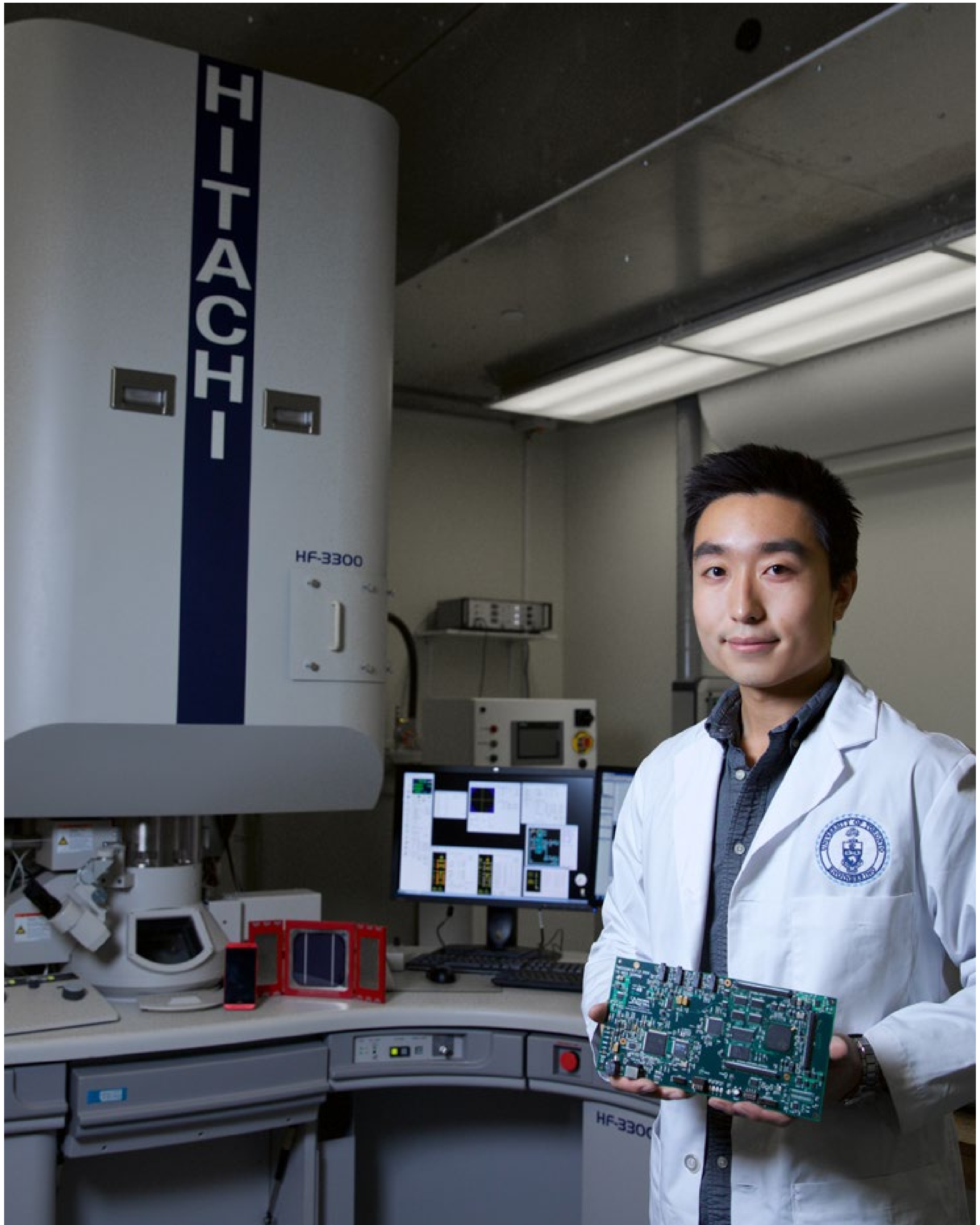
Her training in failure analysis at U of T has been particularly helpful in evaluating design submissions for potential safety problems and pinpointing the causes of equipment malfunctions that may result in near-misses or injuries to consumers. "The course I took in failure analysis has helped me to problem-solve and figure out why an incident happened by looking for possible flaws in the design of the equipment," says Javier, who grew up in the Philippines and whose father is also an engineer. With water slides, for example, certain safety modifications may be recommended to protect users. "There are cases where people come out too fast and hurt themselves, breaking bones. You can change the angle of the slide channel or increase the flow of water to slow down the ride and make it safer for consumers," says Javier, who also learned about using design to change patron behaviour working on retrofits for amusement rides while doing her master's in mechanical engineering at Ryerson University.

One of Javier's biggest and most interesting responsibilities is as a member of the American Society for Testing & Materials (ASTM) International F24 technical committee, which meets twice a year and brings experts from around the world together to develop codes and standards for these devices in North America and globally. "I learn about all the newest developments and trends in amusement devices and activities around the world. We're developing a standard for zorbing, for example, which can be very dangerous. There have been some serious accidents and deaths that occurred in Russia," she says.

Javier would eventually like to take the next leap forward in her career to creating new amusement rides that are thrilling and safe for consumers. "The amusement ride industry is

Alumna Joelle Javier—Technical Standards & Safety Authority (TSSA) device review associate in front of the Swing of the Century ride at Canada's Wonderland

> "The amusement ride industry is still growing and there are gaps in expertise. I see a lot of opportunities for my generation to apply what we know."



David Yang in the U of T Ontario Centre for the Characterization of Advanced Materials (OCCAM)—this new Hitachi environmental transmission electron microscope (E-TEM) is the first-of-its-kind at a Canadian university

> "The world is moving towards using more renewable energy sources and green technologies, and I would like to be part of that. That's how I can change the world in my own little way."

still growing and there are gaps in expertise. I see a lot of opportunities for the younger generation to apply what we know. In the future, I would like to combine my skills in safety regulation with my knowledge of materials science and human factors engineering to go into designing amusement rides," she says.

People who fly through the air on zip lines are looking for adventure, with a safety net. But in his Professional Experience Year (PEY) internship placement, **David Xuchao Yang** (MSE 1T4+PEY) helped people fly safely through the air at 39,000 feet on commercial aircraft, without the thrill factor.

"Everybody rides planes and there are so many lives at stake. The technology on airplanes is very complex and the risks are really high if the electronics systems fail. The aircraft is constantly vibrating, with massive acceleration on takeoff and turbulence during the flight. We would do vibration tests on electronic components used for commercial aviation to simulate those conditions and assess their reliability," explains Yang, a fourth year student who recently completed a 16-month stint as a materials analyst responsible for quality and reliability at Celestica Inc. in Toronto, a leading electronics manufacturer for the aerospace, computing and telecommunications industries.

Yang worked in the company's materials lab as part of a team testing the quality and reliability of customized printed circuit boards (PCBs) for products ranging from planes and smartphones to cloud computing servers and telecommunications switching gear. The types of testing vary depending on the application, but the PCBs in small, portable consumer products must be highly durable too. "A lot of companies are pushing fitness apps on smartphones. When you're jogging, the phone will be constantly vibrating and you don't want that to impact the reliability of the device," he says.

Yang chose the Celestica placement because he wanted hands-on lab experience in a real-world industry setting. He gained extensive experience and became very skilled at preparing samples of new products for field tests, analyzing solder joint quality for defects and doing failure analysis on electronic components to identify the causes and solutions to problems. He also became adept at using different types of testing equipment to meet the demands of manufacturing electronic components that continue to get smaller, thinner and lighter for applications like cloud computing. "I learned how to use an electron microscope to look at the grain structure of solder joints on PCBs to detect tiny cracks or any location where a crack could develop," says Yang, noting that the oral communication and report preparation skills he learned at U of T helped him to confidently and effectively present his field testing results to co-workers.

The strong theoretical grounding in materials science and engineering that he gained at school enabled Yang to understand and quickly learn how to apply these concepts to testing of newly developed commercial products in the lab. As he acquired these specialized skills with the help of his co-workers, Yang was able to work much more autonomously through the course of his placement. "I appreciate that my co-workers supported my learning in the early stages and then trusted me to perform the testing, prepare the samples and use the equipment with less supervision. I was working with some of the loveliest people—even now I still miss them," he says. "I think every engineering student should go through a PEY placement because it gives you a fantastic opportunity to be exposed to the field and it's different from what you learn at school."

Yang also had an opportunity to do testing on the quality and reliability of polymer materials used in solar panels, stoking his interest and opening up new avenues for pursuing a career in the renewable energy field. "My fourth year thesis project is related to the application of new and better anti-reflective coating materials in solar cells. Knowing what goes on in industry through my placement, I'm now interested in a career in manufacturing. If I can eventually take my idea from the lab into the market, I would want to work in a company that manufactures solar panels using anti-reflective coatings. The world is moving towards using more renewable energy sources and green technologies, and I would like to be part of that. That's how I can change the world in my own little way," he says.

THE GLOW OF

arket

T
G
O

By Robert Hercz, EngSci 7T9
Photos by Roberta Baker

MSE alumni make the leap from lab to market

CONFI-DENCE

> “LIGHTING IS STILL IN ITS DARK AGES. EVEN THE LATEST TECHNOLOGY —THE LED— COMES PACKAGED TO RESEMBLE EDISON’S 1880 BULB.”

Opening Spread
OTI Lumionics’ organic LED-powered aerelight

Google “OLED,” and you’ll find scores of articles confidently predicting that this is the year of the organic light-emitting diode. Some of those articles are ten years old. Still, there are reasons to believe the OLED age is finally dawning. In fact, Dr. **Michael Helander** (EngSci 0T7, MSE PhD 1T2) is betting on it. Three years ago, he was a PhD student with an important discovery just published in *Science*, a rising star who could have had his pick of academic postings. Instead, he gave up a life in research to start a technology company he named OTI Lumionics. The failure rate of technology startups, by some estimates, is 90 percent.

Who would trade the life they’d dreamed of for a chance to play Russian Roulette with five chambers loaded? Someone who’s counting on a lot more than just luck.

Why the fuss about OLEDs? And what on earth is an OLED? The best answer to both questions is OTI’s first and only consumer product, the aerelight. It’s an aluminum table lamp—sleek, angled, and a little retro (reminiscent of an older Canadian beauty, 1968’s Contempra phone). The light comes from a 10-cm square wafer no thicker than two sheets of paper—an OLED.

Not only is the lamp beautiful, so is its light. OLEDs are cool to the touch but warm to the eye, dimmable, flexible, and efficient. They don’t blaze from a single spot like an LED; they diffuse evenly from every point on their surfaces, which can be arbitrarily large. After seeing the aerelight, other light sources—whether incandescent, fluorescent, or LED—immediately seem huge, hot, and obsolete.

Like a conventional light-emitting diode, an organic LED produces light when a voltage is placed across it. The difference is the material between the electrodes. Instead of a crystalline semiconductor, OLEDs use organic compounds—plastics, in essence—similar to the pigments used in colour Xeroxes.

“LEDs are grown from perfect single crystals,” Helander says. “The probability of a defect increases exponentially with size, so it’s limited to a point source. Organic molecules don’t have any long-range order, so they don’t need a perfect single-crystal structure to work. That’s what allows you to distribute it across a large surface.”

Lighting isn’t the only place the OLED shines. It’s already made an appearance in smartphone displays and television screens, where its other advantages—richer colours, deeper blacks, and near-instantaneous response times—make it the heir apparent to the liquid crystal display. But OTI is staying away from displays. Multinationals like Samsung and LG have already spent billions to enter and fight over that market.

Lighting, on the other hand, is still in its dark ages. Even the latest technology, the LED, comes packaged to resemble Thomas Edison’s 1880 bulb. That paradigm is about to shift. Soon, a light won’t be a product, but a feature of a surface—any surface. Windows, walls and wallpaper, furniture, cars, and clothes: light will come from everywhere.

If OTI succeeds, Toronto-born Michael Helander will be the reason. He’s a force of nature, intense, ambitious, and at 29, astonishingly accomplished.

As a kid, he wanted to be a scientist. Then he enrolled in the U of T’s Engineering Science program (“because people said it was the hardest”) and realized he wanted to be an engineer. While working on his PhD with **Zheng-Hong Lu**, Professor and Canada Research Chair in Organic Optoelectronics in the Department of Materials Science & Engineering (“They had lots of shiny equipment, so that got me excited”), he realized he really wanted to be an entrepreneur.

He reached that decision after stumbling on a major discovery. Helander and OTI cofounder Dr. **Zhibin Wang** (MSE MASc 0T8, PhD 1T2) were working with indium tin oxide (ITO)—the industry-standard, transparent-yet-conductive coating used in every kind of flat-panel display—when they noticed something unexpected. Some of their samples were working far more efficiently—carrying much more current—than they should. They assumed their equipment was improperly calibrated, but soon ruled that out. The effect was real. Their ITO had been contaminated.

It took months to find the culprit: chlorine from open bottles of cleaning fluid. “Basically, breaking the safety rules,” Helander quips. “The next step: how do we make use of it?”

Helander, Wang and Professor Lu published their answer in *Science* in May of 2011: chlorinated ITO. A one-atom thick layer of chlorine dramatically increased the brightness of OLEDs while reducing their energy consumption by up to 50 percent. It also drastically lowered their cost by reducing the number of organic layers needed to make a diode from as many as eight to just two or three.

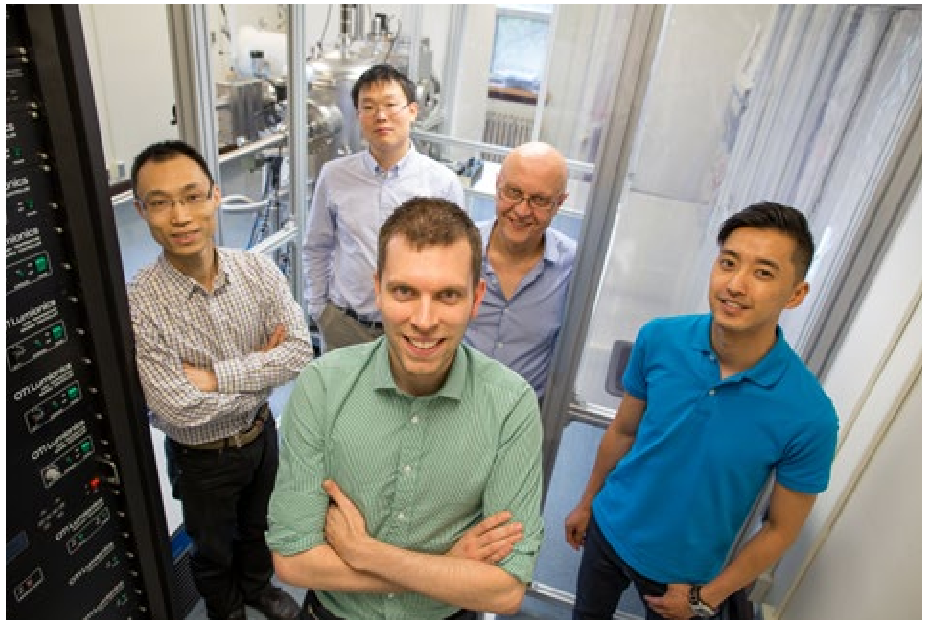
That news was greeted with considerable interest. “Big companies started approaching us,” says Helander. “They wanted to license or buy the technology. We thought, if they’re willing to pay this much now, there must be much more value than they’re letting on. Let’s try making a go of it ourselves.”

So they created OTI Lumionics. The initials don’t stand for anything. It’s just ITO backwards, a declaration that their approach

“

IF THEY’RE WILLING TO PAY THIS MUCH NOW, THERE MUST BE MUCH MORE VALUE THAN THEY’RE LETTING ON – LET’S TRY MAKING A GO OF IT OURSELVES.

”



OTI Lumionics co-founder Dr. Michael Helander (centre) with U of T Engineering alumni colleagues (L to R): Dr. Zhibin Wang, Jacky Qiu, Michael Augustinavicius and Ray Kwa

would be 180 degrees from usual. “Lumionics” is a fabricated word that sounds like light, a choice Helander somewhat regrets because nobody seems able to spell it.

At first, Helander thought OTI would be nothing more than a stepping-stone to an academic career. “When we started the company, we viewed it as another checkbox on the academic CV. Successfully commercialized tech: check.”

But as the months rolled by, a desire to finish what they’d started in the lab took root. Helander and Wang decided their future lay with OTI. Giving up academia for entrepreneurship wasn’t hard, Helander says. By the time he’d earned his PhD, his name was on over a hundred publications, more than most researchers produce in an entire career. “When you get up to that number of publications it’s almost like a paper mill; it’s just a formula you’re repeating,” he says. “It felt like we had learned the game and it wasn’t challenging anymore. We wanted new challenges.”

New challenges? Check.

Helander takes me into the back corner of OTI’s new offices in the University of Toronto’s venerable Banting Building on College St. The room is dominated by a seven-foot-tall vacuum-deposition chamber that looks like a giant robotic squid.

“This is our rapid prototyping module for organic LEDs,” he says. “It allows us to make large, flexible panels in about an hour.” He bends a six-inch square sheet of shiny blue-green plastic—a freshly-made OLED—into a half-cylinder. I want to ask for details, but Helander is already talking about his plans for the larger, still empty, room adjacent. “The pilot scale-up next door will be the same process, except it’ll be ten modules next to each other, so the production time goes down from an hour to minutes.”

Before I can quiz him on that, he’s shifted gears again. “The step after that, starting next year, is building a full production plant, hopefully somewhere in southern Ontario.” Helander speaks very fast, at the edge of comprehensibility, skipping syllables and sometimes entire words in a losing fight to keep up with his own thoughts. “We’ll be pulling together a whole syndicate of partners that are throwing in a whole bunch of support. We’re hoping to get money from the province as well and raise another round of financing. It’s a massive project.”

Sounds ambitious, I manage to interject. “Very ambitious,” he agrees. “People tell us we have lack of focus. But to understand our customers, we have to have our hands in everything. At the same time, we’re a small company. For what we’re doing we should have ten times the personnel and twenty times the capital. Trying to do the impossible—that’s how you succeed.”

It’s clear Helander’s ambition doesn’t stop at table lamps. In fact, it doesn’t even include table lamps—or didn’t, until he and OTI’s senior product designer, **Ray Kwa** (EngSci 0T0+PEY), built a few prototypes. Everyone who saw them had the same three questions: “When can I buy it? When can I buy it? When can I buy it?”

So OTI’s nine employees are making OLED panels and assembling lamps on College St. At the same time, multibillion-dollar giants like Philips, LG, and Konica Minolta are preparing to turn out OLED panels by the million. In a few months, OLED table lamps may be going for a fraction of the price—$239 (US)—of an aerelight.

Remarkably, Helander is unfazed by that prospect. “That would make us so happy,” he says. “It would prove that we’re on the right track and the market is there.”

Helander’s plan is not to sell lamps but to service niches—lots and lots of niches—that are too small for the giants. “There are a lot of partners we work with who only want 10, 50, 100, units. A massive production line can’t do that effectively. Our vision is to enable *hundreds* of companies, delivering on-demand whatever people need, for applications in lighting, furniture, automotive, wearables, whatever you want.”

Like any entrepreneur, Michael Helander sounds more confident than he has any right to be. For the foreseeable future, OTI will live amongst threats: an untested market, ever-mutating technology, giants ready to grind him to paste, uncertain financial backing. To defend himself, Helander has little more than a small pool of talents, patents, and ambitions.

Of course, in his case, that might just be enough.

MATERIAL INTEREST

Materials—they are the basis upon which all things are made and how they are made. New developments at every stage of their life cycle are the common thread to solving our energy, sustainability and environmental challenges.

Here are five of our newest professors who are pushing boundaries in materials innovation to address some of today's most pressing issues.

Purified solar-grade silicon

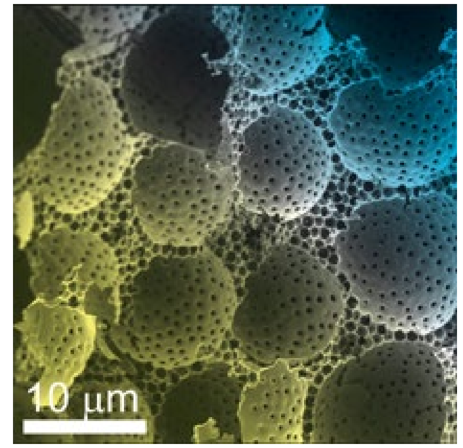
Enabling grid parity for solar-based electricity

Silicon—it's the second most abundant element in our Earth's crust. Many of our products today are fabricated from silicon-enabled materials, including high-strength alloys in our cars and airplanes to semiconductors that make up our electronics and solar panels.

One major roadblock in taking photovoltaic power mainstream is its materials production cost. Professor Barati and his group work on energy-efficient ways to make solar-grade silicon, lowering production costs to enable grid parity for electricity from our sun.

"There's no doubt that our energy mix is moving towards renewable sources, such as solar power. Silicon is the backbone for large-scale harvesting of the sun's energy; the ability to effectively produce this material will allow us to generate electricity for mainstream use with the lowest environmental impact possible."

Mansoor Barati
Associate Professor & Gerard R. Heffernan Chair in Materials Processing / *Sustainable Materials Processing Research Group*



SEM image of nanoporous silica (SiO_2) glass fabricated around a self-assembled polymer template

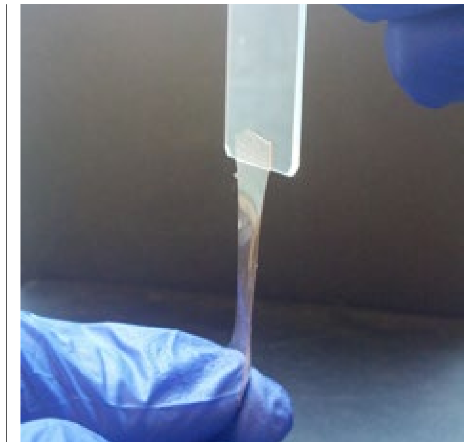
New materials with properties inspired by nature

Nature provides wonderful blueprints. Natural materials such as enamel, bone, mollusc shell, and plant leaves are examples of complex nano-composites that often have multiple structural and biochemical functions, and the ability to adapt to their environment.

Taking cues from these naturally-occurring materials and processes is what inspires Professor Hatton's research. He and his group investigate materials structures formed by self-assembly—a fabrication approach beyond the capability of conventional methods.

"I'm excited about the future of programmed self-assembly. The ability to control and organize complex 3D structures at the micro- and nano-scale can allow us to design materials with novel properties for applications such as switchable adhesion, triggered drug release, and self-cleaning anti-microbial surfaces."

Benjamin Hatton
Assistant Professor / *Microstructured Surfaces & Adaptive Materials Laboratory*



Lian's polymer electrolyte film

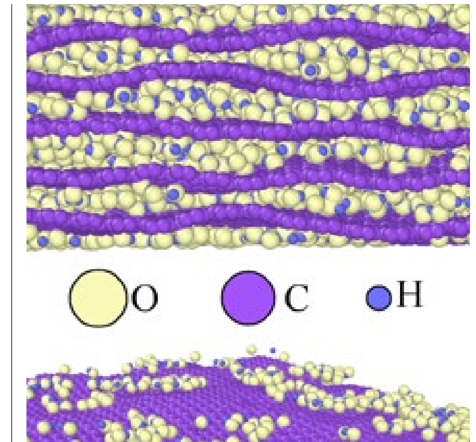
Powering the future with polymers

Conventional batteries and super-capacitors use liquid electrolytes to conduct current, which require bulky and rigid structures for containment, and pose both safety and environmental hazards if it leaks.

Professor Lian has an answer to this problem—don't use liquid. Instead, she and her group work on ionic conducting polymer membranes—an electrolyte film that conducts electricity in the solid-state, alleviating the need for containment structures and opening the door for a range of compact form factors.

"Polymer electrolyte films will allow us to develop technologies that are much safer and portable than ever before. Their lightweight and flexible attributes make them efficient in applications ranging from wearable electronics to automotive without adding extra volume from packaging."

Keryn Lian
Associate Professor / *Flexible Energy & Electronics Laboratory*



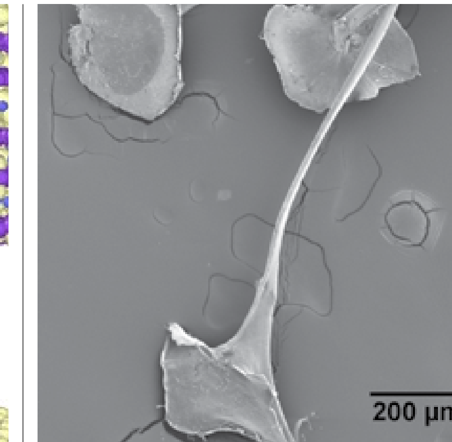
Graphene oxide model comprised of oxygen & hydrogen groups bonded between carbon sheets

Modelling 2D materials to chart new capabilities

Graphene—the world's strongest material is also one of the lightest. As a one-atom thick layer, it is 100 times stronger and three times lighter than steel and can conduct both heat and electricity better than copper. Since its first synthesis over a decade ago, graphene research has expanded dramatically to tap into this wonder material's potential.

Modelling graphene and other two-dimensional materials with a computational approach is the focus of Professor Singh and his group's efforts. "The availability of high-powered computing has allowed us to investigate novel 2D atomic structures like graphene through simulation. This data can then aid in more controlled experimental approaches, accelerating the lab to commercialization process. We're going to see new materials become available to us at a much faster pace."

Chandra Veer Singh
Assistant Professor / *Computational Materials Engineering Laboratory*

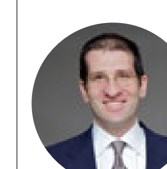


SEM image of the zebra mussel adhesive apparatus

Bio-inspired adhesives and coatings

Zebra mussels are an invasive species that cause major problems for Great Lakes industries. They secrete protein-based adhesive plaques and threads that allow them to anchor on a range of surfaces. The buildup of these mussels on water-intake pipes, for instance, creates significant bio-fouling complications for freshwater resources in the region.

Professor Sone's group, in collaboration with Professor Hatton's team, work to uncover the proteins used in this process in order to design anti-fouling coatings for adhesion prevention. They also investigate the mussels' gripping mechanism in order to enable the design of bio-inspired adhesives for medical and dental applications.



Eli Sone
Associate Professor (IBBME / MSE) / *Composite Biological Materials Laboratory*

NEW FACULTY

U of T MSE is home to Canada's top experts in materials science and engineering. Meet our two newest professors who will be making an impact in our global sustainability and energy efforts.

Gisele Azimi
ChemE PhD 1T0, PEng

Assistant Professor
Laboratory for Strategic Materials

Rare earth elements (REEs)—they're the stuff your smartphone is made of. These materials extracted from the ground and applied to many of our technologies today are what make speakers small enough to fit in your ears and displays able to light up in vibrant colours.

The efficient and sustainable extraction, processing, application and recycling of these strategic materials is the focus of Dr. Gisele Azimi's research. As an expert in hydrometallurgy, electrochemical processes and advanced materials, Professor Azimi will head the Laboratory for Strategic Materials where she will pursue multidisciplinary research to address energy and cost-related challenges surrounding the life-cycle of these rare earth elements.

Dr. Azimi obtained her undergraduate and master's degrees from Sharif University of Technology in Iran and her PhD in chemical engineering from the University of Toronto in 2010. She returned to U of T after completing two post-doctoral appointments at the Massachusetts Institute of Technology (MIT), one of which was with alumnus and sustainable energy icon, Professor Donald Sadoway (EngSci 7T2, MMS MASc 7T3, PhD 7T7).

Dr. Azimi is joint-appointed between the departments of Chemical Engineering & Applied Chemistry and Materials Science & Engineering.

Kinnor Chattopadhyay
PhD, PEng

Assistant Professor
Process Metallurgy & Modelling Group

Canada is one of the largest producers of metals in the world. It represents a multi-billion dollar economy for our nation. But as the demand for metals production increases to satisfy all types of manufacturing, the need to balance the environmental impacts of its extraction and production also needs to be addressed.

Dr. Kinnor Chattopadhyay is an expert in the physical and mathematical modelling of metallurgical processes. Recruited from Hatch, Professor Chattopadhyay brings years of expertise as a global lead in metallurgical process simulation to U of T where he will apply his industrial experience to address environmental impact during metals production along with quality enhancements in existing and new processes.

Professor Chattopadhyay received his undergraduate degree from Jadavapur University in India, and his master's and PhD in materials engineering from McGill University.

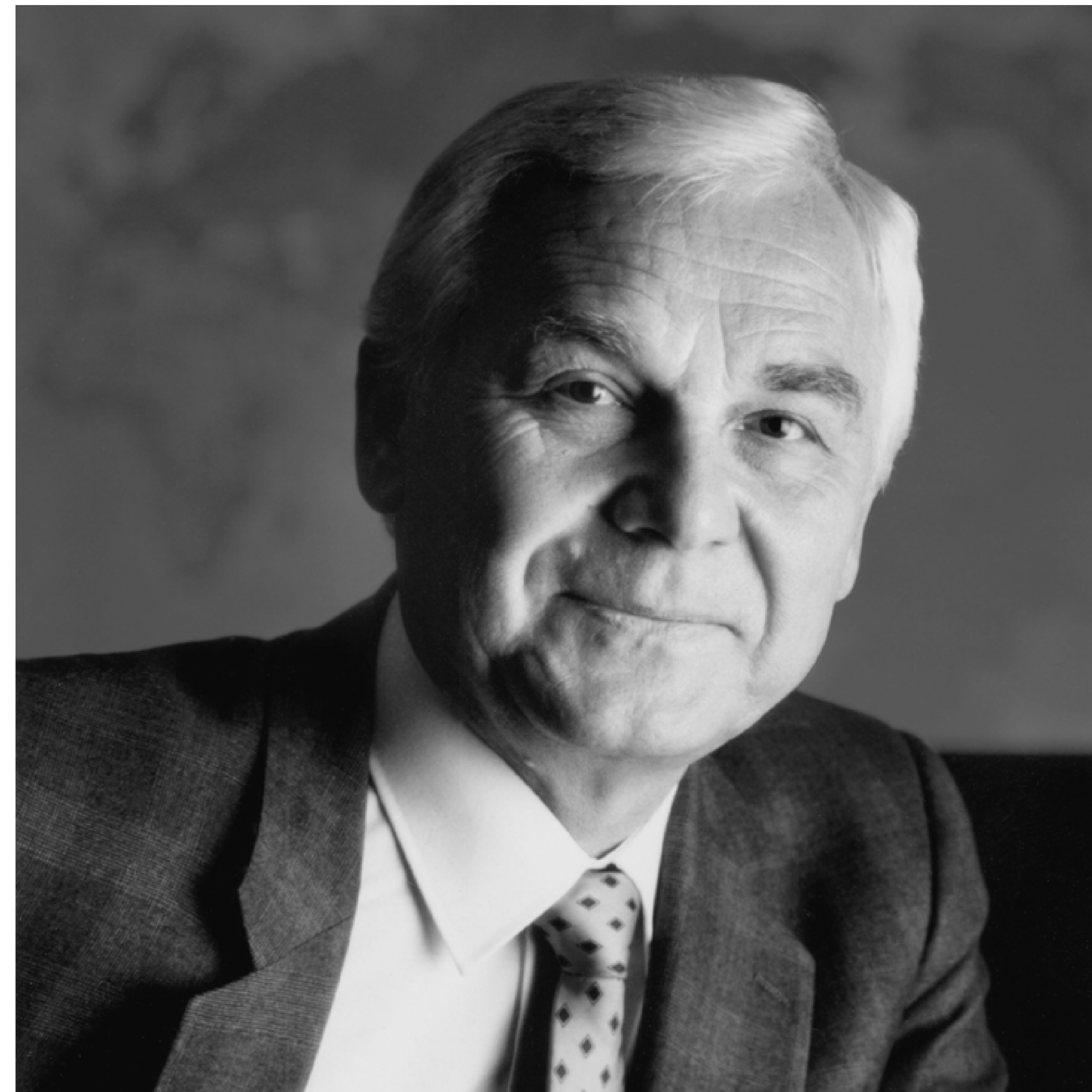
LASTING IMPACT
By Cynthia MacDonald

Below
Dr. Walter Curlook

Photos courtesy of the Curlook family

IN MEMORIAM: DR. WALTER CURLOOK (1929–2014)

CM, MMS 5T0, MASc 5T1, PhD 5T3, DEng, DSc, FCAE, PEng



A young Walter Curlook conducting research at U of T circa 1950s

Nickel is a metal that's both strong and remarkably versatile. These two qualities also describe Walter Curlook: an engineer, executive, community leader and teacher whose extraordinary career was forged in and around the nickel mines of his native Sudbury.

Curlook, who passed away last October 3 at the age of 85, first sought part-time work in his teens for the company that would eventually be known as INCO Ltd. After earning his PhD in metallurgical engineering at U of T, he returned to INCO and rose meteorically through its ranks: from research metallurgist to top executive, overseeing operations in Canada and abroad.

His forward-thinking advancements in productivity, processing and environmental safety vastly improved INCO's operations at a time when it stood atop the world in nickel production. Curlook himself invented more than a dozen process patents related to metals production: even at the highest administrative level, he remained an engineer at heart.

"He was an executive, but he also got right down in the labs and contributed directly to technical development," says Professor Doug Perovic. "He insisted on staying close and keeping his ear to the ground; he just worked so hard."

Late in the twentieth century, the environmental impact of mining assumed an importance it never had back in Curlook's youth, when sulphur gas from the mines used to burn flowers in his family's garden. "Under his leadership, INCO was always progressive in that area," says Associate Professor Mansoor Barati. "They were on the frontier in making changes that improved environmental conditions." The most significant of these was a $600 million sulphur dioxide abatement program, completed in 1993 and described as the largest environmental project ever completed by the industry.

Curlook's Ukrainian immigrant father—who worked in the mines himself—instilled a love of continuing education in his son. The vast array of initiatives Curlook supported is testament to this. Among many others, he was founding Chairman of Sudbury's Cambrian College Board of Governors, and was a driving force behind SNOLAB. This former mine site was converted into one of the world's best neutrino detectors in order to answer fundamental questions about the universe.

Above all, he never forgot the University of Toronto. "I connected initially with Walter in the 1990s, when our department was in a lot of trouble," says Perovic, who convened a board of supporters that not only saved the department, but helped strengthen and secure its status during his two terms as Chair. "Walter was in that group, and he was a leader among leaders."

After retiring from INCO in 1997, Curlook was appointed to the department as Distinguished Adjunct Professor. In this role, he brought invaluable real-world expertise to students. "He wanted them to be well-rounded," Perovic says. "Particularly in connecting metal refinement and production to the financial side of how companies operate." Curlook left a lasting legacy for the department in 2013—a gift that provided modern tools for researchers and students alike—through the Walter Curlook Materials Characterization & Processing Laboratories in the Wallberg Building.

Curlook was justifiably honoured with many awards. In addition to two honorary doctorates, he was named a Member of the Order of Canada in 1996, and inducted into the Canadian Mining Hall of Fame the following year.

"Pit bull" is the affectionate term that comes to Perovic's mind now, when he thinks of Curlook. "He was the most loving, big-hearted person you could meet," he says, "but his passion, spirit and energy were boundless, and that could be intimidating. He always wanted to do better—and he expected that of others as well."

Originally published in the Spring 2015 issue of U of T Magazine

#1

IN CANADA & TOP 20 IN NORTH AMERICA FOR MATERIALS SCIENCE

US News & World Report: Best Global Universities 2014

National Taiwan University (NTU) Performance Ranking of Scientific Papers for World Universities 2014

QS World University Rankings 2014

impact

Impact is the University of Toronto Department of Materials Science & Engineering's magazine. Named after a traditional materials testing technique, it also describes how members of our community make a difference through excellence and dedication.

Published annually, the magazine features the talent and commitment of our students, alumni, faculty and staff to engage our stakeholders and the engineering community at large.

Stay in touch.
Get engaged.
Make an Impact.

www.mse.utoronto.ca
@uoftmse

Department of Materials Science & Engineering
Faculty of Applied Science & Engineering
University of Toronto

Wallberg Building, 184 College Street, Suite 140
Toronto, Ontario M5S 3E4 Canada

Publication Mail Agreement #40062475

Materials Science & Engineering
UNIVERSITY OF TORONTO

BOUNDLESS