

# WIN

2019-2020

# ANNUAL REPORT



UNIVERSITY OF  
**WATERLOO**



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## OUR PEOPLE

\*faculty members who hold either an NSERC Canada Research Chair (Tier 1 or Tier 2), a University Chair or a WIN Endowed Chair position.

**16** research chairs

**96** faculty members  
since 2019

## SCHOLARLY TALKS

**2** distinguished lectures

**1** industry seminars

**16** seminars  
\*4 seminars cancelled due to COVID-19

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## 10 DEPARTMENTS

- › Applied Mathematics
- › Biology
- › Chemical Engineering
- › Chemistry
- › Electrical and Computer Engineering
- › Environment, Enterprise, and Development
- › Mechanical and Mechatronics Engineering
- › Pharmacy
- › Physics
- › Systems Design Engineering

## RESEARCH

**6,095**

papers published

since 2008, Scopus source

**157,145**

citations

from 2008-2019, Scopus source

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## NANOFELLOWSHIPS

**12** rounds of nanofellowship competitions

**42** nanofellowships awarded  
(2019-2020)

**436** nanofellowships awarded  
since 2008

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## INTERNATIONAL

**29** international partners in fifteen countries

**23** International publications from WIN-initiated partnerships



## A MESSAGE FROM THE **EXECUTIVE DIRECTOR**

While finishing my three years at WIN, it seems it was just yesterday that I arrived at the University of Waterloo to lead this exceptional jewel in Waterloo's research and innovation ecosystem. Over the past three years, we have evolved significantly – being now the largest nanotechnology institute in Canada with a focused mandate to meet the United Nations' Sustainable Development Goals. With our expansion and growth, we didn't lose our focus of our very existence – to serve our exceptional WIN members and more than 200 graduate students, researchers, post-doctoral fellows who support our research enterprise in an incredible way. Because of this extraordinary human capital, we can surmount ongoing challenges – particularly the current global pandemic due to COVID-19. Our researchers are working tirelessly in partnership with industry and community partners to ensure that we help Canada fight against COVID-19 and create a more just and healthy society. I am proud of our WIN members and indeed their collective energy and efforts keep me and my staff engaged, and maintain our commitment to serve our community in an efficient and empathetic way.

SUSHANTA MITRA

EXECUTIVE DIRECTOR

# STAFF AND GOVERNANCE

## WIN MANAGEMENT AND ADMINISTRATION

Sushanta Mitra	Executive Director	Isabella McKenzie	Operations Assistant
Lisa Pokrajac	Assistant Director, Research Programs	Aman Somel	Financial and
Oleg Stukalov	Business Development Manager		Administrative Assistant

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## BOARD OF DIRECTORS

### CHAIR

Charmaine Dean Vice-President, University Research, University of Waterloo

### MEMBERS

Rina Carlini	President, Optimal Innovation Group Inc.
Lora Field	Team Leader, Cleantech and Advanced Manufacturing Branch, Ontario Investment Office
Karin Hinzer	Professor, Electrical and Computer Engineering, University of Ottawa
Na Young Kim	Professor, Electrical and Computer Engineering, University of Waterloo
Holger Kleinke	Professor, Chemistry, University of Waterloo
Bob Lemieux	Dean, Faculty of Science, University of Waterloo
Sushanta Mitra	Executive Director, Waterloo Institute for Nanotechnology (WIN), University of Waterloo
Linda Nazar	Professor, Chemistry, University of Waterloo
Carolyn Ren	Professor, Mechanical and Mechatronics Engineering, University of Waterloo
David Sinton	Professor, Mechanical and Industrial Engineering, University of Toronto
Pearl Sullivan	Dean, Faculty of Engineering, University of Waterloo
or designate	
Shirley Tang	Associate Dean Research, Faculty of Science, and Professor, Chemistry, University of Waterloo
Boxin Zhao	Professor, Chemical Engineering, University of Waterloo

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## WIN INTERNATIONAL SCIENTIFIC ADVISORY BOARD

### CHAIR

John Thompson Senior Associate Vice-President, Office of Research

### MEMBERS

Fernando Galembeck	Professor, Universidade Estadual de Campinas, Brazil
Kazuhito Hashimoto	President, National Institute for Materials Science (NIMS), Japan
Iain Klugman	President and CEO, Communitech, Canada
Eugenia Kumacheva	Professor and Canada Research Chair in Advanced Functional Materials, University of Toronto, Canada
Richard Martel	Professor and Canada Research Chair in Electrically Conductive Nanostructures and Interfaces, Université de Montréal, Canada
Sushanta Mitra	Executive Director, Waterloo Institute for Nanotechnology (WIN), University of Waterloo

Ajay Sood	President, Indian National Science Academy, Professor, Indian Institute of Science, India
Chen Wang	Former Director General of National Center for Nanoscience and Technology, China
Sir Mark Welland	Deputy Vice-Chancellor; Master of St. Catharine's College, Director of Maxwell Centre, University of Cambridge, United Kingdom
Albert van den Berg	Distinguished Professor, University of Twente and Scientific Director of MESA+, Netherlands

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## SPACE COMMITTEE

### CHAIR

Vivek Maheshwari Professor, Department of Chemistry, Faculty of Science

### MEMBERS

Chris Kleven QNC Facility Technician, Provost Office  
 Isabella McKenzie Operations Assistant, Waterloo Institute for Nanotechnology (WIN)  
 Sushanta Mitra Executive Director, Waterloo Institute for Nanotechnology (WIN)  
 Scott Nicoll Manager, Space Planning, Provost Office  
 Michael Pope Professor, Department of Chemical Engineering, Faculty of Engineering  
 Aman Somel Financial and Administrative Assistant, Waterloo Institute for Nanotechnology (WIN)

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## HEALTH AND SAFETY COMMITTEE

### CHAIR

Tom Dean Director of Technical Operation, Department of Chemical Engineering

### MEMBERS

Dhananjai Borwankar Senior Safety Officer, Safety Office  
 Laura Deakin Continuing Lecturer, Department of Chemistry  
 Chris Kleven QNC Facility Technician, Provost  
 Isabella McKenzie Operations Assistant, Waterloo Institute for Nanotechnology (WIN)  
 Leonardo Simon Professor, Department of Chemical Engineering  
 Aman Somel Financial and Administrative Assistant, Waterloo Institute for Nanotechnology (WIN)  
 A representative from the Waterloo Institute of Nanotechnology Graduate Students Society (WINGSS)

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## SPECIAL PROJECTS AND RESEARCH COMMITTEE (SPARC)

### CHAIR

John Thompson Senior Associate Vice-President, Office of Research

### MEMBERS

Bernie Duncker Associate Vice-President of Interdisciplinary Research, Office of Research  
 David Clausi Associate Dean of Research and External Partnerships, Faculty of Engineering  
 Lisa Pokrajac Assistant Director, Research Programs, Waterloo Institute for Nanotechnology (WIN)  
 Shirley Tang Associate Dean of Research, Faculty of Science  
 Zbig Wasilewski Professor, Department of Electrical and Computer Engineering, Faculty of Engineering



A MESSAGE FROM THE

# CHAIR OF THE BOARD OF DIRECTORS





Every year brings its challenges, and 2020 has certainly brought its share. The 2019 coronavirus disease (COVID-19) has caught the entire world by surprise, spreading quickly and significantly impacting everyone, everywhere – human lives, the economy, and healthcare. One year ago, few of us could have anticipated the trials and problems that we face today. But I am very impressed by and proud of our UWaterloo community in how we have come together to support those who have been directly affected by this crisis; be it in terms of assistance for graduate students who have lost research funding, or how quickly our researchers have been able to pivot to address the current needs of this pandemic.

Nanotechnology has shown its mettle as an enabling technology to address the needs of society during this outbreak bringing new prospects to healthcare, diagnostics and devices, and safe personal protection equipment. WIN and its members are playing a vital role in the fight against this pandemic, with each theme research area providing significant contributions to the battle. From novel sanitizing technologies and nano-coatings for PPE (smart and functional materials), to new bio-sensors for rapid testing for infection (connected devices), to lighter and more efficient batteries to power medical devices for front-line workers (next generation energy systems), to efficient DNA-based vaccine technology that can be easily administered (therapeutics and theranostics), researchers at WIN have risen to the challenges brought forth. I applaud each of them for their hard work and dedication. Not only will nanotechnology help to keep people safe from the Coronavirus now, the new discoveries made in this research will enable us to safely open the Canadian economy. It will be impetuous to the global recovery through a number of these innovations such as a rapid testing kit for contact tracing, vaccine technology for mass deployment, and effective sanitization to protect our workplaces. Overall, it will provide the tools we need to combat such global pandemics as they may arise in the future.

WIN, through the leadership of WIN Executive Director, Sushanta Mitra, is to be commended for its commitment to community service, graduate student and faculty support, and organization throughout this crisis.

**DR. CHARMAINE DEAN**  
**VICE PRESIDENT,**  
**RESEARCH AND INTERNATIONAL**



# SCHOLARLY OUTPUT

## *Publications, Citations and Impact*

WIN members have an impressive record of publications in reputable scientific journals, with an equally impressive number of citations.

### BIBLIOMETRIC ANALYSES

WIN has championed bibliometric analyses within the University of Waterloo through the use of tools such as SciVal and Scopus (Elsevier). In this way, WIN can identify key strengths based on global comparative indices such as field-weighted citation impact (FWCI\*) and collaborations.

#### Total Publications, Citations and Collaborations

2014 to 2019, based on SciVal (Scopus) data

GROUP	PUBLICATIONS	CITATIONS	FWCI*	COLLABORATIONS		
				NATIONAL	INTERNATIONAL	INDUSTRY
WIN Members (total)	3,416	59,541	1.60	11.5%	49.1%	4.5 %
Smart and Functional Materials	2,157	39,343	1.58	10.2%	49.0%	3.6%
Connected Devices	1,527	18,290	1.27	11.6%	46.8%	4.6%
Next Generation Energy Systems	1,207	30,800	2.10	8.7%	47.5%	5.7%
Therapeutics and Theranostics	1,349	22,683	1.49	12.2%	48.9%	2.4%

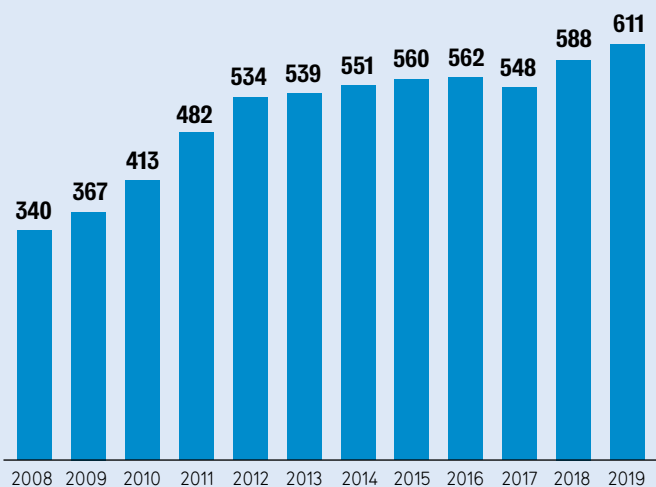
\*FWCI: Field-weighted citation impact compares the number of citations received by a researcher with the average number of citations received by all other similar publications indexed in the Scopus database (ie: a score of 1.44 means the publications have been cited 44% more times than average)

# PUBLICATIONS	# CITATIONS	FWCI	% PUBS TOP 10%
607	2035	1.43	26.70%

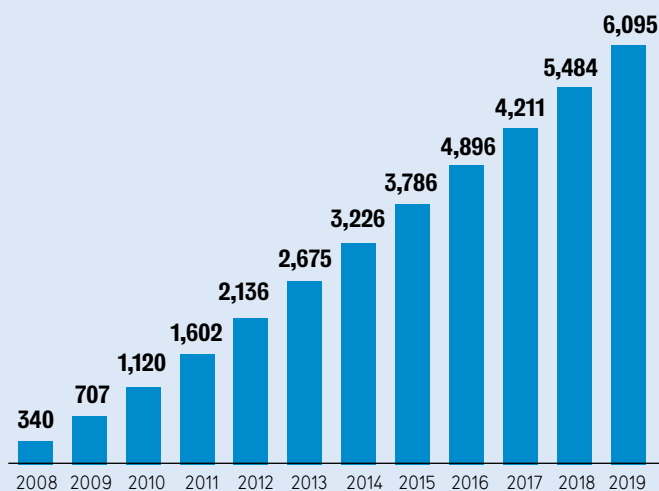




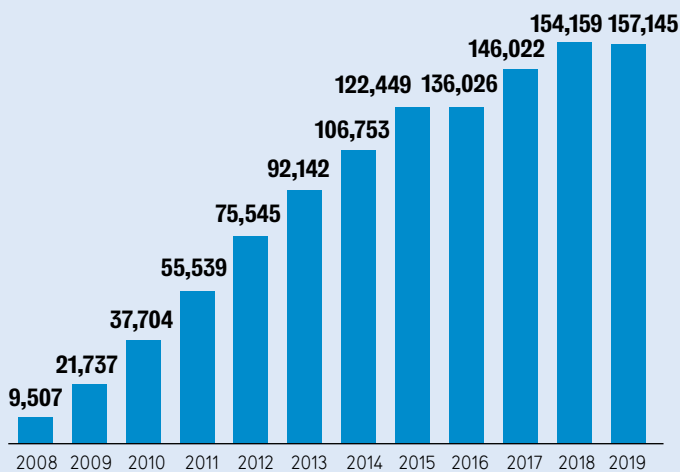
## Total Publications by WIN Members



## Cumulative publications by WIN members



## Cumulative Citations by WIN Members



## WIN Members' Publications in High Impact Factor Journals

Nature Energy	54.0
Nature Materials	38.9
Advanced Materials	25.8
Advanced Energy Materials	24.9
Energy Storage Materials	15.9
Advanced Functional Materials	15.6
Nano Energy	15.3
Journal of the American Chemical Society	14.05
ACS Nano	13.9

## Most Frequently Selected Journals for WIN Members' Papers

Langmuir	17 (IF 3.8)
Analytical Chemistry	14 (IF 6.35)
ACS Applied Materials and Interfaces	12 (IF 8.5)
Nano Energy	9 (IF 15.3)
Nanoscale	9 (IF 6.9)
Angewandte Chemie	8 (IF 12.3)
ACS Sustainable Chemistry and Engineering	8 (IF 7)
Journal of Colloid and Interface Science	8 (IF 6.4)
Advanced Materials Chemistry	7 (IF 24.9)

# THEME LEADS AND CO-LEADS

Thematic leads and co-Leads offer guidance and advice on the best ways to support and promote each research area, particularly in terms of funding opportunities and external academic, industry or international partnerships for each of the four theme research groups at WIN. Below lists each lead or working group member.

Theme leads and co-leads were identified to work closely with WIN staff to offer guidance and advice on the best ways to support and promote each research theme, particularly in terms of funding opportunities and external academic, industry or international partnerships.



- › **Professor John Honek**  
Chemistry (cross- appointed with Pharmacy)  
**Research interests:** bionanotechnology, mechanistic enzymology; recombinant DNA and biophysical methods; medicinal chemistry and molecular modeling
- › **Professor Yuning Li**  
Chemical Engineering (cross-appointed with Chemistry)  
**Research interests:** molecular engineering of polymer/transparent semiconductors for organic electronics (OTFT, OPV, DSC, OLED) and low temp-process conductive inks on plastic substrates
- › **Professor Carolyn Ren**  
Mechanical and Mechatronics Engineering  
**Research interests:** micro/nano-fluidics; lab-on-a-chip; protein separation; live-colony detection
- › **Professor Michael Tam**  
Chemical Engineering  
**Research interests:** sustainable nanomaterials, nano-structured systems for drug/pesticide delivery; polymer-surfactant interactions; magnetic nanoparticles for novel separation processes; functional cellulose nanomaterials for agriculture, biomedical, environmental and personal and homecare applications
- › **Professor Hany Aziz**  
Electrical and Computer Engineering  
**Research interests:** organic electronic and optoelectronic materials and devices; flexible and printable electronics
- › **Professor Boxin Zhao**  
Chemical Engineering  
**Research interests:** fundamental and practical aspects of adhesion, wetting, and friction of soft bio-nanomaterials



## CONNECTED DEVICES

- › **Professor Vassili Karanassios**  
Chemistry  
**Research interests:** micro- and nano-analytical chemistry and instrumentation
  - › **Professor Na Young Kim**  
Electrical and Computer Engineering  
**Research interests:** large-scale solid-state quantum computer; quantum simulator for quantum information processing and communications
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## NEXT GENERATION ENERGY SYSTEMS

- › **Professor Linda Nazar**  
Chemistry (cross appointed with Electrical and Computer Engineering)  
**Research interests:** nano-materials for the design of rechargeable lithium-ion batteries
  - › **Professor Eihab Abdel-Rahman**  
Systems Design Engineering  
**Research interests:** dynamics of micro and nano systems; micro power generators; MEMS and NEMS; atomic force microscopes
  - › **Professor Michael Pope**  
Chemical Engineering  
**Research interests:** directed assembly of graphene-based nanocomposites; supercapacitors; next generation batteries; electrochemical sensors, electrocatalysts; thin films and membranes
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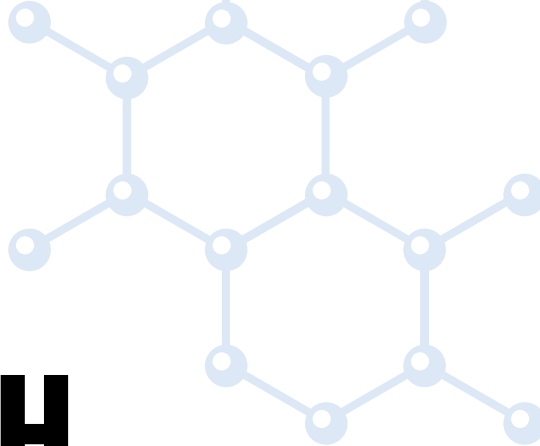
## THERAPEUTICS AND THERANOSTICS



- › **Professor Karim Karim**  
Electrical and Computer Engineering  
**Research interest:** silicon thin-film applied research; microelectronic circuits; device and process development for large area electronics
- › **Professor Alfred Yu**  
Electrical and Computer Engineering  
**Research interest:** nanodroplets and nanoparticles as agents for ultrasound imaging contrast enhancement and drug carriers for therapeutic ultrasound

SELECTED 2019

# RESEARCH HIGHLIGHTS



## NEXT GENERATION ENERGY SYSTEMS



AFFORDABLE AND CLEAN ENERGY

## SMART AND FUNCTIONAL MATERIALS



INDUSTRY, INFRASTRUCTURE AND INNOVATION

*Nature Materials* V 18 I8 pp 874-882 (IF: 38.7; Citations: 3; FWCI: 1.33); Title: “A hybrid material that reversibly switches between two stable solid states”; Authors: Yang, F.K. | Cholewinski, A. | Yu, L. | Rivers, G. | **Zhao, B.**

*Journal of Physical Chemistry Letters* V10 I19 pp5742-5747 (IF: 7.33); Title: “Trapping a Photoelectron behind a Repulsive Coulomb Barrier in Solution”; Authors: Cheng, M. | Rivas, N. | Lim, S.J. | Pichugin, K. | Petruk, A.A. | **Klinkova, A.** | **Smith, R.** | **Hopkins, W.S.** | **Sciaini, G.**

## CONNECTED DEVICES



INDUSTRY, INFRASTRUCTURE AND INNOVATION

*ACS Nano* V13 I11 pp 13285-13292 (IF: 13.9); Title: “Large-Area and Broadband Thermoelectric Infrared Detection in a Carbon Nanotube Black-Body Absorber”; Authors: Zhang, M. | **Ban, D.** | Xu, C. | **Yeow, J.T.W.**

*Nano Letters* V19 I8 pp5739-5745 (IF: 12.34; Citations: 7; FWCI: 3.04); Title: “Tailored Tunnel Magnetoresistance Response in Three Ultrathin Chromium Trihalides”; Authors: Kim, H.H. | Yang, B. | Tian, S. | Li, C. | **Miao, G.-X.** | Lei, H. | **Tsen, A.W.**

*Advanced Materials* V31 I6 (IF: 25.8; Citations: 31; FWCI: 14); Title: “Impact of the Mechanical Properties of a Functionalized Cross-Linked Binder on the Longevity of Li-S Batteries”; Authors: Liu, G. | Li, J. | Fu, J. | Jiang, G. | Lui, G. | Luo, D. | Deng, Y.-P. | Zhang, J. | Cano, Z.P. | Yu, A. | Su, D. | Bai, Z. | Yang, L. | **Chen, Z.**

*Angewandte Chemie – International Edition* V58 I26 pp 8681-8686 (IF: 12.26; Citations: 27; FWCI: 8.05); Title: “Boosting Solid-State Diffusivity and Conductivity in Lithium Superionic Argyrodites by Halide Substitution”; Authors: Adeli, P. | Bazak, J.D. | Park, K.H. | Kochetkov, I. | Huq, A. | Goward, G.R. | **Nazar, L.F.**

## THERAPEUTICS AND THERANOSTICS



GOOD HEALTH AND WELL-BEING

*Nano Letters* V19 I5 pp 3214-3220 (IF: 12.34; Citations: 20; FWCI: 8.67); Title: “Manganese as a Catalytic Mediator for Photo-oxidation and Breaking the pH Limitation of Nanozymes”; Authors: Zhang, J. | Wu, S. | Lu, X. | Wu, P. | **Liu, J.**

*Advanced Drug Delivery Reviews* V145 pp4-17 (IF: 15.6; Citations 9; FWCI: 2.22); Title: “Bacteriophage interactions with mammalian tissue: Therapeutic applications”; Authors: Huh, H. | Wong, S. | St. Jean, J. | **Slavcev, R.**



Figure 2. United Nations Sustainable Development Goals (UN SDG) mapped to the Waterloo Institute for Nanotechnology (WIN) thematic research areas.

**ACS NANO** | This issue ACS Nano 13, 11, 1247-1253 | www.acsnano.org

## The Waterloo Institute for Nanotechnology: Societal Impact and a Sustainable Future

**T**he Waterloo Institute for Nanotechnology (WIN) is Canada's largest nanotechnology institute and a world leader in the broader areas of nanoscience and nanotechnology. Located at the University of Waterloo (UW) in Waterloo, Ontario, Canada, it is truly an interdisciplinary research enterprise representing nine departments and schools spanning across the Faculties of Engineering, Science, and Mathematics.

As WIN enters its 12th year of operation, we have set out to be world leaders in nanoscience and nanotechnology, meeting the targets for the United Nations Sustainable Development Goals (UN SDG) as set out in 2015 that will lead to sustainable development, economic growth, and environmental protection. We are pleased to assemble this WIN Virtual Issue for ACS Nano, highlighting our members' research breakthroughs as shared in ACS publications, with special attention to energy harvesting and storage technology.

As WIN enters its 12th year of operation, we have set out to be world leaders in nanoscience and nanotechnology, meeting the targets for the United Nations Sustainable Development Goals that will lead to sustainable development, economic growth, and environmental protection.

**The University of Waterloo.** The University of Waterloo (UW) in Waterloo, Canada, was founded in 1957 to be an academic center for innovation and entrepreneurship to tackle some of the world's serious problems at the time. During the height of the Cold War and the Space Race, there was a critical need for more scientists and engineers in North America, and the founders envisioned a new type of education to train engineers and technicians through cooperative education. This bold and daring approach to the education system, which has made UW well-known throughout the world, enables academic and research excellence while serving the needs of society throughout its history to present day.

Over the past 60 years, UW has become one of the world leaders in engineering, mathematics, and science, with 2019 QS world subject rankings of #46 for Engineering & Technology, #43 for Mathematics, #22 for Computer and Information Sciences, and #84 for Materials Science. In addition, for the past two decades, UW has been continuously recognized as Canada's Most Innovative University by *Maclean's Magazine* and *The Globe and Mail University Report*, citing UW as the most innovative institution for higher learning, the best experiential learning, and generating graduates best prepared for careers.

Since its inception in 2008, 97 researchers have joined WIN, boasting an impressive publication record and numerous invention disclosures, patent filings, and start-up companies. The Waterloo Institute for Nanotechnology strives to promote research excellence in four key theme areas of nanotechnology—Smart and Functional Materials, Connected Devices, Next-Generation Energy Systems, and Therapeutics and Theranostics—

**Societal Impact and a Sustainable Future.**

Published: November 26, 2019

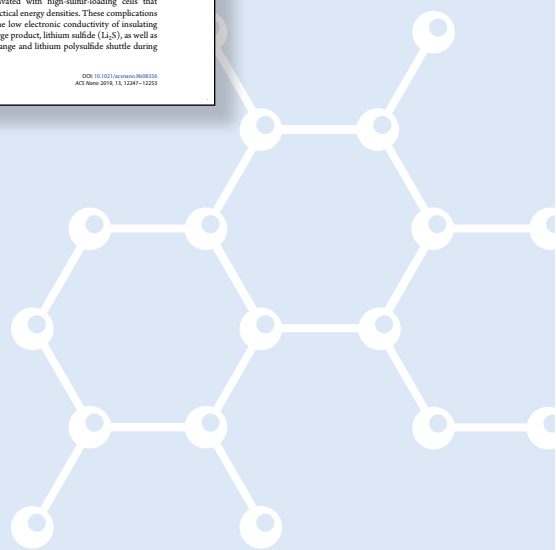
DOI: 10.1021/acsnano.9b02856  
ACS Nano 2019, 13, 1247-1253

conductive Ti-oxide-based materials are a key factor in the charging mechanism for Li-O<sub>2</sub> batteries.<sup>35</sup>

Model studies using electrodes preflled with commercial Li<sub>2</sub>O<sub>2</sub> powders revealed that the nature of the surfaces of materials can play critical roles in the oxygen evolution reaction (OER) by either promoting or limiting charge transport. By using a combination of S/TEM, online mass spectrometry, X-ray photoelectron spectroscopy, and electrochemical methods to probe the surface of carbon and conductive Ti-based nanoparticles, the researchers determined that oxygen evolution during charging is strongly dependent on their surface properties. For instance, two TiO<sub>2</sub> nanocrystalline materials with identical bulk properties but different surface passivation can lead to very different charging profiles. Insulating TiO<sub>2</sub> surface layers on one of the TiO<sub>2</sub> and TiN materials—even as thin as 3 nm—can completely inhibit the charge reaction. This finding demonstrates that facile electron transfer from the catalyst through a nanometric surface layer and into the bulk of a conductive component in a Li-air cathode is the key to efficiency in Li-O<sub>2</sub> chemistry (Figure 3).

Lithium-sulfur batteries are also promising because of their high theoretical energy density, in addition to the natural abundance, low cost, and innocuity of sulfur as an active material. Although Li-S batteries are expected to provide specific energy that surpasses that of LIBs, there are several key problems associated with Li-S battery commercialization, including low sulfur utilization and poor cycle life. These problems are aggravated with high-sulfur-loading cells that attempt to reach practical energy densities. These complications arise mainly from the low electronic conductivity of insulating sulfur and its discharge product, lithium sulfide (Li<sub>2</sub>S), as well as the large volume change and lithium polysulfide shuttle during cycling.

2249 | DOI: 10.1021/acsnano.9b02856  
ACS Nano 2019, 13, 1247-1253



## ACS NANO ARTICLE

This past year WIN was proud to contribute to two Virtual issues – the first published on 22nd October 2019, for which Executive Director Sushanta Mitra co-authored with 20 other Nano-centre directors and leaders, “**The Global Roles and Opportunities for Nanoscience and Nanotechnology**” which outlines the very important role of nanotechnology as the connective thread between traditionally different/divergent disciplines – the nanoscale is the scale of function in many areas – biology for example, novel materials for devices and energy.

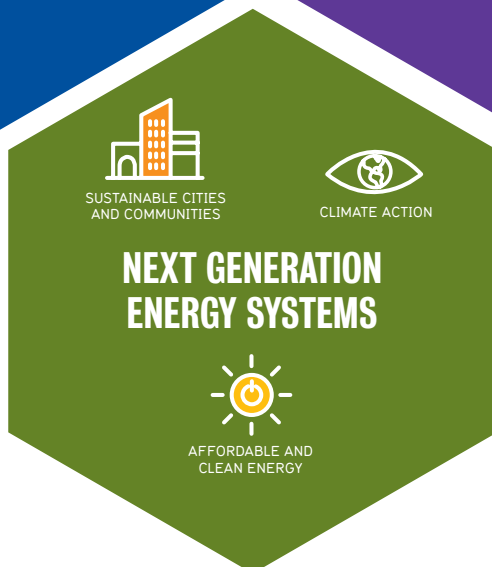
The second article was titled “**The Waterloo Institute for Nanotechnology: Societal Impact and a Sustainable Future**” authored by Lisa Pokrajac, Linda Nazar, Zhongwei Chen, and Sushanta Mitra showcased the nanotechnology research excellence at WIN. This article was published in November 2019.

# SOCIETAL IMPACT OF RESEARCH

To achieve societal impact and sustainable future, WIN's thematic areas are mapped with the United Nations Sustainable Development Goals (SDGs).

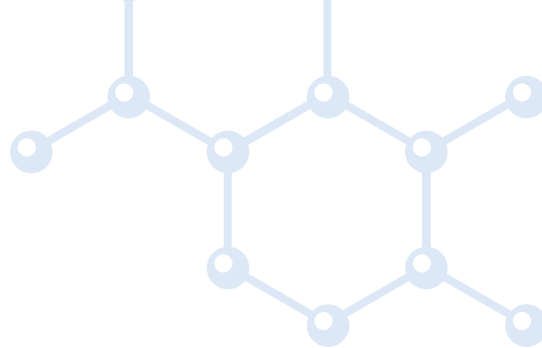
## WIN THEMATIC AREAS:

## UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS:



# COVID-19

## RESEARCH PROJECTS



This year has been an exemplar of humanity's ability to work together for a common good. WIN faculty are tackling COVID-19 and public needs through innovative and groundbreaking research ranging from new nanostructured antibacterial coatings for surfaces and protective gear, sensors for rapid detection and imaging, and battery technology to efficiently power medical devices. Some groups are modelling virus structure through computer simulations for therapeutics and vaccine discovery, while others have teamed

up with local startups to provide fast-to-market technology such as point-of-care tests of COVID-19 virus in patient's bodily fluids, and wearable medical IoT devices for patient monitoring. These projects are being developed for grant applications to upcoming national fast-track programs.

In response to the COVID-19 pandemic, NSERC called out to Canada's talented researchers with their COVID-19 Research Competition to address the global crisis with a total envelope of \$15M in funding. WIN members were recipients of eleven of these awards totaling over half a million dollars. As these projects are ongoing, WIN will report on the findings and impact in 2020-21.

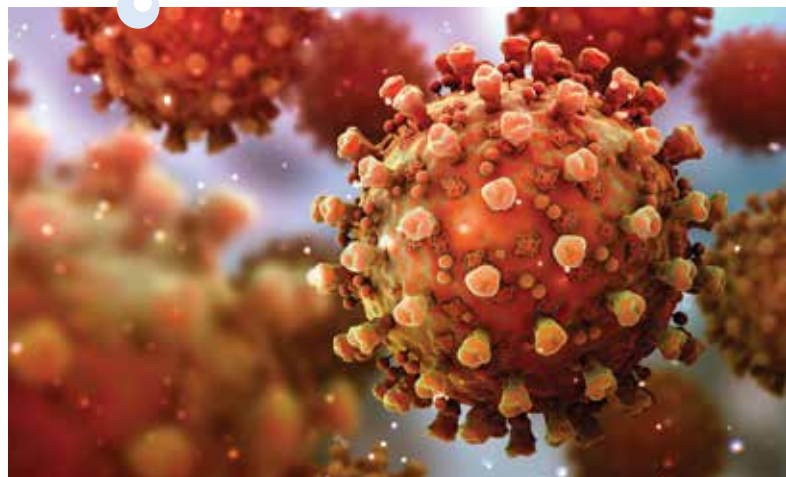
WIN MEMBER	PROJECT TITLE	SECTOR
Aucoin, Marc (ChE)	COVID-19: Inactivation of human coronaviruses in aqueous solutions using UV-C	Advancement of knowledge; Life sciences (including biotechnology)
Ban, Dayan (ECE)	A remote, high-throughput temperature monitoring system for COVID-19 screening	Human health (including medically-related psychological research); Health, education and social services
Hopkins, Scott (Chem)	Ultraviolet Photodissociation (UVPD) Spectroscopy of DMS-selected COVID-19 peptide residues	Human health (including medically-related psychological research); Human pharmaceuticals
Liu, Juewen (Chem)	Development of localized surface plasmon resonance biosensor for COVID-19 antibodies in blood	Human health (including medically-related psychological research);
Mitra, Sushanta (MME)	Characterization of nano-bubble enabled disinfection system for COVID-19	Engineering; Manufacturing processes and products
Mitra, Sushanta (MME)	Testing of antiviral coatings for COVID-19	Engineering; Human health (including medically-related psychological research)
Musselman, Kevin (MME)	Development of COVID-19 antiviral coatings for N95 respirators	Medical equipment and apparatus; Manufacturing processes and products
Pope, Michael (ChE)	COVID-19: Indoor light-activated, self-cleaning surfaces for continuous decontamination of transparent PPE	Human health (including medically related psychological research); Materials performance
Poudineh, Mahla (ECE)	Purification of SARS-CoV-2 Virus-Like Particles (VLPs) Using a Microfluidic Technique for Downstream COVID-19 Vaccine Production	Biomedical engineering; Human pharmaceuticals
Tam, Michael (ChE)	COVID-19: Development of Sustainable and Compostable Face Masks for Enhanced Protection Against COVID-19 Virus Particles	Human health (including medically-related psychological research); Fibres and textiles
Yavuz, Mustafa (MME)	Real-time COVID-19 detection in wastewater from long-term care homes	Human health (including medically-related psychological research); Water

# SYNTHETIC INFECTION

A safe and targeted DNA vector encoding a SARS-CoV-2 Virus-Like Particle as a durable vaccine strategy against COVID-19

Professor Roderick Slavcev at the School of Pharmacy specializes in microbial genetics and biochemistry of nucleic acids and has experience in both academic and industrial settings. His current research encompasses genetics, molecular biology, virology and technology transfer with the goal to bring new therapeutic platforms and treatments to the global environment, and where possible in under-developed countries. In addition to active research, Professor Slavcev serves as the Director of Translational Initiatives for the Faculty of Science at UWaterloo where he works with professors and student teams to translate scientific initiatives and facilitate technological discovery and development.

Professor Slavcev is Founder, Chief Scientific Officer and Executive Director of Mediphage Biocentials, a Toronto-based genetic medicine company that has developed ministring DNA - a unique and novel gene delivery vector that harnesses the power to cure genetic diseases. Mediphage is currently developing world-class genetic medicines that utilize the ministring DNA platform to improve quality of life for patients suffering from chronic genetic diseases with few or no treatment options. He is also co-Founder and CEO of Theraphage Inc, designing and developing specialized, safe and effective bacteriophage-based immunotherapeutics that can be accessed around the world.



The Slavcev lab team, in collaboration with Professors Marc Aucoin in Chemical Engineering and Emmanuel Ho in the School of Pharmacy is currently focusing on applying the new therapeutic platform for developing a COVID-19 vaccine.

This DNA-based vaccine platform can be delivered through a nasal spray, targeting the COVID-19 virus and other viruses as they emerge. The vaccine will work by using engineered bacteriophages, a process that will allow the vaccine to stimulate an immune response in the nasal cavity and target tissues in the lower respiratory tract. When completed, the vaccine will enter cells in targeted tissues and cause them to produce a virus-like particle (VLP) that will stimulate an immune response in people. The VLP will look similar to the structure of SARS-CoV-2 (the virus which causes COVID-19) but is harmless. This similarity will activate the body's natural immune response to protect against viral infections comparable to VLPs, including SARS-CoV-2. It will also bind to receptors that SARS-CoV-2 would bind to, limiting the possible sites for transmission. By causing these changes in the body, the vaccine will build immunity against COVID-19 and decrease the severity of infections in progress – serving as both a therapeutic and a vaccine. Professor Roderick Slavcev will design the nanomedication that will be delivered by the nasal spray and Professor Marc Aucoin (Chemical Engineering) who will construct and purify the VLP and boosting immunity following the initial administration of the therapeutic vaccine.

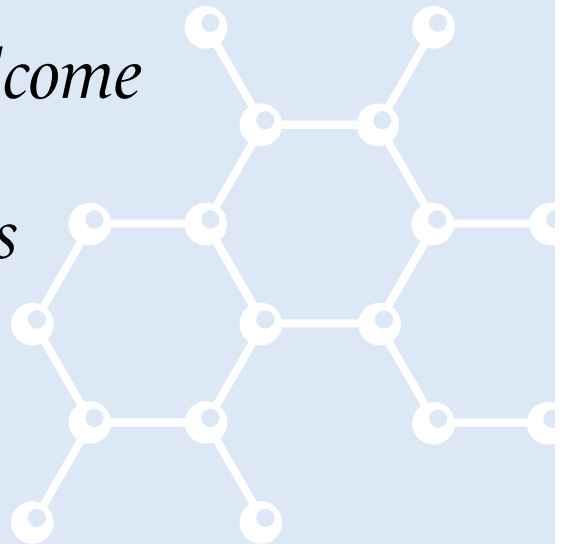


EARLY CAREER RESEARCHERS —

# RISING STARS IN NANOTECHNOLOGY FORGING NEW PATHS

*WIN is delighted to welcome two new Early Career Researchers (ECR) to its membership in 2019.*

Each rising star in their fields – in mechanical engineering (artificial leaf/biomemristors) and electrical engineering (biosensors and devices for cancer detection).





GOOD HEALTH  
AND WELL-BEING



INDUSTRY,  
INFRASTRUCTURE  
AND INNOVATION



WIN welcomed Mahla Poudineh as a Core Member in January 2020 as she started her position as Assistant Professor in the Department of Electrical and Computer Engineering.

Professor Poudineh's research has nanotechnology at its core: truly multidisciplinary, combining new nanomaterials with novel device designs. Her laboratory is aptly named "IDEATION" which stands for Integrated Devices for Early disease Awareness and Translational applicatIONS where new biosensing approaches are being discovered for therapeutics and diagnostics, to translate this technology to a user-friendly biomedical device for clinical use. IDEATION's overall mission is to deploy advanced engineering tools and techniques to help improve the quality of life and long-term survival of patients. At IDEATION, Professor Poudineh is seeking new diagnostic methods for cancer and other diseases – wearable micro/nano devices, and real-time detection of small molecules and biomarkers in living systems.

Her passion to help patients in need started when she was a Masters student at the University of Tehran,

where she was able to put the knowledge and engineering theory she learned during her undergraduate program (also at the University of Tehran) to practical use in a research laboratory. She went on to pursue doctoral studies at the University of Toronto, and under the guidance of her thesis advisor, Professor Ted Sargent and Professor Shana Kelley, she published a very impactful article "Tracking the dynamics of circulating tumour cell phenotypes using nanoparticle-mediated magnetic ranking" in the journal *Nature Nanotechnology* 12 (3), 274-281 (2017).

In this work, Professor Poudineh successfully designed a microfluidic chip to process whole blood samples for cancer patients using a process known as Magnetic Ranking Cytometry (MagRC). This technology utilizes magnetic nanoparticles functionalized with antibodies that bind to specific sites on the tumour cell membrane. When a blood sample is treated with these nanoparticles and introduced

“I always wanted to apply my engineering knowledge to medical problems. At WIN it is wonderful to be surrounded by other researchers in so many different disciplines with similar passion to serve the community. It is a source of inspiration.”

MAHLA POUDINEH

into the microfluidic chip, the magnetic field applied to the MagRC system traps the labelled cancer cells, physically separating them from all other healthy blood cells. This technology can be used to identify the biochemical differences or ‘phenotype’ between circulating tumour cells (CTC) from certain cancers, which would lead to a better understanding of disease progression, and ultimately allow personalized treatment options.

Professor Poudineh's interest in biosensors continued throughout her work at Stanford University as a Post-doctorate Fellow. With Professor Tom Soh's group, a device was developed that could continuously track multiple analytes in blood samples at very low concentrations. The publication titled, “Continuous Detection of Glucose and Insulin in Live Animals” describes how the team developed “real-time ELISA” or RT-ELISA to track different biomarkers – an aptameric probe for blood glucose,

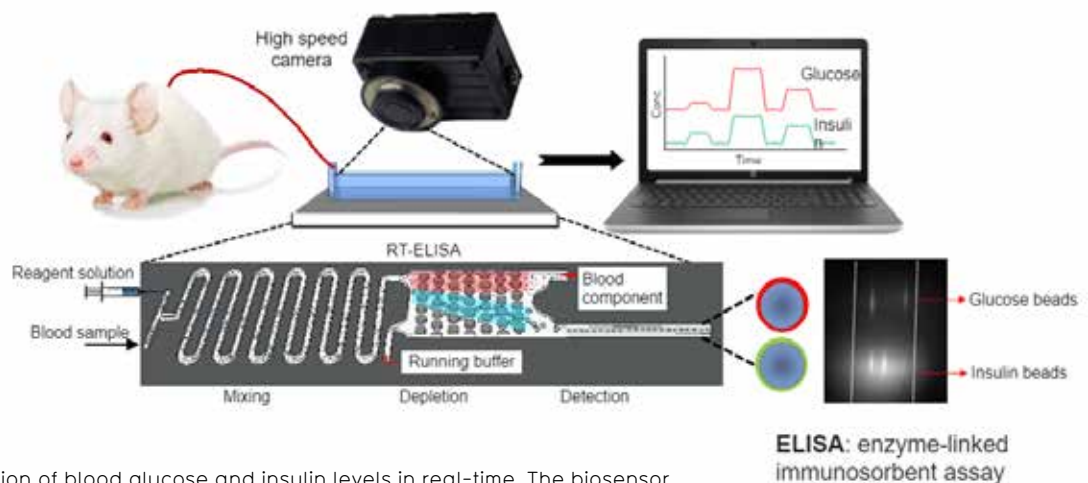
and a fluorescence-bead based immunoassay for insulin detection. This assay was the first to simultaneously and continuously measure both blood glucose and insulin in-vivo with live diabetic rats at pico-molar concentrations.

Additionally, this system was able to distinguish the dynamics and response of insulin moving through a living system (pharmacokinetics and pharmacodynamics). The results of this study can ultimately lead the way for clinicians to create optimal therapeutic regimens tailored to individual patients, and can provide a platform testing system for health conditions beyond diabetes, detecting miniscule amounts of critical biomarkers for cardiovascular disorders and other metabolic or neurodegenerative diseases.

At IDEATION, Professor Poudineh is now exploring new platforms for detection of other cancer biomarkers such as exosomes and circulating tumor DNA, and will also expand to wearable platforms to monitor metabolic diseases such as diabetes, and new devices for vaccine development with direct applicability to SARS-CoV-2.

When asked why she chose the University of Waterloo she replied, “I always wanted to apply my engineering knowledge to medical problems. At WIN it is wonderful to be surrounded by other researchers in so many different disciplines with similar passion to serve the community. It is a source of inspiration.”

WIN is delighted to have Professor Poudineh as a member, and we know she will excel in all aspects of her research. Welcome aboard!



ELISA platform for detection of blood glucose and insulin levels in real-time. The biosensor draws blood sample from rat. The blood then mixes with detection reagents, passes through a chamber to eliminate excess cells, and then arrives at the fluorescent beads detection area.



AFFORDABLE AND  
CLEAN ENERGY



INDUSTRY,  
INFRASTRUCTURE  
AND INNOVATION



CLIMATE ACTION



Yimin Wu joined the University of Waterloo in July 2019 as Assistant Professor in the Department of Mechanical and Mechatronics Engineering and WIN welcomed him as a member in August that year. His research focus is advanced microscopy and imaging techniques, thin film and transition metal oxides, and 2D materials for energy. In 2019-2020, Professor Wu authored a seminal paper in one of the field's top journals – Nature Energy.

Professor Wu's work on the 'Artificial Leaf' directly addresses climate change and the need for affordable energy at the same time by converting carbon dioxide to an organic compound, much like photosynthesis. While other carbon capture and sequestration technology focuses on removing atmospheric CO<sub>2</sub> – a major contributor to climate change – this work converts the CO<sub>2</sub> into methanol which is an alternative to diesel fuels. Using operando transmission electron microscopy (TEM) and high-resolution X-ray powder diffraction (HRXRD), copper oxide (Cu<sub>2</sub>O) nanocrystals were examined for facet-specific active sites capable of binding and reducing CO<sub>2</sub> + H<sub>2</sub>O when combined with radiation

with a wavelength of 532nm (in the visible-light spectrum). It was found that the (110) sites on Cu<sub>2</sub>O served to redistribute electron density for CO<sub>2</sub> + H<sub>2</sub>O adsorption, lowering the energy barrier allowing for complete reduction to methanol. This provides an unprecedented solar-to-fuel efficiency of 10 per cent to any other CO<sub>2</sub>-photocatalysis method. This paper demonstrated the first operando multimodal characterization of light matter interaction under an atmospheric environment and opens the door for finding catalytic materials with other active sites that would give a different reaction pathway to produce fuels other than methanol. The results of this paper were featured in The Independent, CBC News, Canadian Press, BNN Bloomberg, Fast Company, and French Science Magazine.

“WIN was the right fit for me, a very inclusive institute and truly interdisciplinary. This allows research to make a difference – you can really attack problems that matter – to directly improve people’s lives.”

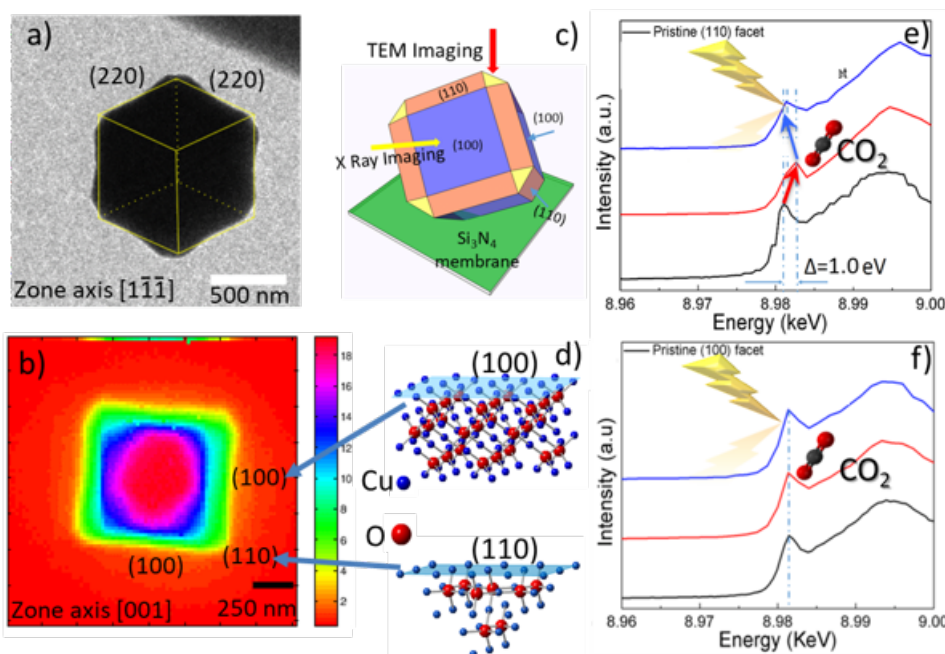
YIMIN WU

Nanotechnology was always a focus for Professor Wu, even during his undergraduate degree in China, where he studied materials science and engineering. From there, he went on to pursue doctoral studies at the University of Oxford in the United Kingdom, focusing on two-dimensional quantum materials, thin film devices, and aberration corrected scanning transmission electron microscopy. After graduation, he was awarded the SinBeRise Postdoctoral Fellowship at the University of California at Berkeley, and the Lawrence Berkeley National Laboratory for one year. He then joined the University of Illinois as Research Assistant Professor

and also at the Center for Nanoscale Materials and Joint Center for Energy Storage Research (JCESR), Argonne National Laboratory in Chicago, where he focused on the advanced catalysts and battery research using integrated imaging approaches.

Yimin Wu first learned about the University of Waterloo from his colleague at the University of Oxford who was a UWaterloo alum in Physics. He was attracted to Canada as a nation because of its reputation for inclusivity, and to UWaterloo for its reputation for research excellence and its unique policy on intellectual property. “WIN was the right fit for me, a very inclusive institute and truly interdisciplinary. This allows research to make a difference – you can really attack problems that matter – to directly improve people’s lives.”

Yimin Wu has been very productive as an early-career researcher since he graduated from Oxford seven years ago; he has already authored and co-authored more than 30 peer-reviewed journal papers and is listed as an inventor on a US/international patent. He has also received 10 awards since graduation – including the MIT Technical Review Innovators Under 35 Award Finalist (2020). We look forward to what the next seven years will bring!



a) TEM image showing Cu<sub>2</sub>O truncated cube nanoparticle. b) High-resolution SFXM image of the particle shown in a). c) Schematic of how the electron and X-ray beams aligned with the facets of the nanoparticle. d) location of Cu and O atoms in the nanoparticle facets, e) and f) are graphs received using X-ray scanning nanospectroscopy which demonstrate oxidation state changes at the (110) and (100) facets respectively of nanoparticle in the pristine state, with CO<sub>2</sub>/H<sub>2</sub>O gas exposure under dark and under illuminated conditions.

GORETTY DIAS AND ANNA KLINKOVA

# INTERDISCIPLINARY COLLABORATION



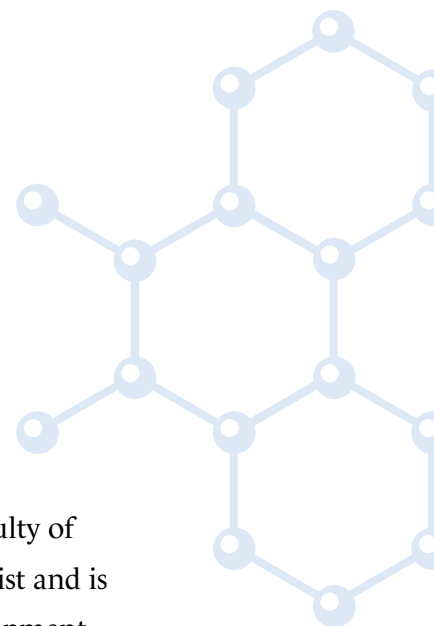
INDUSTRY,  
INFRASTRUCTURE  
AND INNOVATION



RESPONSIBLE  
PRODUCTION AND  
CONSUMPTION



CLIMATE ACTION



In 2019, the WIN membership expanded beyond the Faculties of Science, Engineering and Mathematics to welcome the first researcher from the Faculty of Environment. Goretty Dias is a sustainability scientist and industrial ecologist and is an associate professor in the School of Environment, Enterprise and Development.

With her background in natural sciences and engineering, Professor Dias' research has evolved to focus on Life Cycle Assessment (LCA) and other tools to create more sustainable agriculture, bioproduct, and food systems. In 2017, Professor Dias published a popular article which provided an environmental and economic overview of pyrolysis technologies for converting ligno-cellulosic biomass into biofuels and other bioproducts.

In 2019, a research collaboration began between Dias and Assistant Professor/Early Career Researcher Anna Klinkova from the Department of Chemistry on the conversion of industrial pollutants into value-added products. Specifically, CO<sub>2</sub> and nitrogen-based pollutants, such as ammonia, can be turned into specialty chemicals and nitrogen fertilizer, contributing to the growth and goals of a circular economy.

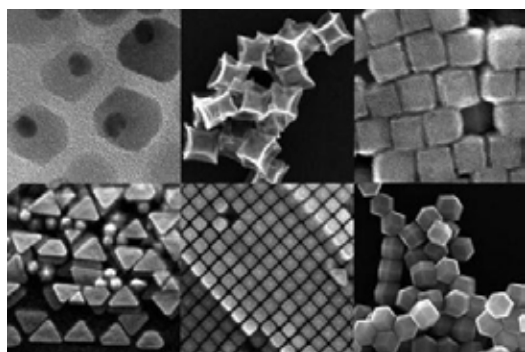
Many researchers around the world are primarily focusing on the direct electrochemical conversion of CO<sub>2</sub> into various chemicals such as fuels or feedstock for other useful materials (formate, formaldehyde, formic acid, methane, methanol, ethanol, etc). However, such substances are usually lower-priced commodities, and many conversion processes are proving to be economically disadvantaged in terms of scale-up costs. Building on the results first published by Klinkova's lab in ACS Sustainable Chem. Eng. in 2019, this joint project focuses on advancing electrochemical methods to convert CO<sub>2</sub> via electrocarboxylation in an electrolyzer operating with non-sacrificial anodes. In this approach, CO<sub>2</sub> is made to react with other lower value substances that are readily available at the industrial scale, resulting in the production of industrially relevant carboxylic acids. To further improve the commercial potential of this CO<sub>2</sub> reduction approach, Professor Klinkova's lab has demonstrated that coupling this chemistry with anodic oxidation of wastewater components is a means to minimize energy requirements of operating the electrolyser, while introducing additional environmental benefit.

## ANNA KLINKOVA



Anna Klinkova with her research group, Anna is fourth from the left, seated.

**Professor Anna Klinkova** received her undergraduate degree from Saint Petersburg State University in 2009 in organic chemistry, followed by a master's degree in photochemical sciences from Bowling Green State University in 2011, sparking her interest in chemistry for sustainable energy generation, studying alloy and hybrid semiconductor nanocrystals for incorporation into solar cell devices. She continued her graduate studies on nanomaterials chemistry in the Kumacheva group at the University of Toronto, earning a doctorate in Chemistry in 2015, followed by a prestigious Connaught Postdoctoral Fellowship with the Sargent group in the Electrical and Computer Engineering Department, also at the University of Toronto. Professor Klinkova joined the University of Waterloo in 2017, where her research goals are to build functional (electro) catalytic devices for energy and sustainability needs, and studying the effects of nanocrystals for their physiochemical properties for thermal, photo, and electrocatalysis.



On the left: a collection of TEM images of nanocrystals demonstrating precision with which Prof. Klinkova's lab can control its size, shape, surface morphology, and surface chemistry. On the right: Cartoonistic diagram showing a proposed sustainable eco-system which converts waste into value-added chemicals using waste CO<sub>2</sub>, sunlight, renewable electricity as inputs and water as by-product.

## GORETTY DIAS



**Professor Goretty Dias** received her undergraduate degree from University of Guelph in 1993 and a PhD in Atmospheric science in 1998. In her undergraduate degree, she was introduced to the concept of how biology and associated mass and energy fluxes influence the atmosphere, which led to her work on spectroscopic methods to measure trace gases from agriculture for her PhD. During her post-doctoral work on metals and trace gases in Environmental Engineering, she became interested in the importance of economics, business, and policy on decision-making, and turned to life cycle thinking and LCA as a way of evaluating and communicating environmental impacts in a holistic way. She worked for five years in consulting, working on evaluating technology projects. Her academic and consulting experience has made her an expert in the LCA of biomass systems. She joined the Faculty of Environment in 2010 and has been working on evaluating systems and technologies related to biofuels, bioproducts, and food. She has been expanding her LCA work to other systems, such as construction materials and green chemicals, through collaborations with engineers and scientists at various universities.





# INTERDISCIPLINARY RESEARCH FUNDING PROGRAM (IRFP)

# PROJECT UPDATE HIGHLIGHTS

Increasingly, more diversified teams are needed for inclusion in high-profile networks and large-scale national and international funding programs, and economics and social sciences is proving instrumental in today's research climate for STEM research. Since 2018, WIN has promoted collaboration between traditionally dissimilar fields to spark new ways of thinking of large-scale problems requiring a multi-faceted approach to finding solutions.

The overall objective is to support 'high-risk/high-reward' discovery research with significant impact on society. This seed-funding will assist WIN members to apply for large-scale international funding programs within 18-24 months of commencing the projects.

In October 2019, the WIN-IRFP was tailored to foster research partnerships with WIN's sister institute in the Netherlands, MESA+ Institute for Nanotechnology at the University of Twente, with complementary research strengths and applications in the following areas:

<b>ENABLERS</b>	<b>HEALTHCARE</b>	<b>INFORMATION AND COMMUNICATIONS TECHNOLOGIES</b>	<b>SUSTAINABILITY (ENERGY AND ENVIRONMENT)</b>
Smart Materials	*	*	*
Photonics	*	*	*
Fluidics	*		



In December 2019, five joint applications were received by teams from WIN and MESA+. Three projects were selected for funding at **\$75,000 CAD** each on the WIN side, matched by MESA+ at €50,000 for the Dutch PIs:

## 1 Integrated solution to ammonia and carbon dioxide recycling to fertilizers and fuels

- › Anna Klinkova (WIN/Chem)
- › Jeff Wood (MESA+)

## 2 On-chip platform for tunable nonlinear optics and reconfigurable quantum photonics

- › Hamed Majedi (WIN/ECE)
- › Bo Cui (WIN/ECE)
- › Klaus Boller (MESA+)

## 3 Laser-synthesized 2D nanosheets for epitaxial growth of functional oxides on any substrate

- › Kevin Musselman (WIN/MME)
- › Gertjan Koster (MESA+)



In January 2020, the second call for the Interdisciplinary Research Fund Program (IRFP) was announced to seed innovative research that leads to big impacts in the following three key targeted global challenges:

- 1 CLIMATE CHANGE
- 2 REDUCTION OF GLOBAL WASTE
- 3 BIODIVERSITY LOSS

This round was also aligned with the 2020 New Frontiers in Research Fund Transformation Competition (NFRF-T) to incent and support applications to this program.

The WIN-IRFP has a total envelope of around \$500,000 CAD for this program, offering awards of **up to \$250,000 CAD** each. Four applications from WIN members were submitted to this program, with awards announced in the 2020-21 year.

# NANOTECHNOLOGY IN ENTREPRENEURSHIP

# SMALLEST AFM

# IN THE WORLD



Since its inception in the 1980s, the atomic force microscope (AFM) has become a workhorse for nanoscience and nanotechnology researchers. At the core of any AFM are piezoelectric scanners, an ultra-sharp stylus tip, and a sensing system. Scanning the tip across the surface and recording the measurements from the sensor produces a 3D image of nanoscale features on the surface.

The biggest advantage of AFM is that it does not require ultra-high vacuum conditions to operate and it can be used to scan a wide variety of samples. One University of Waterloo nanotechnology spin-off company is standing above the crowd to create these useful instruments. ICSPI (pronounced as eye-see-spy) at UWaterloo's Velocity Garage is quietly taking over the world with the most portable AFM on the market!

ICSPI was co-founded by Professor Raafat Mansour in Electrical and Computer Engineering and his graduate student, Neil Sarkar. ICSPI designs, manufactures and sells single-chip MEMS-based AFM for educational, research and industrial applications, including failure analysis and quality control. Their flagship product, the nGauge AFM, has reset the expectations for

AFM and nanoscale metrology – all of the scanners and sensors have been integrated onto a single 1 mm x 1 mm CMOS chip, miniaturizing the size, driving down costs, and dramatically simplifying the operation of AFM. The company has customers in over 15 countries – at world-leading universities, government research institutes, and companies of all sizes from start-ups to multinationals.

Some of ICSPi's customers are now collaborators bringing applications for the nGauge to new levels; one such area is related to product inspection and failure analysis in the semiconductor industry. This is one of the first commercial uses of AFM outside academic research labs. Recognizing the huge economic value of rapid inspection in the semiconductor industry, researchers at the University of Texas at Austin integrated

On left is David Morris, ICSPi Director of Operations at the 2019 Nanotechnology Engineering Design Days at UWaterloo; top right is the miniaturized AFM developed at ICSPi; bottom right (Oleg to add details)



multiple AFM chips from ICSPi into powerful in-line inspection systems. This allows inspection right after the processing step, without having to take the part “off-line”, offering unprecedented precision in quality control for manufacturers.

Another amazing story comes from an ICSPi customer in Denmark, a company in the metal analysis/ metallography industry. During the COVID-19 lockdown in March, one of the company’s R&D engineers was able to take an nGauge AFM unit home and was able to continue her product development work. There, it was set up on a living room table – which was immediately converted into a laboratory bench for nanoscale measurements!

ICSPi continues to contribute back to the UWaterloo community. ICSPi’s Director of Operations, David Morris, participated in the University of Waterloo’s second year Nanotechnology Engineering design days in the Fall of 2019. The students were tasked with building a Scanning Tunneling Microscope (STM, a pre-AFM microscope for which the Nobel Prize in Physics was awarded in 1986). A core group of early employees at ICSPi are graduates from the Nanotechnology Engineering undergraduate program, so it was natural for ICSPi to be there sharing their expertise!

# SPOTLIGHT ON NEW STARTUPS

## MICROWAVES MEASURE PROPERTIES OF LIQUIDS

Microwave may be best known for heating food in your oven and telecomm transmission, but it also makes a powerful analytical tool.

In the last 10 years, microwave spectroscopy was invented; however, such devices are bulky and energy inefficient. Professor Carolyn Ren (Department of Mechanical and Mechatronics Engineering) tasked her graduate students to miniaturize the microwave sensor and combine it with a microfluidic device to fingerprint liquid properties. After several years of experimentation, this development culminated with a research paper in 2013 (*Lab on a Chip*, 2013, 13, 3840), which was chosen by the editor for the journal edition's cover page.

QuantWave Technologies Inc., was founded in December 2016 by Professor Ren and two former graduate students from the University of Waterloo, Alex Chen, PhD, and Michael Wang, who brought in industrial experience in commercialization and applications.

The company was created to pursue the growing demands of intelligent sensing for industrial IoT applications. QuantWave aims to improve the quality of industrial manufacturing processes and finished products, minimize the capital and operational costs as well as to provide optimal decision-making tools by developing a real-time,

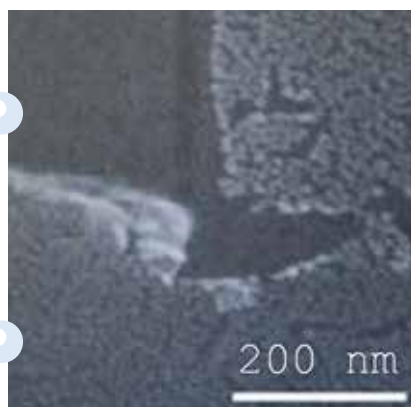
AI-powered and multi-parameter intelligent sensing system. The company integrates microfluidics and high-frequency microwave technologies with AI algorithms to provide online monitoring and predictive data analytics for a variety of industrial liquids, with an initial focus on water, dairy products and beverages. For example, Quantwave has developed sensors capable of monitoring biological oxygen demand, chemical oxygen demand, conductivity, turbidity, and orthophosphate and other parameters in wastewater, and for testing milk for total fats, proteins, solids in real time. Both applications have been successfully demonstrated at the pilot scale with industrial partners.



QuantWave™  
Intelligent Lab-on-chip

## THREE INNOVATIONS EXPAND POSSIBILITIES OF ELECTRON MICROSCOPY IMAGING IN FLUID

When studying nanomaterials using electron microscopy, the pursuit of better image quality never stops.



The common belief is that electron microscopy (EM) can only be used on dry samples because of the vacuum inside the microscope's column. This is no longer the case, as researchers can now visualize fully solvated nanoscale objects in liquids such as water from cryogenic to room temperature conditions. Room temperature in-liquid observations are achieved by squeezing the sample into a nanofluidic chip with a very narrow gap

(down to 50nm) between two ultrathin membranes, so that the electron beam can get through the “sandwich” and reach the image detector. There are commercial fluid cell products offered on the market, but these have limited functionality.

The Sciaini Group in the Department of Chemistry found three unique innovations in this field. One of their microchip designs allows fluid flow to capture time images and videos of in-liquid nanoparticles (see figure). Another innovative design involves the application of electrodes. This type can be used for studying electrochemical processes on the nanoscale in real-time, in-situ morphology changes on the surface of lithium-ion battery electrodes. They also created a cryo-electron microscope (cryoEM) holder, which eliminates the sample drift and vibrations introduced by the liquid nitrogen dewar. This last version is highly sought in biochemistry and pharmaceutical research for studying protein structures with atomic resolution. All the three technologies are compatible with major brand name electron microscopes.

The designs of these innovative nanofluidic chips and the cryoEM holder are protected by several patent applications. Further developments are now supported by the NSERC Idea to Innovation (I2I) program. “NSERC I2I provided vital financial support towards market assessments as well as the production of prototypes. It allows us to finalize the fabrication of commercial-grade liquid-cell and cryoEM holders for Hitachi and FEI transmission microscopes, and we are about to start the production of JEOL holders”, said German Sciaini.

The group's next big thing is to get ready to launch a new startup company. They already engaged with WIN's Startup Catalyst program in developing a business plan.



# UNDERGRADUATE NANOTECHNOLOGY ENGINEERING

The University of Waterloo's Nanotechnology Engineering (NE) program provides a practical education in key areas of nanotechnology, including the fundamental chemistry, physics and engineering of nanostructures and nanosystems, as well as the theories and techniques used to model, design, fabricate or characterize them.

Students acquire comprehensive training in the rapidly developing nanotechnology field, which allows them to work across conventional disciplines in many industry sectors.

This program, Canada's first accredited undergraduate nanotechnology engineering program, celebrates its 15th year in 2020. Its broad interdisciplinary foundation gives graduates a solid start upon graduation, whether they decide to work in industry, pursue additional studies or start their own business. NE alumni's distinction for academic strength is closely matched by their reputation for entrepreneurial skills – more than forty successful NE-alumni-led startups have passed the important five-year milestone.

The NE program shares space with WIN in the Mike and Ophelia Lazaridis Quantum-Nano Centre, and the relationship between NE students and our institute goes beyond location. Many

of WIN's international and industry partners have worked directly with NE students. In 2019, 34 NE students had co-op placements at WIN partnerships, including the University of Bordeaux in France and the National Institute for Materials Science (NIMS) in Japan. Thanks to our partners for providing NE students with opportunities to synthesize their classroom education in such exciting environments.

For information about hiring a  
Nanotechnology Engineering  
co-op student, contact  
[nanoinfo@uwaterloo.ca](mailto:nanoinfo@uwaterloo.ca)

## WATERLOO NANOTECHNOLOGY CONFERENCE

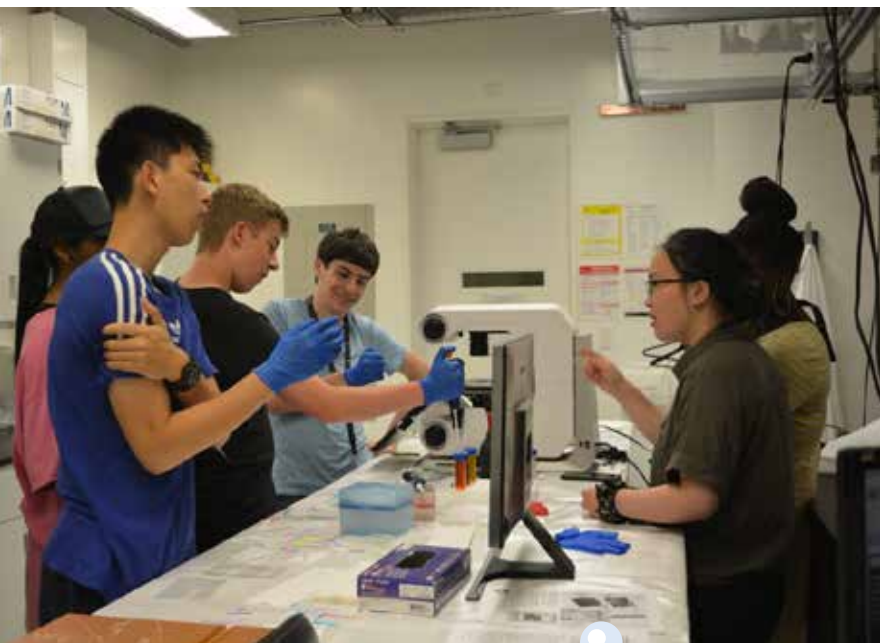
In 2015, an ambitious group of Nanotechnology Engineering students founded the Waterloo Undergraduate Nanotechnology Conference (WUNC). This conference was run by undergraduate students initially and as of 2018, sprouted a collaboration between undergraduate and graduate students in nanotechnology, changing its title to Waterloo Nanotechnology Conference (WNC).

This student-run conference is supported by WIN and through this partnership, the conference invites top academics, industrialists, entrepreneurs and government officials. Each year, exceptional keynote speeches are given by world-renowned researchers in Nanotechnology. In November 2019, WNC speakers included Mathieu Luisier, Associate Professor of Computational Nanoelectronics at Eidgenössische Technische Hochschule Zürich; Eli Yablonovitch, Director of the NSF Center for Energy Efficient Electronics Science at University of California, Berkeley; Ehsan Fathi, VP of VueReal; Carley Miki, Research Scientist at Mirexus Biotechnologies Inc; and Eric Fox, CMOS Image Sensor R&D at Teledyne DALSA.

The event also featured panel discussions, a poster session and several networking opportunities for students. The year's event drew an audience of 250+ students from over 20 different majors of study.



participants in the Micro & Nano-scale Transport Lab, Quantum Nano Centre



## OUTREACH

### SHAD CANADA

Shad is an annual Canadian summer enrichment program, bringing exceptional high school students to Canadian university campuses each summer. In July 2019, six students visited WIN for one week, obtaining hands-on learning in experimental design. WIN member Professor Chris Backhouse from the Department of Electrical Engineering, in collaboration with Professor Sushanta Mitra, hosted the students and introduced them to paper-based microfluidics experiments, illustrating how to easily analyse a mix of fluids which has a variety of applications in medical diagnoses, environmental monitoring, food and water testing.

# COLLABORATIVE NANOTECHNOLOGY GRADUATE PROGRAM

The University of Waterloo's Collaborative Graduate Nanotechnology Program provides students the opportunity to advance their understanding of nanotechnology through a rich, broad and integrated advanced education. The program's six member departments, including Chemistry, Physics, Chemical Engineering, Electrical and Computer Engineering, Mechanical and Mechatronics Engineering, and Systems Design Engineering, offer master's and doctoral degrees with a nanotechnology notation.

Core courses address foundational elements of nanotechnology, while a wide range of nanotechnology elective courses allow students to customize their education and broaden their perspective. The flexible, inter-disciplinary approach provides students with a strong foundation in their choice of nano-engineering, nano-science or a combination of the two, in preparation for the workforce, further graduate study and/or research.

Many WIN members participate in this UWaterloo program by teaching its courses and supervising its students. This past year, the Quantum Nano Centre (QNC) buzzed with the research activity of 54 master's students, 87 doctoral students and 28 postdoctoral fellows, many of whom were involved with the graduate nanotechnology program.

At WIN, students, faculty and industry work together – learning, pursuing innovative ideas and research, and inspiring each other towards technological innovation, social benefit and economic growth.

WIN members are active researchers and mentors to students in many programs. Between 2013 and 2019, they supervised and co-supervised approximately 680 graduate students and post-doctoral fellows in the QNC and many others in their home departments.

WIN provides graduate students and post-doctoral fellows with a supportive, community environment in the QNC by welcoming them to its main office for a wide range of assistance, including key and office allocations; supporting their academic success with Nanofellowships; and enriching their extracurricular activities through the Waterloo Institute for Nanotechnology Graduate Student Society (WINGSS).





Student poster session at the Waterloo Nanotechnology Conference in 2019, photo by: JiaJia Kong



# WINGSS

Since its inception in 2014, WINGSS increases networking and collaboration between graduate students pursuing nanotechnology research (over 200 graduate students across science and engineering). WIN has enabled this club to flourish via financial support (approximately CAD 10,000 in total since 2014) and working directly with the club to help spark new ideas and processes on how to promote and facilitate events.

The WINGSS Career Panel was a special event hosted by the WINGSS team as part of the 2019 Waterloo Nanotechnology Conference (WNC) in an effort to help guide graduate nanotechnology students into various career paths, as well as introduce the undergraduate nanotechnology students career options should they choose to pursue a nano-graduate degree. The executive team secured funding from the Faculties of Engineering and Science, the Waterloo Graduate Student Society (GSA), as well as from WIN. Administrative support from WIN has been instrumental in bringing in industry, government, and academic personnel to participate in a panel geared toward nanotechnology graduate students. The impact of this event helps guide current and future students in discovering all the possibilities offered by the nanotechnology field.



# NANOFELLOWSHIPS

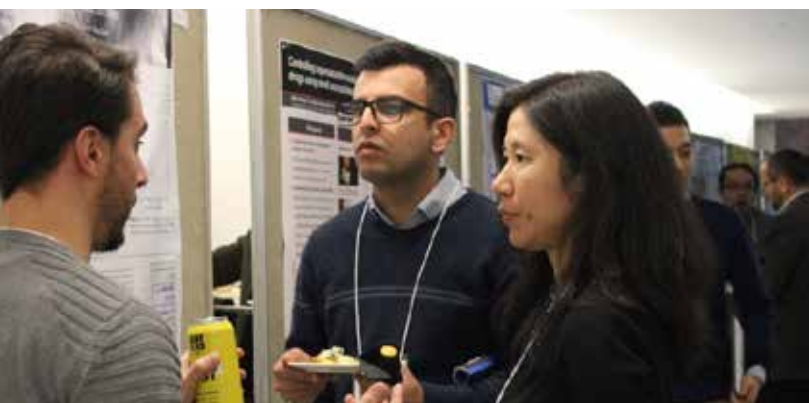
WIN Executive Director congratulates Nanofellowship winner Janine Thoma at the Nanotechnology Research Gala in November 2019

WIN provides significant funding to attract and retain graduate students in the form of scholarships made possible from a generous donation from Douglas Fregin. The \$10.5M endowment provides funds for the scholarships in nanotechnology, with each award valued at \$10,000.

The Nanofellowships are awarded to outstanding students conducting nanotechnology research through an annual competition for international, permanent resident and Canadian students. This scholarship program is designed to recruit students from external Canadian and international universities, and retain exceptional talent from UWaterloo's undergraduate science and engineering programs.

## 2019 RECIPIENTS

- › Alaaeldin Ahmed
- › Navjot Khaira
- › Zachary Strike
- › Ayman Alneamy
- › Asif Abdullah Khan
- › Sina Talebi Moghaddam
- › Elif Pinar Alsac
- › Ivan Kochetkov
- › Chunxia Tang
- › Hatameh Asgarimoghaddam
- › Braden Kralt
- › Janine Thoma
- › Lauren Blanc
- › Monika Snowdon
- › Yannick Traore
- › Remi Casier
- › Feng Li
- › Alexandru Vasile
- › Jialu Chen
- › Dan Luo
- › Guobin Wen
- › Hyunwoo Choi
- › Alireza Mashayekhi
- › Luzhu Xu
- › Ya-Ping Deng
- › Kissan Mistry
- › Fan Ye
- › Run Ze Gao
- › Ryan Moreira
- › Penghui Yin
- › Chulgi Hong
- › Bohua Ren
- › Hyeonghwa Yu
- › Jiahao Huang
- › Stephen Robinson-Enebeli
- › Zhen Zhang
- › Christian Ieritano
- › Muhammad Shahidul Islam
- › Moslem Sadeghi Goughari
- › Geoffrey Sinclair
- › Yiju Zhao
- › Laidong Zhou



## WIN NANOFELLOWSHIP COMMITTEE

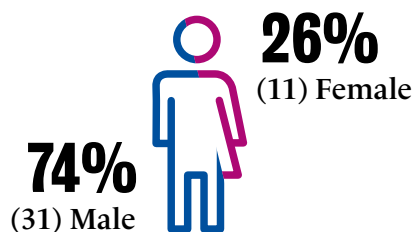
This committee was created to steward the fair and optimal disbursement of funds for the annual competition and to increase transparency of the selection process Members: ADGS Engineering and Science; WIN faculty representing Deans Engineering and Science; WIN ED and ADRP. The Chair of the committee for the 2019 competition was Professor Moira Glerum from the Department of Biology.

CITIZENSHIP	APPLICANTS	AWARDEES
Canadian	35 (33%)	15 (36%)
International	58 (55%)	24 (57%)
Permanent resident	10 (10%)	3 (7%)
<b>Total</b>	<b>103</b>	<b>42</b>

DEGREE PROGRAM	APPLICANTS	AWARDEES
PhD	75 (71%)	38 (90%)
MASc/MSc	28 (27%)	4 (10%)

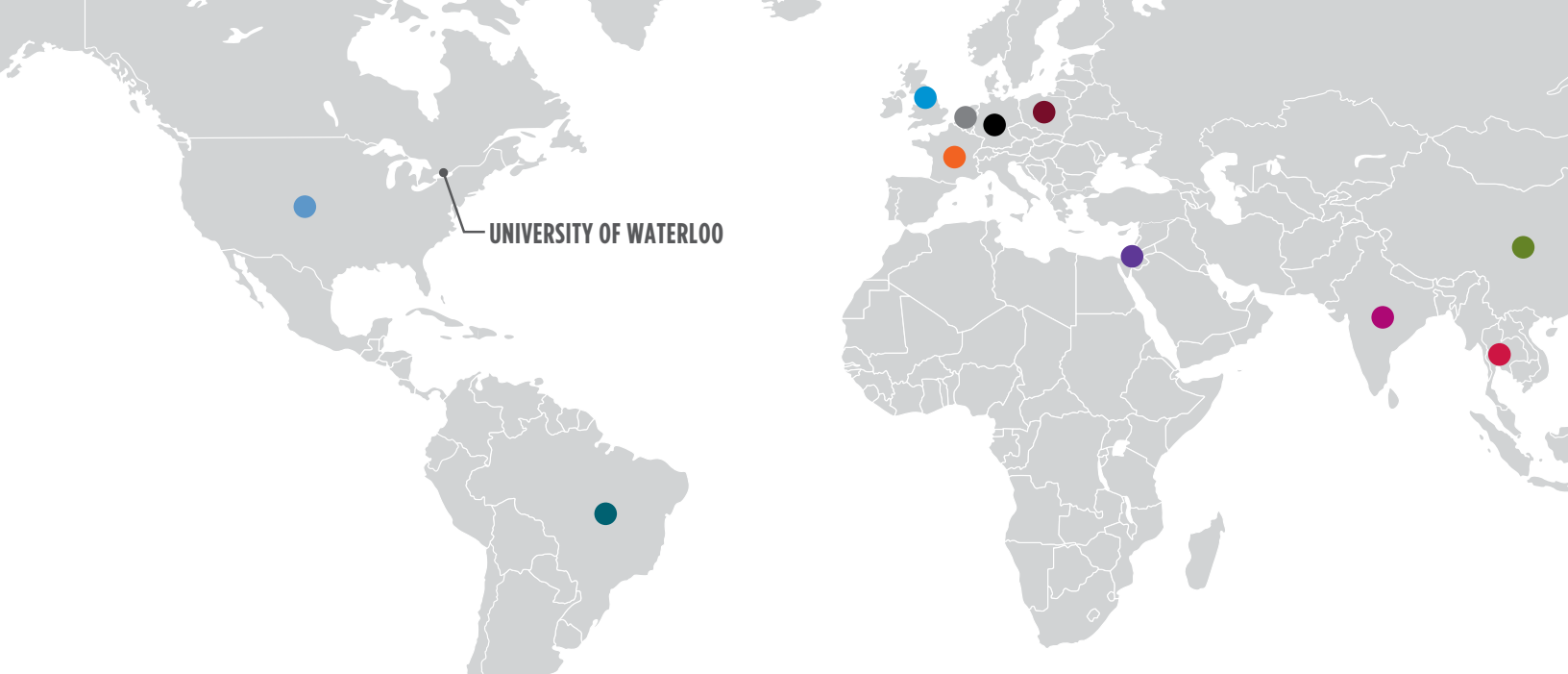
DEGREE PROGRAM	
PhD	90% (38)
MSc	10% (4)

Gender:



DEPARTMENT	APPLICANTS	AWARDEES
Biology	3 (3%)	-
Chemical Engineering	23 (22%)	10 (24%)
Chemistry	31 (30%)	14 (33%)
Electrical Engineering	14 (14%)	7 (16%)
Mechanical and Mechatronics Engineering	16 (15%)	7 (17%)
Pharmacy	6 (6%)	2 (5%)
Physics and Astronomy	7 (7%)	-
Systems Design Engineering	3 (3%)	2 (5%)
<b>Total</b>	<b>103</b>	<b>42</b>



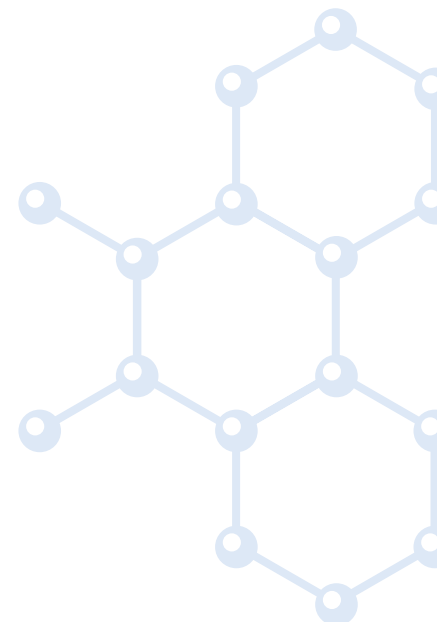


UNIVERSITY OF WATERLOO

# INTERNATIONAL

It is WIN vision to be a global centre of excellence in nanotechnology and its applications.

- AUSTRALIA** ● University of Sydney Institute for Nanotechnology (Sydney Nano)
- BRAZIL** ● Brazilian National Nanotechnology Laboratory (LNNano);  
Federal University of ABC (UFABC)
- CHINA** ● Soochow University (SU)  
Suzhou Industrial Park (SIP)  
Tsinghua University  
Chinese Academy of Sciences National Center for Nanoscience and Technology
- FRANCE** ● Université de Bordeaux
- GERMANY** ● Center for Nano Integration Duisburg-Essen (CENIDE)
- INDIA** ● Indian Institute of Science (IISc)  
Indian Institutes of Technology – Bombay (IITB);  
Kharagpur (IITKGP)  
Delhi (IITD)  
Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR)  
University of Calcutta
- ISRAEL** ● Technion-Israel Institute of Technology
- NETHERLANDS** ● University of Twente, MESA+ Institute for Nanotechnology
- POLAND** ● MISMap College of the University of Warsaw
- SOUTH KOREA** ● Korean Advanced Nano Fab Centre
- TAIWAN** ● Academia Sinica (AS)  
National Taiwan University (NTU)  
National Tsinghua University (NTHU)  
National Chiao Tung University (NCTU)  
National Cheng Kung University (NCKU)  
National Program on Nanotechnology (NPNT)
- THAILAND** ● National Nanotechnology Center, Thailand (NANOTEC)
- UNITED KINGDOM** ● University of Cambridge  
University of Bristol
- UNITED STATES** ● Oak Ridge National Laboratories



# CHINA

SOOCHOW UNIVERSITY, SUZHOU

**WIN-Soochow Workshop in Nanotechnology and Entrepreneurship** *“The WIN-Jiangsu Research and Industry Network: Nanotechnology Innovation and Entrepreneurship with Leading Academic Institutions and Commercialization Hubs in Jiangsu Province”.*



In December 2019, a delegation of 16 WIN members, staff and industry affiliates travelled to Suzhou China for the 4th Reciprocal SUN-WIN Workshop in Nanotechnology Research and Commercialization for a 2-day networking and discovery workshop, also supported by the IRPG from the Office of Research, Faculty of Science, and Departments of Chemical, Electrical and Mechanical Engineering. The participating WIN delegation members include Michael Tam (ChE), Juewen Lui (Chem), Yuning Li (ChE), Boxin Zhao (ChE), Bo Cui (ECE), John Yeow (SDE), Guoxing Miao (ECE), Derek Schipper (Chem), Sushanta Mitra (MME), Linda Nazar (Chem), and Graham Murphy (Chem), with industry affiliates Michael Wang (QuantWave) and Doung Dykaar (Diftek Lasers Inc).

Soochow University is sponsoring a scholarship for PhD students for \$10,000 CAD per year for four years to complete this split-residency program (50 per cent of time at UWaterloo, 50 per cent at Soochow for research). The student will earn a doctorate from the University of Waterloo, with a certificate of international research experience from Soochow University. Soochow University is also offering a Post-doctoral Fellowship of \$40-45,000 CDA per year for three years with a split residency. For both programs, candidates can be from anywhere in the world that meet minimum eligible requirements.

NATIONAL ACADEMY OF SCIENCES, NATIONAL CENTRE FOR NANOSCIENCE AND TECHNOLOGY, BEIJING

## Visit to the National Academy of Sciences, National Centre for Nanoscience and Technology

As part of the trip China in December 2019, the WIN delegation visited the National Centre for Nanoscience and Nanotechnology (NCNST) at the Chinese National Academy of Sciences (CAS) for facility tours and strategic discussions on potential collaboration and funding programs for exchange students, faculty mobility, and large-scale international research funding. NCNST representatives present at the meeting include Guangjun Nie, Director of CAS Key Laboratory for Biological Effects of Nanomaterials and Nanosafety, NCNST researchers Baohang Han, Lele Li, Liming Xie, and Hongjun Xiao, Foreign Affairs Specialist for S&T. The delegation was later joined by NCNST Director and WIN ISAB member, Dr Chen Wang.

In December 2019, an MOU for cooperation in research and education between WIN and NCNST was drafted to allow for student and faculty exchange, knowledge sharing, and other joint activities for scientific discovery.

# AUSTRALIA

UNIVERSITY OF SYDNEY, INSTITUTE FOR NANOTECHNOLOGY, SYDNEY

WIN has commenced an exciting new partnership with the University of Sydney Institute for Nanotechnology (Sydney Nano). WIN and Sydney Nano are an excellent match for international collaboration with significant overlap in research focus and grand challenges set for the coming years. WIN is organizing a hybrid virtual/physical workshop in November 2020 with Australia, Japan and Netherlands expected to span two days to include the following five technical sessions:

1. Nanotechnology and Society, Policy and Science Diplomacy
2. Industry and Innovation (fundamental technology, structural materials, new materials discovery with ML/AI)
3. Energy and Environment (energy harvesting and storage, carbon capture, climate change)
4. Devices and Technology for Healthcare and Communications
5. Resource Management and the Circular Economy

# BRAZIL

FEDERAL UNIVERSITY OF ABC (UFABC), SANTO ANDRÉ

Latin America in general and Brazil in particular, represent excellent potential for internationalization for UWaterloo, with common national mandates for energy, natural resources, climate action and healthcare. UFABC is a leading university in Brazil for Nanotechnology research and education in the areas of nanoparticle and nanocellulose production from natural resources (pulp and paper manufacturing) along with energy, healthcare, and advanced materials.

Research strengths at UFABC include sustainable materials and energy initiative, as well as biomedical/technology research, all of which are strong research areas at WIN. UFABC is also home to the largest nanotechnology research and graduate program in Brazil. There are several funding and scholarship opportunities available through UFABC, including CALDO, FAPESP and the Capes-Print Internationalization government programs which require institution-institution memorandums of understanding (MOU) for participation.

In 2019-2020, an MOU for cooperation in research and education was drafted to allow for student and faculty exchange, knowledge sharing, and other joint activities for research discovery.

# GERMANY

THE CENTRE FOR NANOINTEGRATION DUISBURG-ESSEN (CENIDE), DUISBURG

The Centre for Nanointegration Duisburg-Essen (CENIDE) is a research institute located within the University of Duisburg-Essen (UDE). CENIDE was founded in 2005 and is considered one of the most important nanoresearch centres in Europe. In April-May 2019, eight WIN members participated in a strategic meeting at CENIDE to prepare the Joint Deutsche Forschungsgemeinschaft (DFG, the German Research Foundation) IRTC/NSERC CREATE program focused on Hybrid-Architectures of 2D Materials with Interface-Controlled Functionality. This lucrative IRTG/CREATE program would provide \$1.65M from NSERC, and €4.5M (~\$ 6.79M CAD) from DFG, for a total of \$8.44M over five years. The DTG-IRTG Proposal Title is “Hybrid 2D Materials (Hy2D): From Scalable Synthesis and Processing to Electronic and Energy Storage Applications”. Participating WIN Members in CREATE Grant include Michael Pope (PI, ChE), Zhongwei Chen (ChE), Kyle Daun (MME), Irene Goldthorpe (ECE), Na Young Kim (ECE), Kevin Musselman (MME), German Sciaini (Chem), and Rodney Smith (Chem). DFG Participants include Gerd Bacher (PI), Michael Horn-von Hoegen, Peter Krazter, Axel Lorke, Rossitza Pentcheva, Marika Schleberger, Christof Schulz, Doris Segets, and Hartmut Wiggers.

# JAPAN

NATIONAL INSTITUTE FOR MATERIALS SCIENCE (NIMS), TSUKUBA

Japan is a top priority for WIN, visiting the National Institute for Materials Science (NIMS) consistently every year for the past seven years. Areas of common strength and vision include Electric/electronic materials, polymers and organic molecules, biomaterials, optical materials, sensors and actuators, quantum materials, and green research on energy and environmental materials. The Cooperative Graduate Agreement between UWaterloo and National Institute for Materials Science Japan, signed in October 2018.

## JAPAN

This year, two graduate students have been fortunate to be accepted into Waterloo-NIMS Cooperative Graduate Student Program – Monika Snowdon (Chem; Derek Schipper) and Sirshendu Misra (MME; Sushanta Mitra). The program allows PhD students studying nanotechnology at UWaterloo to gain valuable work experience in a leading international research institution.



top: Sirshendu Misra at NIMS facility; middle: Monika Snowdon at NIMS entrance; (l-r) Monika Snowdon, Sushanta Mitra and Sirshendu Misra at NanoJapan in January 2020

Both Monika and Sirshendu arrived in Japan in January 2020 to conduct research in materials science. Monika is working with Dr Dai-Ming Tang in the Functional Nanomaterials Group on carbon nanotube transistors, while Sirshendu is designing new biomimetic polymer materials with improved repellence and durability against a wide portfolio of fouling liquids with NIMS researchers Dr Masanobu Naito and Dr Mizuki Tenjimbayashi.

When asked how they are managing the work experience, Monika replied, “NIMS is very much a world-class institution with easy access to state-of-the-art equipment. But it’s not just that. Everyone is so friendly here, we are always helped to feel welcome and at home.” Monika and Sirshendu say they have made several friends from other countries, all students participating in the PhD program – from diverse countries such as Poland, Malaysia and Egypt.

Both were prepared for the work culture in Japan. “It is true that everyone works very long hours, but we are encouraged to find time to travel and explore the region. Along with our housing and living costs, we were provided bicycles for our whole trip which helps a lot.”

Unfortunately, the COVID-19 crisis has prevented travel too far away from the research complex, but they have made small excursions. Monika reflected, “At first I was a bit disappointed to be under quarantine, but now it’s slowly being lifted and we can get out more. But that just gave me more time to focus on writing my PhD thesis without added distraction.”

“WIN has been so helpful in this – managing this program and helping with the application. I would have never had this amazing experience without WIN’s assistance. It has really broadened my research focus and helped me create a network of outstanding international, professional contacts,” said Sirshendu.

Monika expects to graduate from PhD student in November 2020, while Sirshendu is on track to complete his degree by August 2022. Both students are scheduled to return to Canada in September 2020.



MESA+ Institute for Nanotechnology at the University of Twente, Netherlands

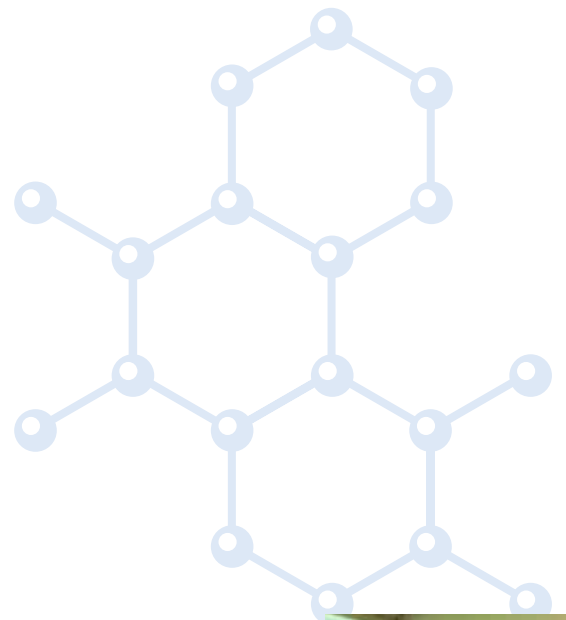
# NETHERLANDS

UNIVERSITY OF TWENTE, MESA+ INSTITUTE  
OF NANOTECHNOLOGY, ENSCHEDE

**WIN-MESA+ Institute of Nanotechnology Workshop, University of Twente:** *“New Interdisciplinary Research Opportunities to Combat Urgent Global Challenges in Health, Information and Communications Technology, and Energy”*

In October 2019, a group of eight WIN members along with WIN Executive Director and Assistant Director travelled to the University of Twente in the Netherlands to participate in a research workshop, supported by the IRPG program from the Office of Research for \$10,000 matched by the Faculty of Science and the Departments of Electrical, Mechanical and Chemical Engineering. WIN members in attendance included Shawn Wettig (Pharmacy), Hamid Majedi (ECE), Rafaat Mansour (ECE), Aanna Klinkova (Chem), Boxin Zhao (ChE), Yuning Li (ChE), Derek Schipper (Chem), Sushanta Mitra (MME), and Kevin Musselman (MME) with MESA+ participants Jos Paulusse, Michel Versluis, Anne-Johan Annema, Klaus Boller, Jeff Wood, Joost Lötters, Remco Wiegerink, Jeroen Cornelissen, Gertjan Koster, Mark Huijben, and Serge Lemay.

To support new collaborations, the WIN-MESA+ Seed Funding Program was announced on 16th October 2019 at the workshop opening, with €150,000 committed by MESA+ and matched by WIN at \$225,000 CAD from its Interdisciplinary Research Funding Program (IRFP).



AMOLF RESEARCH  
INSTITUTE, AMSTERDAM

The WIN delegation also visited the AMOLF Research Institute in Amsterdam on Tuesday 15th October 2019, meeting prominent AMOLF researchers and touring facilities, hosted by the 2018-19 WIN Rising Star Award Recipient, Dr Bruno Ehrler.





# THAILAND

NANOTEC NATIONAL NANOTECHNOLOGY RESEARCH INSTITUTE OF THAILAND, KHLONG NUENG

The National Nanotechnology Center (NANOTEC) is the premier national nanotechnology hub in Thailand, established in August 2003. Research themes at NANOTEC align very well with all four of WIN's key thematic areas which include smart and functional materials, connected devices, energy, and therapeutics and theranostics. In June 2019 a Memorandum of Understanding (MOU) on Research Cooperation was signed between WIN and NANOTEC to allow opportunities for exploration and discovery for innovation in research and commercialization. This MOU facilitates inclusion to significant Asia-based funding programs and networks. This agreement has already created four co-op work term placements for UWaterloo undergraduate students at NANOTEC in 2019-2020.

# UNITED KINGDOM

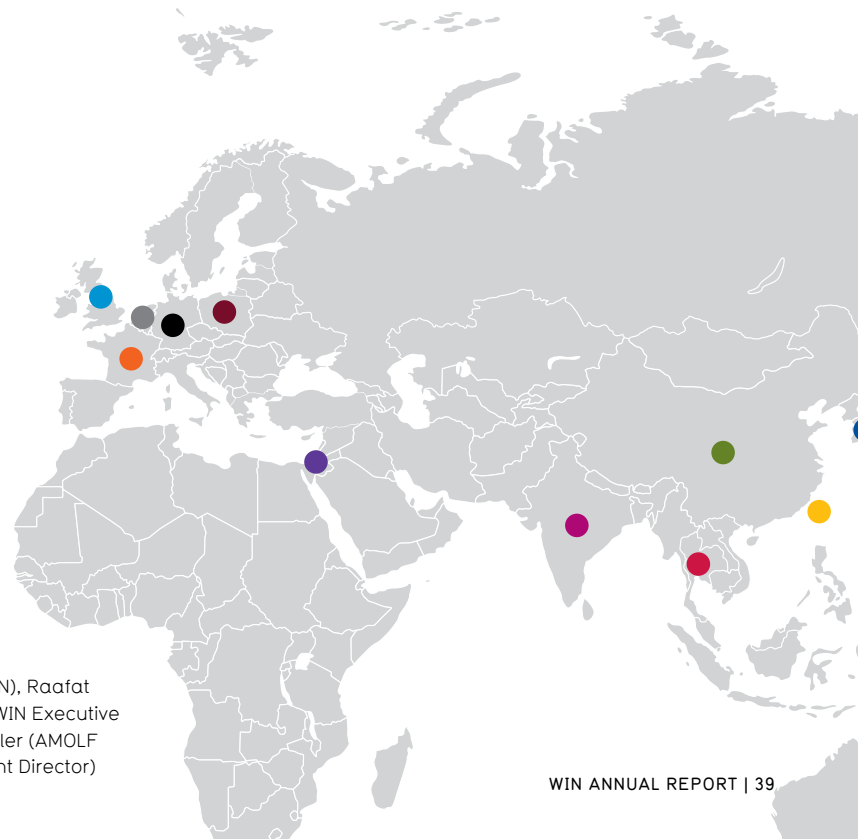
UNIVERSITY OF BRISTOL, BRISTOL

## University of Bristol Graduate Student Training Program

The University of Bristol (UoB) is consistently ranked within the top 50 best universities in the world and top five within the United Kingdom. In 2015, the WIN-UoB partnership commenced in both research and graduate student training programs, which has become an annual event. The Bristol Centre for Functional Nanomaterials (BCFN) delegation was organized by Drs Annela Seddon (BCFN Director), Ian Lindsay (Senior Manager and Director of MSc Program) and Duncan Casey (Business Development Manager). Eleven first-year PhD students from the BCFN program visited WIN for one week for research/lab-shadowing exercises in July 2019, and a one day mini-symposium was held for UWaterloo and BCFN students, hosted by the School of Pharmacy and Associate Dean of Graduate Studies for the Faculty of Science, Shawn Wettig.



From left to right: Shawn Wettig (WIN), Yuning Li (WIN), Hamed Majedi (WIN), Raafat Mansour (WIN), Boxin Zhao (WIN), Anna Klinskova (WIN), Sushanta Mitra (WIN Executive Director), Derek Schipper (WIN), Huib Bakker (AMOLF Director), Bruno Ehrler (AMOLF researcher), Erik Garnet (AMOLF researcher), Lisa Pokrajac (WIN Assistant Director)



# INTERNATIONAL SYMPOSIUM 2019

## ON FRONTIERS IN NANOSCIENCE AND NANOTECHNOLOGY — SMART AND FUNCTIONAL MATERIALS

On June 5 and 6, 2019, WIN hosted the second International Symposium on Frontiers in Nanoscience and Nanotechnology.

This two-day conference showcased prominent researchers from across the globe along with our own talented researchers within the key theme of Smart and Functional Materials. The agenda for the 2019 International Symposium on Frontiers of NanoScience and Nanotechnology included the following featured speakers:

### DISTINGUISHED LECTURERS

- › **Hans-Jurgen Butt**, Professor, Max Planck Institute for Polymer Physics, Germany: “Nanostructuring surfaces to control wetting”
- › **President Kazuhito Hashimoto**, National Institute for Materials Science, Japan: “My experience of nanotechnology from basic research to practical application”
- › **Ajay Sood**, Professor of Physics, Indian Institute of Science, India: “Nanophotonics of two-dimensional crystals”
- › **Sir Mark Welland**, Master of St Catharine’s College, and Deputy Vice-Chancellor, University of Cambridge, United Kingdom: “Nanostructures in disease – pathology and treatment”

### KEYNOTE SPEAKERS

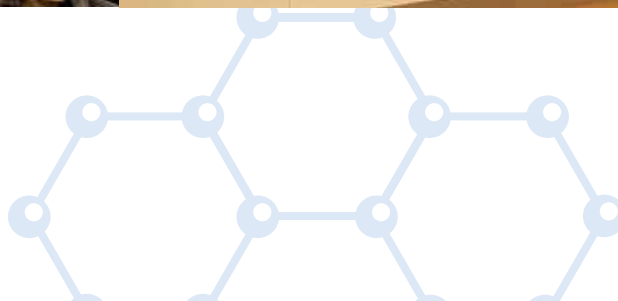
- › **Pavadee Aungkavattana**, Deputy Executive Director, National Nanotechnology Centre (NANOTEC), Thailand: “Nanotechnology in Thailand and its application: from lab to market”
- › **Marija Drndic**, Professor, Department of Physics and Astronomy, University of Pennsylvania, USA: “Can nanopatterned two-dimensional solid-state materials also filter Turkish coffee?”
- › **Drew Higgins**, Assistant Professor, Department of Chemical Engineering, McMaster University, Canada: “Nanomaterial electrocatalysts to enable sustainability for our energy and transportation sectors”
- › **Scott T. Retterer**, Senior Research Staff Scientist, Centre for Nanophase Materials Science, Oak Ridge National Laboratory Tennessee: “Hierarchical assembly – understanding formation, response, and evolution in multiscale heterogeneous materials”

## WIN SPEAKERS

- › **Nasser Abukhdeir**, Associate Professor, Department of Chemical Engineering: “A generalized shapelet-based method for analysis of nanostructured surface imaging”
- › **James Forrest**, Professor, Department of Physics and Astronomy: “Polymer stable glass”
- › **Irene Goldthorpe**, Associate Professor, Department of Electrical and Computer Engineering: “Silver nanowires for printable, flexible transparent electrodes and e-textiles”
- › **Yuning Li**, Professor, Department of Chemical Engineering: “Development of polymer semiconductors for printed electronics”
- › **Kevin Musselman**, Assistant Professor, Department of Mechanical and Mechatronics Engineering: “Rapid, open-air manufacturing of functional oxide thin films by spatial atomic layer deposition”
- › **Carolyn Ren**, Professor, Department of Mechanical and Mechatronics Engineering: “Droplet microfluidic platform technologies for materials synthesis”
- › **Ting Tsui**, Associate Professor, Department of Chemical Engineering: “Manipulating cell behaviours using engineered surfaces”
- › **Xiaosong Wang**, Professor, Department of Chemistry: “Effect of ionic end group on hydrophobic hydration (HH) and hydrophobic effect-driven self-assembly (HEDSA) of metal carbonyl macromolecules”



Left: Graduate student poster session at International Symposium on Frontiers of Nanoscience and Nanotechnology; Right: Dr Scott Retterer from US Department of Energy at Oak Ridge National Laboratories giving a keynote talk at the International Symposium on Frontiers of Nanoscience and Nanotechnology, June 2019.



# WIN RESEARCH CELEBRATION

In 2019, the “WIN Research Leaders Gala and Reception” was held along with the Nanofellowship Celebration. During this evening, we honour our WIN community together and provide an opportunity for all our faculty and students to learn about the innovative research taking place. With such knowledge sharing, we hope to foster new partnerships.

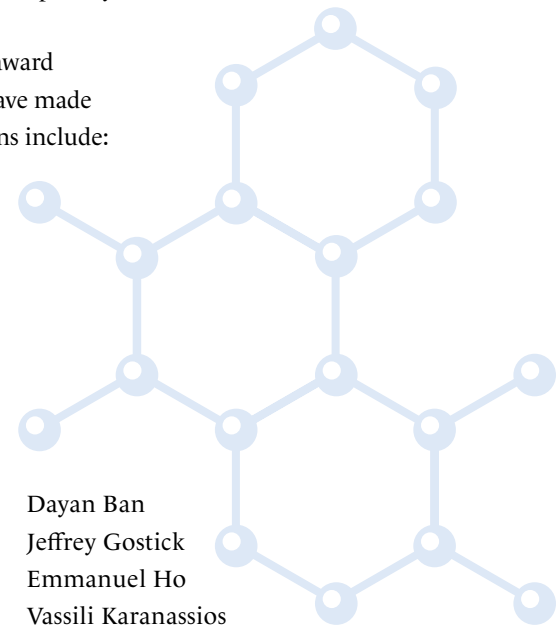
Professor Anita Layton, Canada 150 Research Chair in Mathematical Biology and Medicine, from the Department of Applied Mathematics was recognized as a WIN Research Leader, and gave a keynote presentation on her research and interdisciplinary opportunities with nanotechnology and mathematics. The “WIN Research Celebration” was held in November 2019 to recognize our Nanofellowship award winners (see page 32 for full list) and outstanding faculty researchers who have made significant contributions during the 2018-2019 fiscal year. These contributions include:

- a) Any individual or group receiving major grants with a value equal to or greater than \$500,000
- b) Major national or international awards
- c) Published books or other major scholarships and creativity

**For 2019, the following WIN members were recognized:**



WIN Research Leaders Award Winners (from left to right): Jeff Gostick, Pavle Radovanovic, Roderick Slavcev, Anita Layton, Shawn Wettig, Emmanuel Ho, Vassili Karanassios, Yuning Li with WIN Executive Director Sushanta Mitra



- › Dayan Ban
- › Jeffrey Gostick
- › Emmanuel Ho
- › Vassili Karanassios
- › Anita Layton
- › Zoya Leonenko
- › Yuning Li
- › Linda Nazar
- › Pavle Radovanovic
- › Siva Sivoththaman
- › Roderick Slavcev
- › Michael Tam
- › John Yeow






# ENGAGING INDUSTRY

## AEROSPACE INDUSTRY WORKSHOP

In partnership with the Ontario Aerospace Council (OAC), WIN organized a one-day workshop in January 2020 with the theme “Printable, Flexible and Hybrid Electronics: What’s in it for the Aerospace Industry?” The printable, flexible and hybrid electronics (FHE) technologies provide significant advantages to aircraft manufacturers, reducing the size and weight of electrical cable systems, a high level of automation, and most importantly, it can be customized according to customer needs. FHE technologies are of great interest to aerospace professionals for their unique capabilities, and recently they have reached the level of performance demanded by aviation manufacturers. The objectives of the event were to give the industry perspective to showcase advances in this field, and discuss the state-of-the-art in FHE, and current research undertaken by WIN members. Business use cases and opportunities for growth were also highlighted.

The event was opened by Mark Majewski, President and CEO of intelliFLEX (a Canadian FHE industry membership association) who gave an overview of the worldwide market and eco-system in Canada. The keynote presentation was delivered by Professor Ye Tao, a Group Leader in the Advanced Electronics and Photonics Research Centre at the National Research Council. Participating WIN members include Professors William Wong and Irene Goldthorpe, both with the Department of Electrical and Computer Engineering, and Professor Armaghan Salehian from the Department of Mechanical and Mechatronics Engineering. There was also a startup showcase featuring several UWaterloo spin-off companies. The event culminated with group tours of the Quantum Nano Centre’s NanoFab and Metrology centre and the Giga2Nano laboratories at UWaterloo along with tours of VueReal Inc (a company with a novel manufacturing method for production of microLED displays) and its newly constructed nanotechnology cleanroom facility.



DR. DOUG DYKAAR



Speaker Mikael Rougette from Voltera Inc

## INDUSTRY SPEAKER

In May, WIN hosted Doug Dykaar, PhD, President of DifTek lasers Inc, and former optics consultant for North Inc (previously Thalmic Labs). Dykaar presented his novel technology of active backplane electronics for LED display walls.

## WATERLOO DEFENCE RESEARCH FORUM

In October 2019, WIN hosted a panel on advanced and evolving materials, with WIN's Executive Director giving a short overview of research conducted by WIN members. The panel featured research by Professors Na Young Kim (ECE, materials for quantum computing), Linda Nazar (Chem, materials for batteries), Zbig Wasilewski (ECE/Physics, materials and devices for quantum communication), and John Yeow (SYDE, materials for radiation protection in space). WIN's Business Development Manager, Oleg Stukalov, was a member of the organizing committee.

## INDUSTRY TRADE CONFERENCES

WIN held a booth at the Ontario Centres of Excellence (OCE) Discovery conference and tradeshow in May 2019 which led to two new industry connections, resulting in significant grant application prospects. In October 2019, WIN's Business Development Manager also joined the Advanced Manufacturing Consortium's (a partnership between UWaterloo, McMaster University and Western University) to participate in the Canadian Manufacturing Technology Show and NGen Supercluster partnerships development event.

### INTERNATIONAL INDUSTRY CONNECTIONS

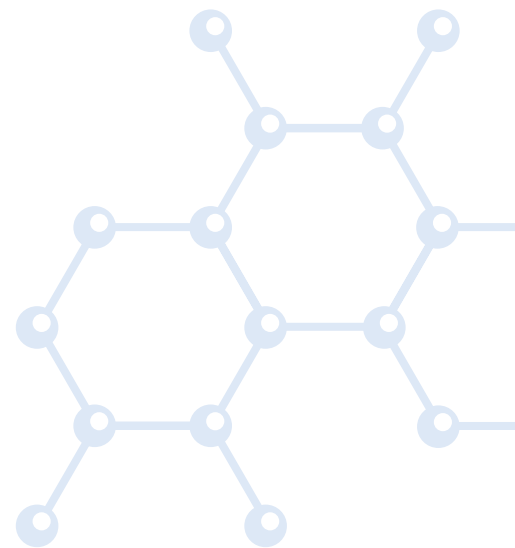
While travelling internationally, WIN Executive Director Sushanta Mitra met with several companies and international organizations in 2019-20 with special interest in the innovative WIN community. One such example was a private research institute, Deltares, located in Netherlands who is working on sensors and technologies for environmental monitoring. Several conference calls resulted in a joint project outline and planned grant submission to a major Canadian funding program. Another European company working in the area of smartphone screen protection is interested to explore novel nanotechnology approaches. Additionally, a company from South Korea is exploring potential areas of interest in production of metal nanoparticles for electronics applications. WIN also hosted business delegations from Taiwan and the Netherlands, for potential networking opportunities. New important connections were developed with the Japanese Industrial Promotion Association (JIPA), which will be developed in 2020-21.

In December 2019, Oleg Stukalov and Ling Loerchner (Managing Director for Asia at the Office of Research) travelled alongside the group of researchers and two UWaterloo spin-off companies to the Jiangsu Province in China. Numerous meetings with private companies in the field of OLED and large area LED displays, semiconductor devices, and MEMS were held in Shanghai, Suzhou and Nanjing. The group also met with the Management of Suzhou Industrial Park and discussed the potential for WIN/UWaterloo to increase presence and visibility at SIP. They also visited the applied research institute dedicated to the commercialization of OLED display technologies, which may lead to potential partnerships for researchers operating in UWaterloo's Giga2Nano facility.

In July 2019, as part of delegation from the University of Bristol, WIN hosted Duncan Casey, PhD, a business development counterpart from Bristol's nanotechnology program. Several meetings with local companies, researchers and entrepreneurship programs (Velocity by Concept and Conrad School of Entrepreneurship and Business) were held with the view of future grant applications for UK-Canada call for proposals, which involves industry participation and entrepreneurial training for graduate students. For example, there are plans to include cross-institutional entrepreneurship programming in the future CREATE grant application.



(Left to right) Doug Dykaar from Diftek Lasers Inc, Oleg Stukalov, and Ling Loerchner visit Sansi Ltd (LED display wall manufacturer) in Shanghai China, December 2019







Canadian delegation at the NanoCanada booth at the NanoJapan Conference and Tradeshow in January 2020

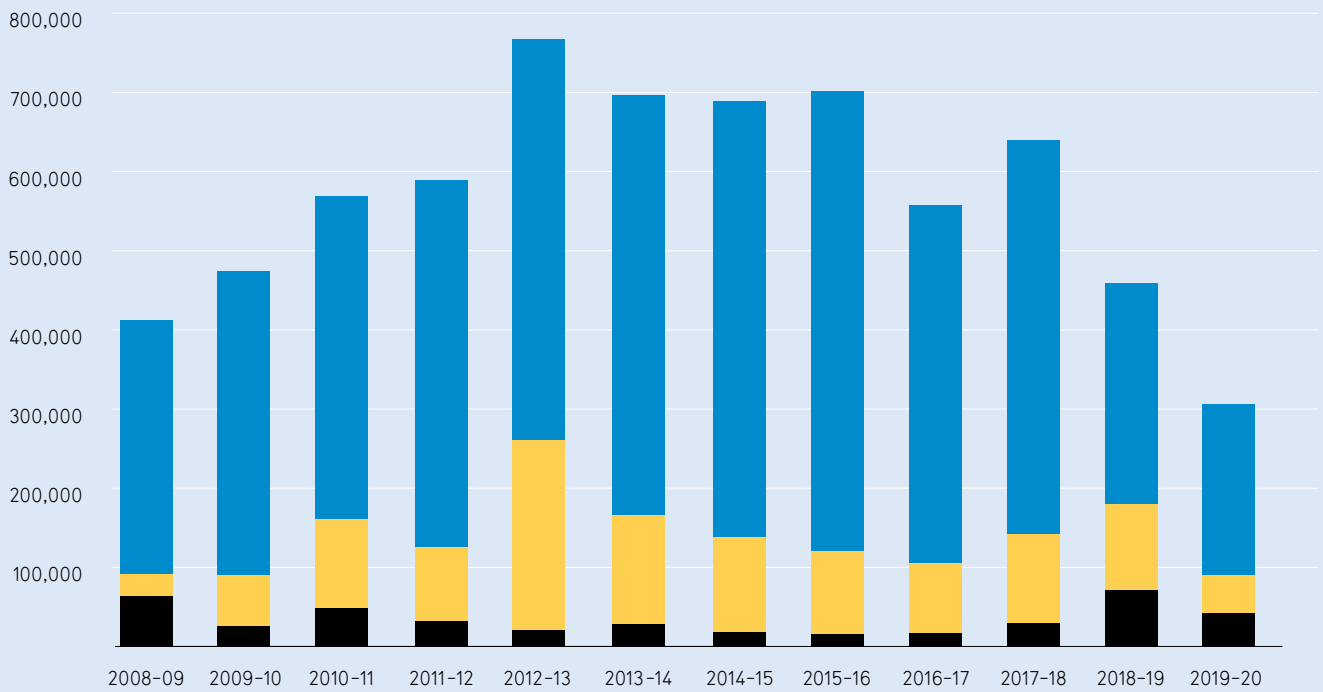
## NEW INDUSTRY PARTNERSHIPS

WIN facilitated three matchmaking meetings with multinational corporations, where multiple researchers presented to the group of representatives. The outcomes of such meetings will be felt in the 2020-21 period. Overall, WIN engaged 45 new companies, with 22 progressing to specific project discussions with faculty members. These resulted in ten grant applications, with over \$4M in funding requested. Interestingly, of all companies engaged, 76 per cent were small-and-medium enterprises (SME) while 24 per cent were large corporations. Furthermore, all 10 grant applications listed SMEs as partners.

## ONTARIO RESEARCH FUND

With support from WIN, a \$3.73M grant proposal was submitted to Ontario Research Fund with 11 industry partners. WIN PIs Professors Norman Zhou and Sushanta Mitra partnered with five co-PIs from the University of Guelph, University of Toronto and McMaster University. The proposed project offered to develop and test a prototype system for photo-oxidative water treatment and disinfection for remote and indigenous communities prone to water boiling advisories.

# BUDGET



# LIFE IN THE QNC

‘Nano’ may mean small but the community within WIN is booming! From social events to research seminars to the day-to-day work done by our members and students, our space in QNC is designed to promote interdisciplinary collaboration. This need to foster collaboration is at the heart of everything WIN does.

**42**

WIN professor  
research  
laboratories

**3**

Lounges

**3**

Meeting  
Rooms

**41**

Student  
Offices

**1**

Seminar  
Room

**169**

graduate  
students

**200+**

Students in  
WIN section  
of QNC

**37**

undergraduate  
students

**1**

Rooftop  
Patio

**50**

Laboratories

**4**

Kitchens

The exterior of the Mike & Ophelia Lazaridis Quantum-Nano Centre is modeled after the hexagonal structure of graphene.

ACKNOWLEDGEMENT OF TRADITIONAL TERRITORY

We acknowledge that the University of Waterloo is located on the traditional territory of the Neutral, Anishnaabeg, and Haudenosaunee people. The University is situated on the Haldimand Tract, the land promised to the Six Nations that includes 10 kilometres on each side of the Grand River.



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