

# Frontiers in Nanoscience & Nanotechnology International Symposium

## Smart & Functional Materials

June 5 and 6, 2019  
Mike & Ophelia Lazardis  
Quantum-Nano Centre (QNC)  
University of Waterloo  
Ontario, Canada





# WIN's International Symposium on Frontiers in Nanoscience and Nanotechnology

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**Dr. Sushanta Mitra**

Executive Director

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Greetings, and welcome to the 2019 WIN International Symposium on Frontiers in Nanoscience & Nanotechnology. This is the second International Symposium held by WIN, with this year's focus on Smart & Functional Materials – a key theme area in nanotechnology.

We are very pleased to host four Distinguished Lectures during this symposium and four keynote speakers to be delivered by some of the world's leading researchers in the Asia, Europe, the United Kingdom, the United States, and from Canada.

Over the next two days, talks will cover topics starting from the fundamental understanding of materials at the nanoscale to a wide range of applications including medicine, energy, environment, and ICT - just to name a few.

We hope this symposium will spark new ways of thinking about global problems, which will continue cross-disciplinary collaboration to push the boundaries of scientific discovery.

It is an immense pleasure to host the 2019 WIN International Symposium on Frontiers in Nanoscience & Nanotechnology, and we welcome everyone to the Mike & Ophelia Lazaridis Quantum Nano Centre!

Sincerely,

Dr. Sushanta Mitra, P.Eng.,  
FASME, FCSME, FEIC, FRSC, FINAE, FCAE, FAPS, FAAS  
Executive Director, Waterloo Institute for Nanotechnology  
Professor, Mechanical & Mechatronics Engineering  
Professor, Physics & Astronomy (Cross-Appointed)  
Professor, Chemical Engineering (Cross-Appointed)

# Wednesday, June 5, 2019 – QNC 0101

| TIME                 | SCHEDULE  |
|----------------------|---|
| <b>8h30 – 8h50</b>   | <b>Welcome</b>  |
| 8h50 – 8h55          | Opening of Symposium and Welcoming Remarks: Associate Vice President University Research, John Thompson   |
| 8h55 – 9h00          | Welcome from the Executive Director of WIN – Sushanta Mitra   |
|                      | <b>Open Distinguished Lecture Seminar 1: Chair - Sushanta Mitra</b>   |
| 9h00 – 10h00         | Hans-Jürgen Butt, Max Planck Institute, Germany – Nanostructuring surfaces to control wetting   |
|                      | <b>Open Technical Session 1: Chair- Lisa Pokrajac</b>   |
| 10h00 – 10h20        | Xiaosong Wang (WIN/Chem): Effect of Ionic End Group on Hydrophobic Hydration (HH) and Hydrophobic Effect-Driven Self-Assembly (HEDSA) of Metal Carbonyl Macromolecules                |
| 10h20 – 10h40        | James Forrest (WIN/Phys): Polymer stable glass  |
| <b>10h40 – 10h55</b> | <b>Coffee/Tea Break</b>   |
|                      | <b>Technical Session 2: Chair – Oleg Stukalov</b>   |
| 10h55 – 11h40        | Keynote Speaker 1: Scott Retterer, Oakridge National Laboratory, USA - Hierarchical Assembly – Understanding Formation, Response, and Evolution in multiscale heterogeneous materials |
| 11h40 – 12h00        | Yuning Li (WIN/ChE): Development of polymer semiconductors for printed electronics  |
| <b>12h20 – 13h30</b> | <b>Lunch on your own</b>  |
|                      | <b>Distinguished Lecture Seminar 2: Chair – Sushanta Mitra</b>  |
| 13h30 – 14h30        | Ajay Sood, Indian National Academy & Indian Institute for Science, Bangalore – Nanophotonics of Two-Dimensional Crystals  |
|                      | <b>Technical Session 3: Chair – Lisa Pokrajac</b>   |
| 14h30 – 15h15        | Key Note Speaker 2: Drew Higgins, McMaster University – Nanomaterial Electrocatalysts to Enable Sustainability of our Energy and Transportation Sectors                               |
| 15h15 – 15h35        | Irene Goldthorpe (WIN/ECE): Silver nanowires for printable, flexible transparent electrodes and e-textiles  |
| <b>15h35 – 15h50</b> | <b>Coffee/Tea Break</b>   |
|                      | <b>Technical Session 4: Chair – Oleg Stukalov</b>   |
| 15h50 – 16h10        | Nasser Abukhdeir (WIN/ChE): A generalized shapelet-based method for analysis of nanostructured surface imaging  |
| 16h10 – 16h30        | Ting Tsui (WIN/ChE): Manipulating cell behaviours using engineered surfaces   |
| <b>16h30 – 19h00</b> | <b>Student Poster Session &amp; Reception</b>   |

# Thursday, June 6, 2019 – QNC 0101

| TIME          | SCHEDULE   |
|---------------|--|
| 8h45 – 9h00   | Welcome  |
|               | Distinguished Lecture Seminar 3: Chair – Sushanta Mitra  |
| 9h00 – 10h00  | Sir Mark Welland, University of Cambridge, UK – Nanostructures in disease – pathology and treatment  |
|               | Technical Session 5: Chair – Lisa Pokrajac   |
| 10h00 – 10h45 | Keynote Speaker 3: Pavadee Aungkavattana, National Nanotechnology Centre (NANOTEC), Thailand – Nanotechnology in Thailand and its application: <i>From Lab to Market</i> |
| 10h45 – 11h00 | Coffee/Tea Break   |
|               | Technical Session 6: Chair – Oleg Stukalov   |
| 11h00 – 11h45 | Keynote Speaker 4: Marija Drndic, University of Pennsylvania, USA – Can Nanopatterned Two-Dimensional Solid-State Materials Also Filter Turkish Coffee?                  |
| 11h45 – 12h05 | Kevin Musselman (WIN/MME): Rapid, Open-Air Manufacturing of Functional Oxide Thin Films by Spatial Atomic Layer Deposition   |
| 12h05 – 12h25 | Carolyn Ren (WIN/MME): Droplet Microfluidic Platform Technologies for Material Synthesis   |
| 12h30 – 14h00 | Lunch on your own  |
|               | Distinguished Lecture Seminar 4: Chair – Sushanta Mitra  |
| 14h00 – 15h00 | President Kazuhito Hashimoto, National Institute for Nanotechnology (NIMS), Japan – My experience of nanotechnology from basic research to practical application         |
| 15h00         | Concluding Remarks   |

# Distinguished Lecture Seminar Presentations

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**Hans-Jürgen Butt**

Professor

Max Planck Institute for Polymer Research

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## **Abstract:** Nanostructuring surfaces to control wetting

Wolfgang Pauli is credited with the saying: “God made the bulk; the surface was invented by the devil.” Wetting phenomena go even beyond. There, two surfaces meet and form a contact line. Indeed, wetting is a multiscale phenomenon. To control wetting we need to understand processes few nanometers around the contact line. I would like to discuss one aspect of wetting: Super-liquid-repellency. Super-liquid-repellency can be achieved by nano- and microstructuring a low energy surface in such a way, that protrusions entrap air under-neath the liquid.

This, however, is not the only requirement. When the liquid impacts on the surface or a hydrostatic pressure is applied at some critical pressure the liquid impales the nano- and microstructure and the desired wetting properties are lost. The challenge is to make super-liquid-repellent surface which combine a high receding contact angle with a high impalement pressure and mechanical robustness. To achieve this, the features constituting the surface should be as small as possible. Thus, “nano” is essential for making useful super liquid-repellent surfaces. As possible applications, self-cleaning and photocatalytically active liquid-repellent surfaces will be discussed.

## **Biography/ Research Interests**

Professor Hans-Jürgen Butt studied physics at the Universities of Hamburg and Göttingen. He received his Diploma in 1986. Then he moved to Frankfurt to work in Ernst Bamberg’s group at the Max Planck Institute for Biophysics on light induced proton transport of bacteriorhodopsin.

After his PhD in 1989, as a postdoc in Santa Barbara with Paul Hansma, he discovered the newly developed atomic force microscope (AFM). From 1990-96 back in Frankfurt as a researcher he studied biological objects using AFM. In this period the work on surfaces, in particular on surface forces, became a central issue. In 1996 he went to the institute for physical chemistry at the Johannes Gutenberg University in Mainz as Associate Professor. There he focused on the physics and chemistry of interfaces.

Three years later he joined the University of Siegen as Full Professor for physical chemistry. In 2002 he followed a call to the Max Planck Institute for Polymer Research in Mainz, where he is now Director. His work focuses on the experimental physics of interfaces.



**President Kazuhito Hashimoto**

National Institute for Materials Science (NIMS),  
Tsukuba, Japan

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**Abstract:** My experience of nanotechnology from basic research to practical application

Over a period of 30 years, Professor Hashimoto has made great contributions to the field of  $\text{TiO}_2$  photocatalysts. He initiated the development of semiconductor photocatalysis utilizing low-level UV light as an excitation source, and then discovered the photo-induced hydrophilicity on the surface of  $\text{TiO}_2$  coated materials. In addition, he also developed highly efficient visible light photocatalysts based on a new principle – the interfacial charge transfer between  $\text{TiO}_2$  and nanometer-sized grafted metal oxides. These studies have opened new fields in the  $\text{TiO}_2$  photocatalysis field in both fundamental understanding and applications. Due to his research and technology transfer efforts,  $\text{TiO}_2$  photocatalysis has created an industry valued at approximately ¥70B JP (~\$850M CAD) in Japan alone. Next, some examples of technology transfer at the National Institute for Materials Research (NIMS) are introduced. NIMS is Japan's sole National Research and Development Agency specializing in materials science and is charged with basic research and development for materials science/nanotechnology. Furthermore, NIMS is expected to transfer their basic research results to industry. According to the 2017 Thomson Reuters ranking of the World's Most Innovative Research Institutions, NIMS ranks 12th. The lecture will also introduce some of the world top-notch facilities & equipment of NIMS.

**Biography/ Research Interests**

Kazuhito Hashimoto accepted the appointment of President of National Institute for Materials Science in Tsukuba in 2016. He is also a professor at the Policy Alternatives Research Institute and serves as a senior counselor to the president of the University Of Tokyo (UT) since 2016. He has been a member of the Science Council of Japan since 2012, and a member of Board of Governors (BOG) of Okinawa Institute Technology (OIST) since 2016. As an executive member of Council for Science, Technology & Innovation (Cabinet Office, Government of Japan), he has also been contributing to the Science and Technology Policy of Japan since 2013. After he received his BS (1978) and MS degrees (1980) of Chemistry from UT, he obtained a research position at the Institute for Molecular Science (IMS) in 1980. He obtained a Doctor of Science degree from UT in 1984. In 1989, he was invited as a lecturer at Department Applied Chemistry at UT, where he was promoted to Associate Professor in 1991. He was appointed a full professorship at the Research Center of Advanced Science & Technology (RCAST) of UT. He served as Director of RCAST from 2004 to 2007. He was also appointed Professor at Department of Applied Chemistry at UT from 2003 to 2016. His research interests are spread over a very broad area including photocatalysis, microbial electrochemistry, functionalized magnetic materials, artificial photosynthesis, and polymer photovoltaics, among many others. His contributions to science are described in more than 650 peer reviewed papers and more than 50,000 citations (h-index 110). He also wrote more than 200 reviews and book chapters. The truths he uncovered are the basis for many manufactured products. His contributions to technology and engineering are described in approximately 200 issued Patents, more than 20 of which are in use. He received many awards including the Japan Prime Minister Award for Academia-Industry Corporation in 2004, the Japan Imperial Award for Invention in 2006, the Chemical Society of Japan Award in 2012, and the Heinz Gerischer Award of ECS in 2017.

**Ajay K. Sood**

Professor

Department of Physics

Indian Institute of Science

Bangalore, India

Email: [asood@physics.iisc.ernet.in](mailto:asood@physics.iisc.ernet.in)**Abstract:** Nanophotonics of Two-Dimensional Crystals

Ultrafast femtosecond laser pulses offer unique possibilities to probe transient processes in nano materials. Following photoexcitation by a femtosecond laser pulse, the carrier dynamics includes many important processes like thermalization, energy relaxation, exciton formation and spin dynamics which are impacted by dimensionality. Their understanding is crucial not only for many optoelectronic applications, but also to gain a deeper understanding of physical processes in nano-materials.

My talk will present our recent results on 2D materials to showcase the power of Raman and ultrafast spectroscopies combined with transparent measurements for deeper understanding of their electronic and optical properties. Examples from our recent work will include: (i) Phonon renormalization due to gate doping by in-situ Raman spectroscopy of a few layer 2H-MoTe<sub>2</sub> and ReS<sub>2</sub>, which will highlight the role of symmetry dependent electron phonon interactions; (ii) Terahertz photoconductivity of single and bilayer graphene using optical pump terahertz probe spectroscopy; and (iii) Hot carrier generation in graphene using ultrathin gold films with periodic array of holes.

**Biography/ Research Interests**

Professor A.K. Sood, FRS is an Honorary Professor in Department of Physics at Indian Institute of Science, Bangalore. He is currently President of the Indian National Science Academy. He was President of the Indian Academy of Sciences from 2010 to 2012 and the Secretary General of The World Academy of Sciences (TWAS) from 2013 to 2018.

Currently, he is a member of the Science, Technology and Innovation Advisory Council of the Prime Minister of India. Prof. Sood's research interests include Physics of Nano systems such as graphene and other 2D materials and soft condensed matter, with a strong focus on innovative experiments. The latter includes the flow behaviour such as rheochaos, nonequilibrium phase transitions, deconstruction of glass physics using colloid experiments, active matter and stochastic thermodynamics. The experimental probes used for exploring physics at nanoscale are Raman spectroscopy, Ultrafast time resolved spectroscopies including terahertz spectroscopy, transport measurements and x-ray diffractions. He has published more than 400 papers in international journals and holds national and international patents.

His work has been recognized by way of many honors and awards including the Fellowship of the Royal Society (FRS), all three science academies of India and TWAS; the civilian honor, Padma Shri by Government of India, S.S. Bhatnagar Prize, G.D. Birla Award, TWAS Prize in Physics, FICCI Prize, Goyal Prize, M.N. Saha Award and Millennium Gold Medal of Indian Science Congress, Sir C.V. Raman Award of UGC, Homi Bhabha Medal of Indian National Science Academy, DAE Raja Ramanna Award of JNCASR, National Award in Nanoscience and Nanotechnology by Government of India, Nano Award by Government of Karnataka, G.M. Modi Award of Science and R D Birla Award for Excellence in Physics by Indian Physics Association. He is Associate Editor of ACS Nano and Executive Editor of Solid State Communications.





### **Sir Mark Welland**

Master of St. Catharine's College, Vice-Provost  
University of Cambridge,  
Cambridge, United Kingdom

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#### **Abstract:** Nanostructures in disease – pathology and treatment

The mis-folding of proteins is part of the pathology of a number of human diseases such as Alzheimer's, Parkinson's and Creutzfeldt Jakob disease. The mis-folding results in the formation of one-dimensional nanostructures with mechanical properties that are amongst the most pronounced in nature. The high stability of these structures in turn makes for a significant challenge in designing drug therapies to remove them. However, the ubiquitous nature of these nanostructures irrespective of protein or peptide monomer, provides an opportunity to design highly controlled drug delivery systems to treat disease. Thus it is possible to use the very process that is part of a range of human diseases to develop new therapies where the drug monomer is controlled to form stable nanostructures that only break down in the appropriate physiological conditions to deliver therapeutic action.

#### **Biography/ Research Interests**

Professor Sir Mark Welland started his career in nanoscience and nanotechnology at IBM Research Laboratories, Yorktown Heights, USA, where he was part of the team that developed one of the first scanning tunnelling microscopes. In 1985, appointed to a Lectureship in Electrical Engineering at the University of Cambridge, he set up the first tunnelling microscopy group in the UK and in 1991 he began the nanoscience research group. Sir Mark is currently Professor of Nanotechnology researching into a broad range of both fundamental and applied problems. These include protein mis-folding problems related to human diseases such as Alzheimer's, nanostructured materials for high efficiency low-cost solar cells, biologically inspired nanomaterials for green technologies and nanoelectronics for future generation communications and sensing.

He has given a number of prestigious lectures that include the Turing Lecture, IEE and British Computing Society, 2002; the Sterling Lecturer, an Annual Appointment made by the Sterling group of Universities, 2003; the Annual Materials Research Society of India Lecture, Mumbai, India, 2006; and the Max Planck Society Lecture 2007, MPI, Stuttgart, Germany.

From April 2008 until May 2012, Sir Mark was Chief Scientific Adviser to the UK Government Ministry of Defence. In April 2011, in recognition of Sir Mark's contributions he was presented with the US Secretary of Defense's Award for Exceptional Public Service. Also in April 2011, in recognition of his outstanding leadership, wise counsel and his significant contribution to the interests of the United Kingdom and the United States, he received the National Nuclear Security Administration (NNSA) Gold Medal for Distinguished Service. The NNSA Gold Medal is the highest medal awarded by the NNSA.

Sir Mark was elected a Fellow of the Royal Society, a Fellow of the Royal Academy of Engineering, and a Fellow of the Institute of Physics in 2002, a Foreign Fellow of the National Academy of Sciences India in 2008 and a Foreign Member of the Danish Academy of Sciences in 2010. Sir Mark was awarded a Knighthood in the Queen's Birthday Honours list in 2011.

Sir Mark was Head of Electrical Engineering from October 2015 to September 2018, has been Head of the Nanoscience Centre since 2012, has been Master of St Catharine's College since October 2016, was elected a Deputy Vice-Chancellor October 2018 and is Special Adviser to the Vice-Chancellor on China. On 1 January 2019 he became the Director of the Maxwell Centre.

# Keynote Speakers

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## **Pavadee Aungkavattana**

Deputy Executive Director

National Nanotechnology Center (NANOTEC)

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Thailand

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### **Abstract:** Nanotechnology in Thailand and its application: *From Lab to Market*

To thrive in the 21<sup>st</sup> century, Thailand 4.0 is an economic model focusing on a value-based and innovation-driven economy by moving from producing commodities to innovative products; emphasizing on promoting technology, creativity, and innovation in focused industries and from a production-based to a service-based economy. Based on the concept of Thailand 4.0, this talk will highlight how nanotechnology generates positive impacts on economy and society.

The National Nanotechnology Center (NANOTEC) is the agency on nanotechnology development in Thailand under the jurisdiction of the National Science and Technology Development Agency (NSTDA) and the Ministry of Higher Education Science, Research and Innovation. NANOTEC in collaboration with National Science, Technology and Innovation Policy developed the 3<sup>rd</sup> National Nanotechnology Roadmap (2016-2021) as an aid for the indication of pathways to conduct research and development activities that are of national importance to social and environment for the betterment of life.

In addition, NANOTEC's core technologies which lie in the pathways towards development platforms in Nanoencapsulation, Responsive materials and nanosensing, Nanocatalysis for biorefinery, Nanohybrids and coating, and Advanced nanocharacterization and safety. One of the major goals of NANOTEC is to be a "solution provider in nanotechnology", therefore a high percentage of the nanotechnology research is focused on industrial applications.

### **Biography/ Research Interests**

Since 2016, Dr. Aungkavattana has been the Deputy Executive Director of the National Nanotechnology Center (NANOTEC). She received her bachelor's degree in Materials Science, with an emphasis in Ceramics, at Chulalongkorn University in Thailand. She then went on to complete her master's degree in Ceramic Science at Pennsylvania State University, and continued there to finish her PhD in Materials Science and Engineering in Ceramics. She started her work as an invited lecturer at Chulalongkorn University and KMUTT before moving on to becoming the Ceramic's Program Leader of National Metals and Material Technology Center (MTEC). In 2003, she became the Senior Researcher and then moved on to become the Principal Researcher of MTEC in 2006. In 2009, she cofounded the company ATCermaics Limited and served as Chief Technology Officer there. Dr. Aungkavattana's research interests include mullite-zirconia composites for refractory brick, the fabrication and heat characteristic of zeolite adsorbent for energy storage, the development of ceramic membranes for Micro- and Ultra-filtration and Zeolite Membrane for Ethanol Separation. Her field of specialization spans from Material Science, Technical Ceramics, and Glasses, with specialties in Ceramic Processing and Fabrications and Ceramic and Ceramic reinforced Geopolymer Composites.



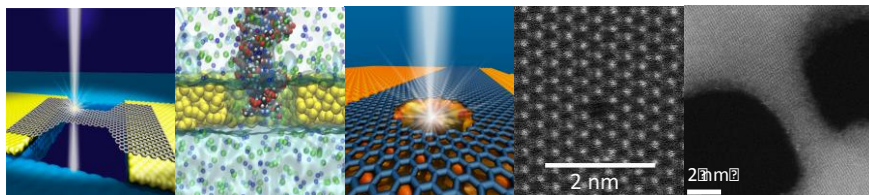
## Marija Drndic

Fay R. and Eugene L. Langberg Professor  
Department of Physics and Astronomy  
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## Abstract: Can Nanopatterned two-dimensional solid-state materials also filter Turkish Coffee?

Atom-scale control and patterning of 2D materials opens new avenues for engineering of their properties and new fundamental discoveries. I will describe efforts on 2D materials growth, transfer and device physics, pushing the limits of device size to atom scale and expanding their function, precision and the range of observed physical phenomena. Examples include nanoribbon field-effect-transistors with nanopores down to sub-nm widths, the ultrafast, all-electronic detection and analysis of molecules, removing atoms from the 2D materials lattice to modulate their electrical and optical properties in novel ways and for membrane applications such as water desalination and energy harvesting. When molecules are driven through 2D nanometer-size holes in solution, they change the ion current flow from which molecule's physical and chemical properties are inferred. DNA, proteins and other biomolecules can be analyzed electrically in this way. Sub-nm defects and vacancies in 2D lattices play a central role in new physical phenomena, from quantum emission to allowing the passage of water molecules but blocking salt ions for efficient water desalination. The temporal, spatial resolution and sensitivity in nanopore experiments have been improved over the last few years thanks to advanced materials, device designs and new electronics.



From left to right: Illustrations of nanoribbon sculpting with the electron beam; passage of a DNA molecule through a nanopore; illustration of nanopore drilling with an electron beam inside of the TEM; one-atom-large nanopore in a MoS<sub>2</sub> sheet; armchair phosphorene nanoribbon sculpted in the AC-TEM. References: G. Danda, *ACS Nano* 11 (2), 1937, 2017; Rodriguez-Manzo *et al.*, *ACS Nano* 10 (4), 4004, 2016 & *ACS Nano* 9 (6), 6555, 2015; Qi *et al.*, *ACS Nano* 9(4), 3510, 2015; Balan *et al.*, *Nano Letters* 14 (12), 7215, 2015; Drndic, *Nature Nanotechnology* 9, 743, 2014. Thiruraman *et al.*, *Nano Letters* 18 (3), 1651, 2018; Masih Das *et al.*, *Nano Letters* 19 (1), 392, 2019.

## Biography/ Research Interests

Marija Drndic is the Fay R. and Eugene L. Langberg Professor in the Department of Physics and Astronomy at the University of Pennsylvania. She received her MPhil from Cambridge University, AB, AM and PhD from Harvard University, all in Physics, and was a Pappalardo Fellow at MIT, before joining Penn in 2003. Her work on cold atom manipulation, and nanocrystal electronics was recognized by the Presidential Young Investigator Award, the Alfred Sloan Fellowship, the DARPA Young Faculty Award, the ONR Young Investigator, and the NSF Career Award. In 2013 she was named the APS Fellow "for development of novel nanofabrication methods for graphene nanoelectronics and fast biomolecular analysis in solution". She also received several teaching awards, including the Edmund J. and Louise W. Kahn Award for Distinguished Teaching. Drndic lab focuses on nanoscale structures in the areas of experimental condensed matter physics, nanoscience and nanotechnology. The group is known for their studies of fundamental physical properties of low-dimensional and small-scale structures and the development of their device applications.

**Drew Higgins**

Assistant Professor  
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Canada

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**Abstract:** Nanomaterial Electrocatalysts to Enable Sustainability of our Energy and Transportation Sectors

For electrochemical energy conversion and storage technologies to become viable component of future sustainable energy infrastructures, the development of nanomaterial catalysts that are active, selective, stable and inexpensive is required. This talk will focus on catalysts for electrochemical reduction of CO<sub>2</sub> to produce industrially relevant fuels and chemicals. While these products are generally fossil fuel derived, electrochemical CO<sub>2</sub> reduction (CO<sub>2</sub>R) provides opportunity to use renewable energy (i.e., wind, solar, hydro) as the energy input to achieve a carbon-neutral artificial photosynthesis process. This talk will take a fundamental approach towards understanding CO<sub>2</sub>R catalysis, and particularly the effects that alloying and surface structure engineering have on the activity and selectivity of copper-based catalysts. A discussion of the remaining challenges facing electrochemical CO<sub>2</sub>R technology development will be included, particularly with regards to the need to apply this fundamental knowledge towards the design of next generation nanomaterial catalysts and electrode structures.

**Biography/ Research Interests**

In January 2019, Drew Higgins began as an Assistant Professor in Chemical Engineering at McMaster University, where his research focuses on the developing, understanding and integrating nanomaterial electrocatalysts into electrode structures for sustainable electrochemical energy technologies, including fuel cells and electrolyzers. Drew completed his PhD in Chemical Engineering at the University of Waterloo in 2015 under the supervision of Professor Zhongwei Chen, as part of the Waterloo Institute for Nanotechnology. His PhD work involved the synthesis, characterization and device integration of nanostructured oxygen reduction catalysts for low temperature fuel cells. During this time, he spent just under one year at the Los Alamos National Laboratory working under the mentorship of Dr. Piotr Zelenay. In 2015, Drew started a Banting Postdoctoral Fellowship at Stanford University in the Department of Chemical Engineering, working in Professor Thomas Jaramillo's group. His research focused on obtaining a fundamental understanding of the mechanisms and properties governing electrochemical CO<sub>2</sub> reduction catalysis. In 2017, he was promoted to an Associate Staff Scientist at Stanford University / SLAC National Accelerator Laboratory, where he oversaw research activities focusing on discovering and understanding new electrocatalyst compositions and structures for a variety of important electrochemical reactions, including water oxidation, CO<sub>2</sub> reduction, oxygen reduction and methane activation. More details are available at: <https://www.higginslab.com/>.



## Scott T Retterer

Senior Research Staff Scientist  
Oak Ridge National Laboratory  
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USA

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**Abstract:** Hierarchical Assembly – Understanding Formation, Response, and Evolution in multiscale heterogeneous materials

Hierarchical assemblies offer the potential to tailor material response in ways not possible with homogenous materials, as multiscale heterogeneous systems exhibit unique properties not inherent in the individual building blocks from which they are comprised. The constituent parts are able to move and transform in response to changes in the environment and applied stimuli. This leads to desirable functional properties that underpin applications in energy storage, transduction, sensing and computation. Taking full advantage of this class of materials demands a deep understanding of the underlying interactions that drive formation and coupled motion. Therefore, the Hierarchical Assembly theme at the CNMS seeks to *deterministically create responsive assemblies of hierarchical soft and hybrid materials by developing a mechanistic understanding of molecular, ionic, and electronic motion as functions of building block composition, chemical environment, and interface architecture*. We actively cultivate capabilities that provide new insights into how the forces that influence coupled motion and structure across molecular, nano- and mesoscales, ultimately drive macroscopic function.

Seizing this opportunity requires new approaches to create and characterize *dynamic multiscale systems*. Correlations between their formation, reorganization and the onset or change of function can be revealed using advanced multimodal characterization tools that operate *in situ*. Such tools are essential for visualizing where these buildings blocks are and how they move in response to local stimuli, providing critical information for the calibration of simulations. Simulation and modeling, in turn, help direct synthesis, guide experiment, and interpret data. Together, these capabilities provide CNMS users with a tightly woven work flow and data analytics framework to understand and direct the assembly and response of complex hierarchical assemblies away from equilibrium.

## Biography/ Research Interests

As a senior staff scientist at Oak Ridge National Laboratory, working across the Biosciences and Center for Nanophase Materials Sciences Divisions, Dr. Retterer's work focuses on the development of materials and fluidic interfaces to biological systems with an emphasis on understanding the effects of nanoscale structure, molecular transport, and spatial organization on biological processes. Dr. Retterer is also a leader of the Hierarchical Assembly scientific research theme at the Center for Nanophase Materials Sciences, which focusses on understanding the impact of material building block structure, environment, and interface architecture, on the formation of functional materials. This theme emphasizes topics focused on understanding the dynamics of assembly processes and the response and reorganization of hierarchically assembled systems to local and global perturbations.

## WIN Members

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### **Nasser Abukhdeir**

Associate Professor  
Department of Chemical Engineering  
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Canada

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**Abstract:** A generalized shapelet-based method for analysis of nanostructured surface imaging

The determination of quantitative structure-property relations is a vital but challenging task for nanostructured materials research due to the presence of large-scale spatially varying patterns resulting from nanoscale processes such as self-assembly and nano-lithography. Focusing on nanostructured surfaces, recent advances have been made in automated quantification methods for orientational and translational order using shapelet functions, originally developed for analysis of images of galaxies, as a reduced-basis for surface pattern structure. In this work, a method combining shapelet functions and machine learning is developed and applied to a representative set of images of self-assembled surfaces from experimental characterization techniques including scanning electron microscopy, atomic force microscopy and transmission electron microscopy. The method is shown to be computationally efficient and able to quantify salient pattern features including deformation, defects, and grain boundaries from a broad range of patterns typical of self-assembly processes.

### **Biography/ Research Interests**

Dr. Abukhdeir is an Associate Professor of Chemical Engineering, cross-appointed in Physics & Astronomy, and a member of the Waterloo Institute for Nanotechnology. He completed his BS and MChE at Carnegie Mellon University (Pittsburgh, USA) and his PhD at McGill University (Montreal, Canada) under the supervision of Prof. Alejandro Rey. His research group is focused on industrial and fundamental research on processes involving soft matter, phase transitions, complex fluids, and multiphase flows.

**James Forrest**

Professor

Department of Physics and Astronomy

University of Waterloo,

Waterloo, Ontario,

Canada

Email: [jforrest@uwaterloo.ca](mailto:jforrest@uwaterloo.ca)

**Abstract:** Polymer Stable Glass

Stable glass materials are of high interest as they are the densest amorphous solids. Using vapour deposition techniques allows for the formation of glasses that are in many ways equivalent to glasses that have been aged for thousands or even millions of years. The ability to make stable glasses out of polymers introduces a new level of tunability and potential thin film applications. We have recently developed a process that allows for the unambiguous production of polymer stable glass films. This process allows for the production of a new class of polymer materials that can be employed in thin film applications. We will demonstrate stable glass formation for polystyrene and poly(methylmethacrylate), and study the density increase of the materials and use their significant kinetic stability to estimate lifetimes of materials at temperatures much below the glass transition temperature.

**Biography/ Research Interests**

At Waterloo, Professor Jamie Forrest is head of the Polymer Physics group that works out of a \$2 million facility funded by the federal and provincial governments. The facility provides a wide variety of characterization techniques to study synthetic polymer and proteins in thin films or near surfaces and interfaces.

A particular strength of the Polymer Physics group is the investigation of the glass transition and associated dynamics in thin polymer films. This is combined with detailed investigations into the static structural properties, as well as surface and interfacial properties. Recently they have begun investigations into a number of biological systems which include the kinetics of protein adsorption onto surfaces as well as the structure of adsorbed proteins. We pursue both applied and fundamental problems and continue to make significant scientific advances in physics, chemistry, biology and health sciences.

Forrest's group is widely published, including a recent article in Science Magazine that showed how solids behave like liquids at the nanoscale. The discovery was considered a major step forward in measuring polymer substances using nanoscale technology. For this, and many of his contributions to the field of polymer physics, Forrest was elected as a 2009 fellow of the American Physical Society, a leading organization of physicists, including 60 Nobel Laureates.

Forrest obtained a BSc from the University of British Columbia and an MSc/PhD from the University of Guelph. He worked at Chalmers University in Sweden and the University of Sheffield in England, before coming to University of Waterloo in 2000.



## Irene Goldthorpe

Professor

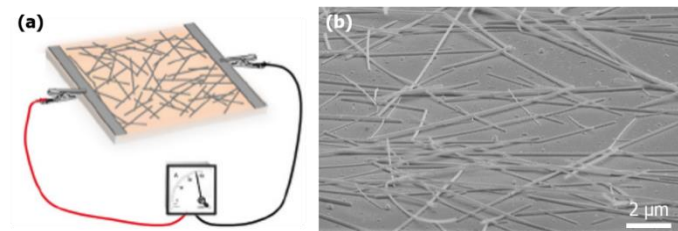
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**Abstract:** Silver nanowires for printable, flexible transparent electrodes and e-textiles

Silver is the most conductive metal and their nanowires can be easily synthesized in solution. Unlike nanoparticles, the elongated shape of nanowires allows them to form an electrically conductive mesh (Figure 1) without covering the entire surface and thus these films are optically transparent. As such, they can be used as transparent electrodes which are required for a range of optoelectronic devices such as touchscreens, solar cells, displays, and light emitting diodes. Interest in using silver nanowire films to replace the commonly used transparent conductor, indium tin oxide, has surged in recent years. Unlike indium tin oxide, silver nanowire electrodes have high mechanical flexibility and can be deposited in solution using high-throughput, roll-to-roll compatible techniques. Their conductivity and transparency are better than competing flexible materials such as carbon nanotubes. This talk will first discuss the fabrication and properties of silver nanowire electrodes, their integration into devices such as smart windows, and the challenges that our research addresses such as their surface roughness, Joule heating, and corrosion.

The second part of the talk will discuss the use of silver nanowires as a conductive ink for e-textiles. Compared to commercially available conductive inks, the nanowire ink is much more mechanically flexible and lighter-weight. They can also be transfer printed rather than laminated which rids the plastic layer between the ink and the textile. I will discuss their use as electrical interconnections, heating elements and electromagnetic shielding on fabrics.



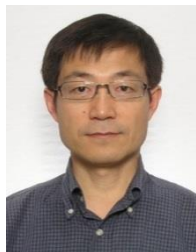
**Figure 1.** (a) Schematic and (b) SEM image of a transparent conductive silver nanowire network.

**Biography/**

## Research Interests

Irene Goldthorpe is an Associate Professor in the Department of Electrical & Computer Engineering at the University of Waterloo. She received her graduate degrees from Stanford University and was a post-doctoral scientist at Eastman Kodak Company. Goldthorpe's expertise is in electronic materials, particularly the use of nanomaterials to enable electronic devices on non-traditional substrates such as plastics and glass. Major research thrusts are currently silver nanowire transparent electrodes and e-textiles.





**Yuning Li**  
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**Abstract:** Development of polymer semiconductors for printed electronics

Polymer semiconductors are the key materials to enable printed electronics for a wide range of applications such as flexible displays, radio frequency identification tags (RFIDs), solar cells, photodetectors, batteries, and chemical sensors. Polymer semiconductors are known for their excellent printability and mechanical properties as well as tunable optical and electronics characteristics. Thanks to the recent significant progress in the development of polymer semiconductors, remarkable performance improvement of printed electronics such have been achieved. For example, high field effect mobility of over  $10 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$  for polymer-based organic thin film transistors (OTFTs) and power conversion efficiency of greater than 10% for polymer-based organic photovoltaics (OPVs), which are close to or exceeding the performances of amorphous silicon-based devices, have been achieved. This presentation introduces several key contributions of our research group has been made to this field. Specifically our design and synthesis of several important novel building blocks for the construction of high mobility and environmentally stable polymer semiconductors as channel semiconductors for p-type, n-type, and ambipolar OTFTs will be discussed.

### Biography/ Research Interests

Dr. Yuning Li is a professor in the Department of Chemical Engineering with affiliation to the Waterloo Institute for Nanotechnology (WIN) at University of Waterloo. He received his bachelor and master degrees in polymer materials from Dalian University of Technology in China, respectively, and his Ph.D. in materials science from Japan Advanced Institute of Science and Technology (JAIST). Prior to joining the University of Waterloo in 2010, he worked in the research labs at Simon Fraser University, the National Research Council Canada (NRC), Xerox Research Centre Canada (XRCC), and the Institute of Materials Research and Engineering (IMRE), the Agency for Science, Technology and Research (A\*STAR) (Singapore). Since 1999, Dr. Li has been working on printed electronics including organic light emitting diodes, organic thin film transistors, and organic photovoltaics with an emphasis of his effort on the development of polymer semiconductors materials. He is a co-recipient of the 2<sup>nd</sup> Runner Up in Materials Category for "The Best and the Brightest New Technology for 2004" by *Wall Street Journal* and a co-recipient of the 3<sup>rd</sup> Annual NASA Nano 50<sup>th</sup> Awards (2007) for Printed Organic Electronics. He has published ~150 refereed journal articles with an h-index of 53 and > 11,000 citations. He also holds 74 granted US patents, which have led to several commercialized products.

**Kevin Musselman**

Assistant Professor

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**Abstract:** Rapid, Open-Air Manufacturing of Functional Oxide Thin Films By Spatial Atomic Layer Deposition

Atmospheric pressure spatial atomic layer deposition (AP-SALD) is an emerging technique for high-throughput manufacturing of uniform, pinhole-free thin films with nanoscale thickness control. AP-SALD systems are in the early stages of development but have key advantages; vacuum equipment is not required, which lowers capital costs and energy requirements, and the deposition occurs in air (rather than in a chamber), which enables high-throughput deposition over large areas (e.g., roll-to-roll processing). Spatial atomic layer deposition techniques can be more than one hundred times faster than conventional ALD, as no vacuum purge is required. These characteristics make AP-SALD promising as a sustainable process for top-down mass production of nanoscale thin films for flexible electronics, display technologies, and photovoltaics, among other applications. The first AP-SALD system in Canada was recently designed and built at the University of Waterloo. This presentation will provide an overview of AP-SALD technology at the University of Waterloo, and our development of nanoscale oxide films for quantum-tunneling diodes and perovskite photovoltaics.

**Biography/ Research Interests**

Dr. Musselman received his doctoral and postdoctoral training at the University of Cambridge. He joined the University of Waterloo as an Assistant Professor in 2015 and currently leads the Functional Nanomaterials Group. His research program focuses on the scalable synthesis of nanomaterials, and using these materials to drive the understanding and development of next-generation functional coatings and devices.

**Carolyn Ren**

Professor

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Email: [c3ren@uwaterloo.ca](mailto:c3ren@uwaterloo.ca)**Abstract:** Droplet Microfluidic Platform Technologies for Material Synthesis

Droplet microfluidic platform utilizes nanoliter-sized water drops as vesicles for chemical reactions. These drops can be generated uniformly in microchannel networks at kHz rates by injecting one fluid (i.e. water) into another immiscible fluid (i.e. oil). If these drops can be manipulated (generating, merging, splitting, trapping, sensing and heating) precisely, droplet microfluidics presents tremendous potential for high throughput analysis towards a wide range of applications such as material synthesis. This presentation summarizes Ren's work on droplet microfluidics with a focus on the fundamental studies of droplet microfluidics, microwave sensing and heating and active control of individual droplets as well as some applications for material synthesis.

**Biography/ Research Interests**

Dr. Ren obtained her bachelor and master's degrees in thermal engineering at Harbin Institute of Technology and her PhD in Mechanical Engineering at the University of Toronto. Dr. Ren is currently a professor of Mechanical and Mechatronics Engineering at the University of Waterloo (UW) and holds the Canada Research Chair in Droplet Microfluidics and Lab-on-a-Chip Technology. She is directing Waterloo Microfluidics Laboratory focusing on advancing fundamental knowledge of microfluidics and developing Lab-on-a-Chip technologies which have significant impact on a wide range of applications such as material synthesis, protein separation, and water quality sensing. Besides the Canada Research Chair, Dr. Ren has also received several awards from the engineering and research community, including: election as a Member of the College of New Scholars, Scientists and Artists of Royal Society of Canada, being recognized as one of 20 leading female innovators in *Women of Innovation* (Dr. Ren is a co-founder of Advanced Electrophoresis Solutions Ltd and QuantWave Technology Inc.), appointment as Fellow of the Canadian Society of Mechanical Engineering, Engineering Excellence from University of Waterloo and an Early Research Award from the Ontario Ministry of Research and Innovation.

**Ting Tsui**

Professor

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**Abstract:** Manipulating cell behaviours using engineered surfaces

Manipulate biological cell morphology using chip-based 3-D nano- and micro-scale topographic surface features is one of the most exciting research topics in the biomaterial field. However, it is difficult to integrate them into the multi-billion dollar health care industry. This difficulty is partially due to the delicate topographic features, short shelf-life, and defect sensitivity. Recently, we developed a novel device with flat, smooth, and mechanical robust surfaces that can be used to manipulate cell behaviors. The composite surface contains a complex pattern of dissimilar classes of materials that induces unique cell behaviors due to the components of various physical properties such as surface energy and protein adsorption. Cells and their internal organelles preferentially attach to one material over another. Results collected from these devices will be presented.

**Biography/ Research Interests**

Professor Tsui is a researcher with over twenty-five years of experience in the integrated circuit (IC) fabrication industry and in the academic environment. At Texas Instruments (Dallas, TX), he developed Plasma Enhanced Chemical Vapor Deposited (PECVD) porous low-k and ultra-low-k thin films to be used for interlayer dielectric and dielectric barriers for 90 nm, 65 nm, and 45 nm technology node. He also developed plasma-based processes to enhance electrical and chip reliability performance. In 2007, Professor Tsui began his role at the University of Waterloo where he has conducted research in the areas of porous ultra-low-dielectric constant materials, nano-mechanics, electron beam lithography, and nanoindentation. His works have led to in-depth understanding of size-dependent strength of single crystalline and nanocrystalline metals — important knowledge to facilitate the development of microelectronic lead-free solder packaging technology. His current research focus is on applying advanced IC-based fabrication processes and devices to advanced biomaterials.

**Xiaosong Wang**

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**Abstract:** Effect of Ionic End Group on Hydrophobic Hydration (HH) and Hydrophobic Effect-Driven Self-Assembly (HEDSA) of Metal Carbonyl Marocomolecules

Hydrophobic hydration (HH) refers to the interaction of water with hydrophobic molecules, which is a hydrophobic effect (HE) crucial for biological events. HH of solutes is affected by various factors, which subtly adjusts the behaviour of HE driven self-assembly (HEDSA). The phosphine end group (P) of metal carbonyl macromolecules, P(FpP), was converted to either  $P^+I^-$  or  $P^+B(Ph)_4^-$  ( $P^+$ : phosphonium cation), in which  $I^-$  is water-soluble and  $B(Ph)_4^-$  is water-insoluble. All the macromolecules are water-insoluble and non-surface active. The backbones for P(FpP) and the analogue with the end group of  $P^+B(Ph)_4^-$  were hydrated in aqueous solutions, which drove the HEDSA resulting in vesicles with the membrane assembled from the stacking of the hydrated macromolecular chains. The end group of  $P^+I^-$  with a water-soluble counterion de-hydrated the backbone and rendered the HEDSA similar to micellization behaviour of amphiphiles. The observed end group-dependent HH is explained by the long-range propagation of the perturbation to water structure by the end group. This long-range effect of water structure varies the HH and modulates the molecular recognition and assembling process. This exploration creates knowledge to understand HE effect on a molecular level and opens up new opportunity for design and synthesis of aqueous assemblies for material exploration.

**Biography/ Research Interests**

Dr. Xiaosong Wang is currently a Professor at the Department of Chemistry and Waterloo Institute for Nanotechnology at the University of Waterloo. He graduated from East China University of Science and Technology in 1998 with a PhD degree in Polymer Materials and Science. After post-doctoral works at the University of Sussex and the University of Toronto, he started to work at the University of Leeds as a lecture in 2006 and later at the University of Waterloo as an Associate Professor. His current research interesting is to explore hydrophobic effect and functional nanomaterials via supramolecular chemistry using synthetic molecules.

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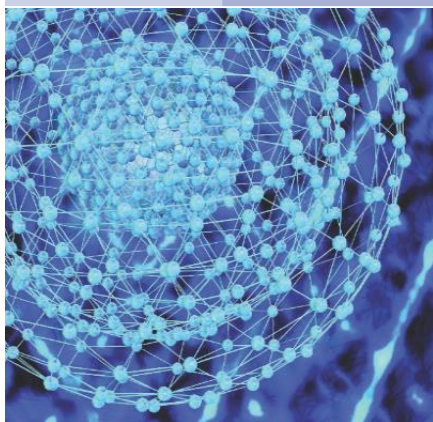
This image shows a single page of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page, leaving small margins at the top and bottom. There are no vertical margin lines, and the paper is otherwise completely blank.



UNIVERSITY OF  
**WATERLOO**



WATERLOO INSTITUTE FOR  
**nanotechnology**



**SMART AND FUNCTIONAL  
MATERIALS**



**CONNECTED DEVICES**



**NEXT GENERATION  
ENERGY SYSTEMS**



**THERAPEUTICS AND  
THERANOSTICS**



# REGION OF WATERLOO IN PICTURES



The Region of Waterloo embraces its heritage from Mennonite German and Scottish-Celtic settlers of the 1800s. Mennonites retained their centuries-long way of living, and you can see them riding horse driven carries around town.

The Region’s technology innovation ecosystem traces its roots to Electrohome, a company that manufactured consumer electronics including record players, radios and TVs since 1907. By 1965, the company’s products were sold in 25 countries. The Electrohome branded electronics are still available in Ontario, and the digital projectors division Christie Digital still operates in the region.



The University of Waterloo (UW) was founded in 1957 with a bold vision of creating a cooperative education program, where students switch between academic semesters and short-term employment in the industry. Today, UW is known for the world’s largest cooperative education program, its inventor’s owned intellectual property policy and Velocity, the world largest free business incubation for startup companies founded by students.



## OPENTEXT™

Starting as a research project for indexing the Oxford English Dictionary, the Waterloo-based OpenText Corporation, founded in 1991, is Canada’s largest software company

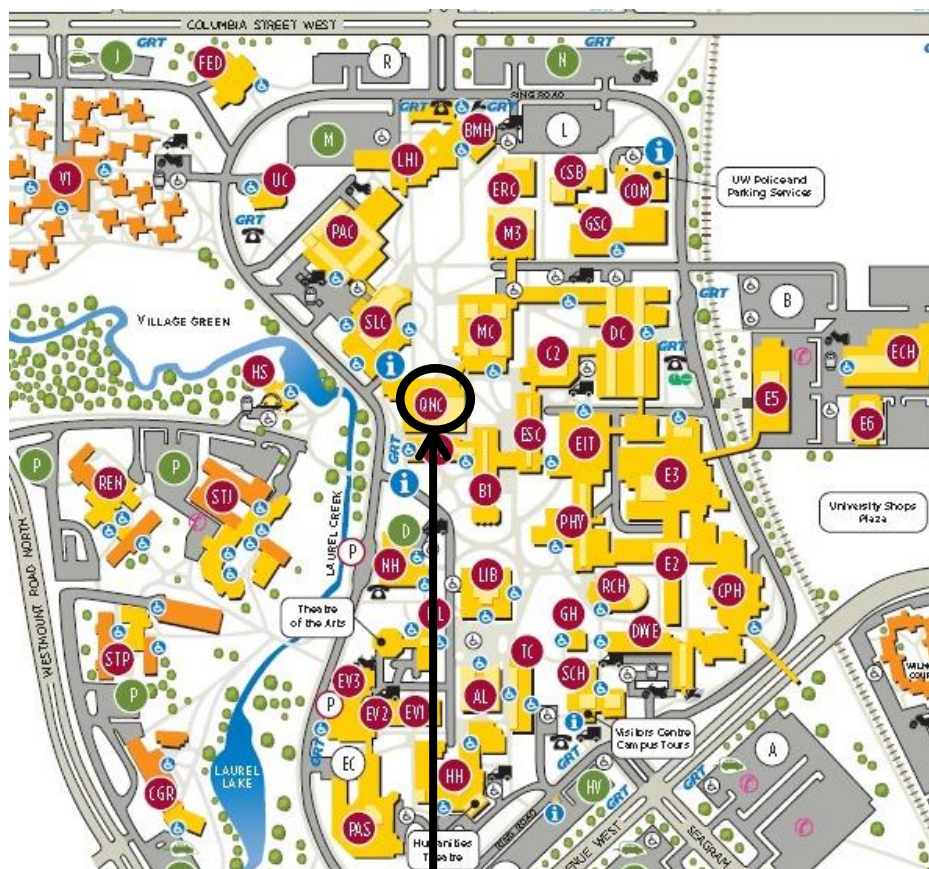
## BlackBerry

Founded by UW students in 1984, BlackBerry is still one the largest employers in the region.

The Toronto-Waterloo Region Corridor is the second largest technology hub in North America, and bolsters second highest density of technology startups in the world (after only Silicon Valley).



# University of Waterloo Campus Map



## Workshop Location

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# Contact Information

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