Waterloo's G2N Centre: Novel approaches to **nanoelectronics**

Professor William Wong, Director of the Giga-To-Nanoelectronics Centre (G2N), outlines new approaches to nanoelectronics and diverse student interests at the innovative edge of applied science in large-area electronics

To begin, why was the Giga-To-Nanoelectronics Centre (G2N) established?

G2N was established to enable academic researchers and industrial partners to share a facility that enables fundamental studies in the processing of thin-film and nanoscale materials for large-area electronics. I am the Director of G2N; I provide guidance for the research in the lab and lead efforts to introduce new areas of research that will expand the capabilities of the lab and sustain its charter to facilitate groundbreaking research that has scientific and commercial impact.

Could you outline the field of nanoelectronics? How are developments opening new research avenues in this area?

Nanoelectronics are the next generation of devices and circuits that will enable new functionalities and performance driven by miniaturisation, easier and cheaper fabrication processes and new properties such as optical transparency or mechanical flexibility. As the size of devices scale down to smaller dimensions, the electronic properties of these materials may be altered. With this understanding, scientists, engineers and students can then begin to find new applications that can take advantage of the nanoscale properties of electronic materials and devices. These electronic materials, ranging from small molecules, quantum dots and nanocrystals, to nanowires, nanorods and macromolecules (ie. polymers) are being studied to exploit their advantages in a variety of applications.

What are the principal objectives of the Waterloo G2N? How is the G2N fostering expertise?

The objectives of G2N are to facilitate novel research that engages students to build and analyse innovative devices and structures that address opportunities for innovation in energy, ICT, consumer electronics, nanotechnology and digital imaging.

G2N is a hands-on facility where the students perform all of their experiments themselves. Senior students train new students on the operation of the lab equipment that provides a constant pool of experts in the lab. Once the students become trained users, they have the ability to test their imagination and innovation with state-of-the-art tools for experimental research.

The lab is also accessed by industries who take advantage of the equipment available to prototype new ideas using equipment that is similar to what is used in their own manufacturing facility. This access allows both the industrial partner and the students to interact in the same environment, stimulating new ideas and new innovation in G2N.

Are there any novel applications of nanoelectronic technology under development at the G2N?

G2N has several projects. One of the first materials studied in G2N was nanocrystalline silicon whose properties provide a high-performance alternative to amorphous silicon in flat-panel display and medical imager applications. This technology was investigated for use in OLED displays and medical X-ray imagers. Another area is research in organic electronic materials and devices for low cost solar cells and next generation solid-state lighting and flat panel displays (flat screens). More recently, my group has been investigating the use of hybrid ZnO nanowires coated with amorphous silicon to create novel solar cell structures for high-efficiency photovoltaics.

Is there any part of the Centre that you are particularly proud about? Why is this aspect of the G2N important?

The most exciting part of G2N is the variety of research that is performed and the diverse interests of all the students and researchers who use the lab. The students are the lab's most important resource. They provide the ideas and the energy to create new innovations for flexible electronics, medical imaging, flat-panel displays, solar cells and nanoelectronic devices. The lab is a central location where all these ideas come together and with industrial partners working in the lab, G2N serves as an important environment for incubating new ideas and new technology.

As G2N evolves, how do you expect it to meet the industry demands in the coming decades? What kind of trajectory do you expect?

G2N is constantly evolving and expanding. It has to in order to be a dynamic research centre in a top university in Canada. G2N has already led in creating new companies with spinoffs such as IGNIS Innovation. In this way we are meeting the demands of industry and also helping to form and guide new industry. Other companies have used G2N for their own research efforts and we continue to provide leading-edge facilities for both internal and external users.

The Giga-To-Nanoelectronics Centre

Established in 2005 at the University of Waterloo, the **Giga-To-Nanoelectronics Centre** is a CAD $17 million laboratory for scientists and engineers to experiment in nanoscale electronics technology

IN 2005, WITH a view to produce the next-generation of electronic technology through applied experimentation with amorphous silicon (a-Si:H) and its allotropes, the Giga-To-Nano group was born. The avant-garde scientists, from the University of Waterloo (uWaterloo), sought to find new processing methods for allotropic forms of silicon. Allotropic forms of a-Si:H offered a variety of applications; the new techniques would inspire unique capabilities for electronics. Using these novel perspectives on a-Si, the group sought to develop a complete package of large-area digital imaging that could compete with foreign markets.

This vast digital imaging project required design of cutting-edge sensors, circuitry and systems architecture, as well as new transient models that could integrate high performance optical and X-ray imaging. Working at the nano level of electrical component development, the team expanded to include talent from a diverse sector of specialities with a collaborative mindset. In 2000, Professors Siva Sivoththman and Andrei Sazonov joined the group, and in subsequent years, research activities broadened to include flexible electronics, organic electronics, nanowire electronics and printed electronics for various applications including imaging, displays, solid state lighting and photovoltaics.

BUILDING PROGRESS

A tremendous breakthrough arrived for Giga-To-Nano in the form of a $9.5 million grant in the late 1990s. Originating from government and provincial sources, the grant was matched by contributions from uWaterloo and industry members. It financed construction of the Giga-To-Nanoelectronics Centre (G2N); 17,000 ft^2 of room space and abundant laboratory facilitates spread across three buildings. G2N, part of a large expansion at uWaterloo, now boasts cutting-edge processing plants for glass and plastic electronics. Expert in electronics, Professor William S Wong is Director of the facility overseeing the running of the vast unit, as well conducting his own research in tandem.

G2N was completed in 2005 realising the Giga-To-Nano group's eight-year dream. G2N has opened entirely new investigative avenues in materials integration, materials characterisation, process development, device testing, and circuit design and fabrication. R&D conducted within the Centre seeks to challenge barriers within large-area electronics and develop innovative new technology meeting 21st Century needs. Specialty areas of G2N examine semiconductor nanostructures, printed electronics and organic electronics using a diverse range of materials and processes G2N now facilitates research for groups in the Faculty of Engineering and the Waterloo Institute for Nanotechnology.

FUNDING FACILITIES

State-of-the-art equipment available in the facility tests and produces electronic devices and modules. A range of characterisation probes, microscopes, spectrometers and semiconductors are used in the lab to take electromechanical measurements capable of detecting profiles up to around six micro-metres. Deposition equipment can be used to produce high-purity, high-performance solid materials in amorphous, nano-crystalline, and nanostructured thin films. The deposited materials can then be used as semi-conductor, dielectric and conductive thin films for electronic devices.

The lab's vacuum deposition systems, plasma enhanced deposition tools, sputtering tools and thermal evaporator tools, are all used by the researchers in the R&D lab. All the equipment can be booked by Committee Members (key researchers) and Main Members (subscribers to the facility); in that capacity the equipment has a certain degree of open accessibility and encourages new and established industry partners to participate in research at the Centre.

INDUSTRY PARTNERS

The design of the G2N laboratory has bridged the gap between researchers and industry partners. By providing a space where members can collaborate, industry ideas can be tested on a large scale without risk for the company. Feasibility testing in this capacity does not require resources from the manufacturers, allowing proof-of-concept testing up to full-scale pilots to take place. The model has worked well for companies such as IGNIS Innovation, which has grown to 40 employees, with aid from the resources on tap to test potential inventions in the G2N suite. Teledyne DALSA (Canada), Xerox (Canada), Rhodia-Solvay (France) and V-Technology (Japan) are some of the current industrial partners of the laboratory.

COLLABORATION

The research teams working within G2N are collaborative in nature; utilising skills across different disciplines, G2N brings multidisciplinary projects in electronic materials and devices to fruition. Intellectual property rights have already been achieved in the area of pixel circuits and architectures for flat-panel displays, a significant advancement that will foster future progress.

Professors Hany Aziz and Wong are working on a joint project developing a model for transparent and flexible screens. Wong's group is discovering novel methods for metal oxide films for thin-film transistors, whilst Aziz's research focuses primarily on the OLED components that will be necessary for the display media. Together the two units will assemble technology to produce a prototype transparent screen – the next big thing in media electronics.

G2N PROJECTS

Many projects underway at G2N will have further innovative and revolutionary consequences for electronic technology:

- Novel stamping techniques for patterning nanoscale elements (flat and curved surfaces), with an aim to develop next-generation low-cost and high-throughput manufacturing

- Investigations towards novel medical imagers based on thin-films; low cost technology for global healthcare purposes

- Development of new materials for organic light emitting devices (OLEDs), sensors and photovoltaics

- Flexible photovoltaic devices (energy reducing cells) for lightweight energy production; working towards an energy dependent future for homes and businesses

THE VALUE OF NANOSCALE

The main benefit of working at the nanoscale is that researchers can gain intricate and complex understanding of electrical components that lead to the synthesis of increasingly smaller devices. This type of technology is already powering the technology of today and will be the technology of the future. There used to be a joke in the 1960s about a computer that could fit inside a light bulb. It was a totally irrational belief at that time to think that computers, which were on the scale of houses, could ever fit inside a light bulb. Now of course, just a few decades later, this concept has become a reality.

EDUCATION AND TRAINING

Preparing students for careers in nanoelectronics is one of the principal objectives of the G2N's programme and facilities. Professors at the laboratory take pride in teaching courses at the undergraduate, Master's and PhD levels. These students are often hired within Canadian and international companies such as Teledyne DALSA, IGNIS Innovation and Apple, thereby sharing G2N knowledge and methodology on a global stage. With a secure grounding in pure and applied nano principles, graduates can expect to have high-flying careers in what is a growing and in demand field.

MEETING CANADIAN AND GLOBAL NEEDS

G2N has established relationships with several Canadian and international companies such as IGNIS Innovation, Teledyne-DALSA Corporation, Xerox, TeTechS Inc, Rhodia-Solvay and V-Technology. The collaborative research at G2N is enabling technological development to benefit both Canadian and global markets. As demand for smaller, more efficient electronic products becomes ever greater, G2N is remaining competitive in this sector at home and overseas.

With the wide range of laboratory equipment, state-of-the-art facilities and expert research knowledge in nanoelectronics that G2N has established in such a short time-frame, it is clear that G2N has secured its place as a world leader in electronic engineering. Having a critical mass of world-class researchers and students fully engaged with the G2N laboratory, it will be exciting to see what technological advances will emerge from this institute over the coming years.

FOCUS ON
PROFESSOR BO CUI

Professor Bo Cui is head of the Waterloo Nanofabrication Group and a leading expert directing research into nano and microstructure fabrication using nano-imprint lithography and electron beam lithography, thin-film disposition and wet or dry etching. The aims of his studies are to fabricate electrical elements at an increasingly small size with a fast production throughput.

The pure research focus of Cui's team has not been directed towards any technological application in particular, however, it has been working on nanostructures of bio-sensors, photo-detectors, tissue-engineering, surface plasmon resonance bio and chemical sensors. Cui also successfully achieved the invention of high aspect ratio tips for the Atomic Force Microscope which have enabled nano-imaging of none-flat surfaces.

FOCUS ON
PROFESSOR HANY AZIZ

Professor Hany Aziz holds the Natural Sciences and Engineering Research Council of Canada (NSERC) – DALSA Industrial Research Chair in Organic Light Emitting Devices for Flexible Displays, and works within G2N as a Professor. Aziz has been working predominantly with materials and devices for extra slim and flexible flat panel screens, solid state lighting and solar cell systems – all his research is conducted in the laboratories of G2N.

Through his study of the interplay between photons, electrons and excitons, he has developed new devices based on organic semiconductors. From these constituents, Aziz can make light emitting devices, solar cells, sensors and transistors; components that go into electronic devices and solar panels. Other exciting and innovative applications can be harnessed by taking advantage of the properties of these new materials; with a possibility to produce high-tech flexible, high definition screens for the electronics market.

FOCUS ON
PROFESSOR KARIM KARIM

Professor Karim Sallaudin Karim is a recipient of several prestigious awards such as the 2009 CIHR Science to Business Fellowship and the 2012 Grand Challenges Rising Stars in Global Health prize. His research interests lie in developing processes, devices and circuits for large area digital imaging electronics for biomedical applications.

Some of the technology Karim developed is currently being used by industry in electronic flat panel organic LED displays and port-of-entry biometric imagers for security purposes. In 2012, Karim put forward the concept of a disease specific digital X-ray imager to lower capital infrastructure costs and to enable the proliferation of screening clinics for tuberculosis, a WHO global health priority. The proposed modular nature of the screening clinics make them a low cost, scalable platform to deliver personalised healthcare in emerging economies for improved global health outcomes.

Karim is a Distinguished Lecturer for the Institute of Electrical and Electronics Engineers (IEEE) and consults regularly for high technology firms in the US and Canada. He currently serves as the Associate Director for the Centre for Bioengineering and Biotechnology at the University of Waterloo, a university-wide centre he helped found that bridges the gap between Science and Engineering interdisciplinary research. Karim is a registered Professional Engineer in Canada.

FOCUS ON
PROFESSOR WILLIAM WONG

Director of G2N, Professor William Wong, joined the facility in 2010 with over a decade's experience in electronics, and a special focus on large-area electronics: printed electronics, Hydrogenated Amphorous Silicon (a-Si:H) Thin Film Transistor (TFT) Fabrication, silicon nanowire synthesis and flexible electronics for image sensors and displays. He is a member of the Materials Research Society and en elected member of Electronic Materials Conference Committee (TMS/ECM).

Currently his research focuses on novel methods to integrate disparate materials – using processing technologies – with a view to create new functionally enhanced microsystems. His most successful project to date has been laser processing of state-of-the-art high-brightness blue light-emitting diodes; automobiles and houses now benefit from the low-energy-solid-state lighting that the diodes enable.

Wong has a passion for educating students and hopes through this process they will foster a deep seated interest in electronics similar to his own: "My aims and objectives are to instil in students the same curiosity I have for discovering how things work and how that knowledge can be used to create new technologies".

INTELLIGENCE

GIGA-TO-NANO (G2N)

OBJECTIVES

Established in 2005, the Centre is a hands-on facility providing users with training and access to run their own research. This facility consists of groups within the University of Waterloo and external partners that make up the interdisciplinary research that spans nano-materials to large-area electronics. In addition to facilitating academic research programmes, G2N also provides the capability to develop and prototype novel and emerging technologies for commercial applications.

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HANY AZIZ is a Full Professor in the Department of Electrical & Computer Engineering and is the Associate Director of the Giga-to-Nanoelectronics Centre at the University of Waterloo. Aziz received his PhD from McMaster University, Ontario in 1999. From 1999-2007, he was a Research Scientist at Xerox Research Centre of Canada.

BO CUI is an Assistant Professor in the Department of Electrical & Computer Engineering at the University of Waterloo and heads the Waterloo Nanfabrication Group. Cui received his PhD from Princeton University in 2003. From 2003-08, he was at the National Research Council of Canada.

KARIM KARIM is currently the Associate Director of the Centre for Bioengineering and Biotechnology and a Full Professor of Electrical and Computer Engineering at the University of Waterloo in Canada.