NANOFELLOWSHIPS PAGE 24

36 (2015-2016) nanofellowships awarded

8 rounds of nanofellowship competitions

276 nanofellowships awarded since 2008

INTERNATIONAL PAGE 20

27 papers from WIN international collaboration in 2015

19 international partners in ten countries

OUR PEOPLE PAGE 28

82 Faculty Members

19 Research Chairs

WATERLOO INSTITUTE FOR NANOTECHNOLOGY
SCHOLARLY OUTPUT

3,104 papers published since 2008 (cited 37,273 times)

521 papers published since in 2015

7 papers from industrial collaboration in 2015

27 papers from international collaboration in 2015

To become a global centre of excellence for nanotechnology and its applications.

Our research is about science and engineering at the atomic scale, where the design, fabrication and exploitation of materials and structures are measured within billionths of a metre — a nanometre. At this scale, the properties of materials change, sometimes radically. By taking advantage of the unique phenomena that predominate at the atomic scale, our scientists and engineers are discovering and developing nanomaterials, nano-electronics, nanoinstrumentation and nanobiosystems that will fundamentally change the world.
Looking back over the eight years since I took on the mantle of Executive Director of the Waterloo Institute for Nanotechnology (WIN), I feel privileged to have had the opportunity to lead this institute from pre-startup to the present — globally recognized powerhouse of nanotechnology.

Let me summarize briefly a few of the landmark achievements in its brief history.

**BUILDING A CRITICAL MASS OF RESEARCH TALENT**
WIN was created to build a critical mass of researchers to explore and exploit the exciting new discoveries emerging from the unique properties displayed by matter at the nanoscale. This task was undoubtedly made easier by the acquisition of 21 new “nanohires” by the three founding departments of the Nanotechnology Engineering Program. WIN has played a key role in mentoring and supporting the research programs of these rising stars. Today, these researchers have matured and developed into a core of excellence in WIN, approaching the most prolific and creative years of their careers. WIN’s growing stature and reputation of the institute has helped to draw other new faculty members with nanotechnology interests to Waterloo.

Since 2008, WIN has grown from 47 members to 82. WIN Nanofellowships have helped attract outstanding graduate students and increase total enrolment in nanotechnology research to over 400. While WIN is still young and growing, it is endowed with a core of prolific research talent that augurs well for global excellence in nanotechnology in the years ahead.

**MULTIDISCIPLINARY COHESION AND COLLABORATION**
Nanotechnology is inherently cross-disciplinary where the solution to a problem often requires inputs from different disciplines. One of the principal challenges for WIN was to create a working environment which fosters and enhances multidisciplinary collaboration and cohesion. With researchers drawn from nine different departments and many disciplines, fostering close interaction, communication and collaboration is an ongoing challenge.

The new Mike & Ophelia Lazaridis Quantum-Nano Centre with its custom designed labs, spacious meeting and conference rooms, white boards and faculty/student office space has helped create a conducive environment for the exchange of ideas and sharing of resources. This environment, co-ordinated and fostered by WIN has been one of the principal assets in building a unique faculty-grad-undergrad relationship.

**INTERNATIONAL PARTNERSHIPS WITH LEADING NANOTECH CENTRES**
A key strategy, with the goal of raising the profile and stature of WIN around the globe has been to build partnerships and collaborations with leading players in nanotechnology. This has been particularly successful! WIN has signed collaborative agreements with 19 nanotechnology centres and programs in 10 countries. Through workshops, conferences and reciprocal visits, these agreements have spawned more than 100 collaborative projects, generating funding, graduate and undergraduate training and student degrees, many publications in refereed journals, patents and even spin-off companies.

WIN has hosted many eminent nanotechnology scholars from around the world as Distinguished Lecturers, Seminar Speakers and visitors. The QNC building and the Nano labs and facilities have attracted countless delegations, companies and governments — all intrigued to see what is happening in a state-of-the-art nanotechnology facility!
**FOSTERING INDUSTRY PARTNERSHIPS**

Faculty have increasingly looked to industry for partnerships on joint projects. WIN has hosted visits, arranged roundtables and convened workshops to help faculty establish connections to industry and develop applications for funding. Collaborations have gone from small NSERC ‘Engage’ projects, to larger Collaborative R&D Grants in partnership with SME’s, to joint projects with large MNE’s. The ‘Open Innovation’ concept provides a means for the company to access key knowledge and innovation via a strong partnership with a university. The SME would not be able to take on all of the exploratory R&D on its own and the concept is one that could be valuable to many companies in Canada.

One example of a major collaboration which WIN has cultured and supported is that with EcoSynthetix, an SME in the cleantech/biopolymers area, producing nano-based biolatex materials from natural starch, for the paper coating and wood composite industries.

**Dr. Arthur J. Carty**

Executive Director
Waterloo Institute for Nanotechnology

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Arthur Carty honoured as a Fellow of the American Association for the Advancement of Science

On February 13, 2016, Carty was honoured with a fellowship from the American Association for the Advancement of Science (AAAS) for his enlightened scientific leadership, his seminal role as science advisor to governments and his contribution to organometallic chemistry. Election as a fellow is an honour bestowed upon members by their peers.
The ability to print electronics, like printing paper, will have a profound effect on society and the economy. Circuits printed on thin, transparent, flexible films have captured the minds of innovators and researchers for decades. With innovators dreaming of wearable electronics, intelligent packaging, flexible display screens and smart windows. Research at WIN is enabling the fundamental science and engineering of nanomaterials underpinning these printed electronic devices.
The industrial demand for printable, flexible electronics is growing. Printing, copying, packaging, lighting and sensing companies are already building the supply chain for new printed materials and delivering early innovations to the marketplace, including Xerox, Fujifilm, 3M and Terepac.

“The type of nanomaterials that we build convert electricity into light and will go into solid-state lighting devices, solar cells and displays.”

– HANY AZIZ

The goal of the network is to fabricate low-cost electronic devices that are light, flexible and large in area. It’s an interdisciplinary team of partnerships, with chemists working on the development of inks and substrates, physicists focusing on device design and optimization, and engineers dedicated to improving the printing process, manufacturing and circuit design.

Li knows a thing or two about industry and research. He worked for Xerox Research Centre Canada (XRCC) on their electronic-paper technology, holds 72 US patents and was the recipient of the NASA Nano-50 Award for Printed Organic Electronics.

“When printed on solar cells, metal nanoparticles can greatly enhance light harvesting through the plasmonic effect.”

– YUNING LI

PROFESSOR YUNING LI

Li is part of a Printable Electronics Network that combines conventional printing methods with conducting and superconducting inks with an emphasis on high mobility polymer semiconductors and functional nanoparticles.

Aziz is also part of the Network, contributing to the transducing and sensing elements of the project, with a special focus on material physics, performance and reliability of OLED devices. The perfect partnership with Li was hatched when they both worked at XRCC, and now both work at WIN where Aziz held the NSERC DALSA Industrial Research Chair in Organic Light Emitting Devices.

“The type of nanomaterials that we build convert electricity into light and will go into solid-state lighting devices, solar cells and displays.”

– HANY AZIZ

The industrial demand for printable, flexible electronics is growing. Printing, copying, packaging, lighting and sensing companies are already building the supply chain for new printed materials and delivering early innovations to the marketplace, including Xerox, Fujifilm, 3M and Terepac.
Research at WIN is often conducted by experimental groups. These groups need theoretical modeling and computer simulation to validate and interpret experimental data. Professors Zoran Miskovic and Hamed Majedi are the organizers of WIN's first workshop for Modeling and Simulation in Support of Experimental Research.
WIN’s workshop on Modeling and Simulation provides an opportunity for theoreticians to showcase their modelling expertise in several areas of nanotechnology to WIN experimentalists. The workshop creates that vital link between experimental and theoretical researchers to facilitate interdisciplinary collaboration. That is one of WIN’s core missions.

**PROFESSOR ZORAN MISKOVIC**
Miskovic is a WIN member from the Faculty of Mathematics who theorizes about nanoscopic devices and novel nanomaterials. He studies graphene at the interface between physics and electrochemistry, where he is able to model reactions involving protons and ions to create an “electrolytically-gated” graphene. His work will lead to a model that can help engineers design compact, low cost graphene-on-a-chip sensors for disease detection and diagnosis.

**PROFESSOR HAMED MAJEDI**
Majedi developed a computational platform to investigate the features of self-assembled and nanowire quantum dots. His theories link material composition, shape, size, crystal growth direction to their optical characteristics. This model is used in systems that can generate entangled photons, and in detectors that can count one photon at a time. Majedi then builds hybrid nanostructures that integrate these single and entangled photon sources with quantum waveguides to make a quantum photonic transceiver that detects and processes photons-on-a-chip. He was the first in Canada to develop two types of Superconducting Nanowire Single Photon Detectors (SNSPDs) which put the quantum properties of light into practical use.

“Information encoded on individual photons offers new ways to enhance communication security, and also new ways to perform sensing, imaging, computation and metrology”

– HAMED MAJEDI

**PROFESSOR MARK MATSEN**
Professor Mark Matsen’s group makes brushes. Not the kind you can hold. But charged polyelectrolyte brushes that can be controlled by an electric field for use as nano-sized actuators and gates for nano-sized pores through thin membranes.

His self-assembly of block copolymers into nano-sized structures can lead to many useful applications such as the development of nano-sized vesicles for drug delivery, patterning surfaces on the nano-scale, and environmentally-responsive nanostructures.

To study these systems, Matsen developed Self-Consistent Field Theory (SCFT) for which he is regarded as a world leading expert. The theory models very subtle effects, predicts behavior confirmed by experiment, corrects major experimental errors and plays a vital role in experimental studies. SCFT is highly predictive and accesses many quantities that experiments cannot measure.

Currently, he is using his theory to create materials to improve the properties of renewable plant-based materials in the hope they will compete and outperform conventional petroleum-based materials.

“The ability to combine polymers with different characteristics into well-ordered nanostructures provides a powerful way of controlling material properties.”

– MARK MATSEN
After five years in the Research Advancement Centre, Professor Adrian Lupascu loves his new lab in the Mike & Ophelia Lazaridis Quantum-Nano Centre.

The lab is very stable in terms of temperature and vibration and in close proximity to the Quantum NanoFab cleanroom which is what is needed for world class fabrication of quantum devices. Perhaps most welcome is the close proximity of WIN collaborators.
Zbig Wasilewski in the MBE Facility

Superconducting flux qubit, made of aluminum on silicon. The four overlap areas at the bottom are Josephson junction. – Adrian Lupascu

**PROFESSOR ADRIAN LUPASCU**

Lupascu wants to understand the connection between quantum mechanics and the physics of superconducting qubits to build something practical. “There is merit to having a pragmatic goal. When you are asked for something specific, you may come up with solutions more quickly.”

“We can make ‘giant atoms’ that are very strongly coupled to an EM field. And when we excite an atom it can emit radiation. The rate of emission is constant over time which leads to an exponential decay. As time passes, the probability of detecting a photon goes down exponentially. This is a result of weak coupling between matter and light. But with our superconducting qubits you can increase the coupling between light and matter to an extent that this whole picture breaks down. So you would no longer expect the decay of an atom to be exponential. But rather it follows a different law with all sorts of strange effects. Elucidating this new phenomena is the very aspect of our research.”

Theorists are quite excited because it goes against conventional wisdom and is a new parameter regime. And this makes it a potentially useful quantum technology.

The most important measurement of an atom is its transition frequency. When you do a quantum operation you are sending a microwave pulse which induces a rotation in the states, which is how you can get superposition. So looking at our strongly coupled qubits we can get 99.9 per cent fidelity, and do it very fast.

The device is a nanofabricated structure on a silicon chip. It’s a superconducting resonator, one of the main building blocks a superconducting quantum computer. The qubit stores the information and a resonator couples the qubits to each other and reads out the state of qubits.

On the chips we have a superconducting ring. It includes a Jefferson-junctions with two barriers made of aluminum oxide. When the temperature is low enough you have two quantum states that are lower in energy than all the other states, and these states are characterized by persistent currents moving in the ring one way or the other. When you apply magnetic flux then these two states are equally likely, and these two states can talk to each other and that’s what gives you the qubit.

This all happens in a dilution refrigerator where temperatures are maintained in the milli-kelvin range. The really interesting collective states in the atom only occur at very low frequencies so when the temperature is very low, there is a much higher probability to be in this quantum state where all the electrons move in sync.

“We’re trying to understand the limitations of physics and technology.”

Lupascu would like to make a major development toward a quantum computer in his lifetime. “If there is to be a quantum computer, it will be based on superconducting qubits.”

**PROFESSOR ZBIG WASILEWSKI**

By improving the quality of the materials you can improve dramatically the coherence of qubits. There is a lot of materials science to making better superconducting qubits. Lupascu collaborates with WIN Endowed Chair, Professor Zbig Wasilewski, and his Molecular Beam Epitaxy (MBE) facility where they use Aluminum to grow high quality devices epitaxially.

To develop a quantum sensor, you must have the most sensitive measurement devices, which are essentially atoms themselves. Lupascu’s group understands how that system works and how to extract information from that quantum state. “You are looking at the limits that nature puts on how you can measure a signal and acquire information.”
“There are over 9.9 million new cases of dementia each year worldwide, implying one new case every 3.2 seconds.”

Three quarters of the 46 million people worldwide with dementia have not received a diagnosis, and thus have no access to treatment. Definitive diagnosis only occurs after death. At a cost of US $818 billion per year.
**PROFESSOR MELANIE CAMPBELL**

Campbell believes early, non-invasive diagnosis would allow more patients to be treated sooner and maintain their quality of life longer. Her idea? Look through the eye for early signs of Alzheimer’s Disease (AD). Specifically, looking at the retina of the eye for the formation of proteins that deposit in the brain in the early stages of AD.

Campbell developed an optical instrument to detect the formation of amyloid beta (Aβ) fibrils (plaques) in neural tissue which is present in the retina. When a patient looks through the lens of her instrument, Aβ polarization properties are used to non-invasively detect Aβ in the living retina.

The new instrument will allow doctors to detect the presence and density of amyloid beta in patients who can then be referred to a neurologist. While the disease cannot be cured, drugs are available that can help people have a better quality of life for months and possibly years.

Campbell is at the vanguard of the intersection of physics and nanomedicine and says her work would not be possible without the collaboration of people from different disciplines.

“I think you absolutely have to have an interdisciplinary group and collaborations across disciplines if you want to solve the emerging medical problems of today.”

**PROFESSOR ZOYA LEONENKO**

Campbell’s collaborator, Professor Zoya Leonenko, was able to visualize amyloid fibril formation in the retina with Atomic Force Microscopy (AFM) and fluorescence. Correlation of fluorescence and AFM images allowed for testing the proof of principle that detection of amyloid deposits in the eye is linked to Alzheimer’s progression.

Leonenko is an expert in Scanning Probe Microscopy (SPM), including atomic force microscopy, Kelvin probe force microscopy, and single molecule force spectroscopy as well as surface enhanced spectroscopies and their applications for biosensing and biomedical nanotechnology.

Her laboratory is equipped with three advanced SPM instruments. SPM in life sciences allows high resolution imaging at the nanoscale and single molecule level, as well as force measurements and nanomanipulations while keeping the biological system in its native environment, and thus providing revolutionary insights into complex biological processes.

Leonenko also believes collaboration is the key to new discovery. She collaborated with WIN member Mikko Karttunen who performed molecular dynamics simulations on the protective role of the hormone melatonin in Alzheimer’s disease. She has a project with WIN member Simarjeet Saini and WIN nanotechnology startup founder Ryan Denomme (CEO of Nicoya Lifesciences) to develop biosensing technologies that involve binding proteins and small membrane active molecules (including drugs) to lipid membranes. She also has a project with WIN member Shawn Wettig of the School of Pharmacy to develop novel gene delivery nanoparticles based on lipids and Gemini surfactants.

**PROFESSOR SHAWN WETTIG**

Wettig’s research is at the interface of biophysical chemistry and nanotechnology, involving solution thermodynamics, biochemistry and cell biology applied to the study of self-assembling systems. While self-assembly is a recognized tool in the design of systems for drug delivery applications, the use of self-assembly in the “bottom-up” construction of nanoparticulate systems for drug delivery is an emerging field. His group designs novel surface-active compounds (surfactants) that leverage the characteristics of self-assembly and controls particle dimensions on the nanometer size scale for pharmaceutical applications in targeted delivery and bio-distribution of active compounds.
Nanotechnology entrepreneurism starts in third year where nanotechnology engineering undergraduate students prepare to enter their Fourth Year Design Project (FYDP). They are engineers who respect and understand fundamental science, but also how to integrate and apply technology to solve real world problems. They also respect commercialization, and that makes them want to innovate.

At Waterloo our ideas are our own. We want to see new ideas move out into the world, through commercialization. Waterloo is where new ideas get started.
Student projects often win startup grants and are encouraged to join Velocity and the Waterloo startup ecosystem where they receive space, funding and business advice from seasoned veterans. Once student teams graduate, they still need a place where they connect with researchers who have access to highly specialized equipment, facilities and knowledge in order to accelerate nanotechnology innovation in their products. And that’s where WIN and the QNC fit into the Waterloo ecosystem.

WIN has a concentration of very talented people, in highly specialized areas, with state-of-the-art facilities specific for nanotechnology innovation. A nanotechnology startup can walk into the QNC and work with researchers to solve materials problems that allow them to innovate more quickly.

Professor Nasser Abukhdeir is a WIN researcher and FYDP student supervisor. “I use simulation based engineering to design next generation liquid crystal based devices. My lab makes materials for ‘smart glass’ at the nanoscale using Polymer Dispersive Liquid Crystals (PDLC). We can make very large films through a bottom up manufacturing process because they can, in a sense, ‘make themselves’. We’re also developing Liquid Crystal Loops as micro-nano pumping mechanisms. In other words shrinking pumps down to the nano-scale by eliminating the moving parts so fluids can ‘pump themselves’, with an electromagnetic field.”

WIN and the Nanotechnology Engineering Undergraduate Program work together to support nanotechnology projects and companies

Jenn Coggan is the lab co-ordinator and instructor for Canada’s largest nanotechnology engineering undergraduate program. She previously spent 10 years at Xerox Research Centre Canada (XRCC), which is one of the largest co-op employers of nanoengineering students. She worked with WIN members Hany Aziz and Yuning Li who also worked at XRCC at the time where the team developed printed organic electronic materials before all coming to Waterloo.

Coggan has real world experience in scaling up nanomaterials and introducing new products. A holder of 49 patents, she knows how innovation can be created and moved into the market place.

“They get stuck. And I help them get unstuck” says Coggan.

When Suncayr needed to produce thin films, they asked Coggan for a spin-coater. Knowing that Suncayr was interested in scaling up to larger sizes, she suggested a “drawbar-coater” process instead, which she was familiar working with printed electronics at XRCC.

The QNC environment is open and free to connect with people and explore R&D ideas in a way that accelerates discovery innovation. The nano startups are now hiring nano students. It’s come full circle.

“WIN is much better than an incubator. WIN is filling in a gap that helps nanotechnology students take fourth year design projects and facilitate them into companies, in the Quantum Nano Centre.”

– NASSER ABUKHDEIR, Fourth Year Design Project research supervisor for Waterloo startups Lumotone and Suncayr

WIN is filling in a gap that helps nanotechnology students take fourth year design projects and facilitate them into companies, in the Quantum Nano Centre.”
student teams

WIN supports teams and events that push the boundaries of science and engineering at the nanoscale.

WATERLOO UNDERGRADUATE NANOTECHNOLOGY CONFERENCE (WUNC)

Mike & Ophelia Lazaridis Quantum-Nano Centre, University of Waterloo
November 7, 2015

Organized by Waterloo Nanotechnology Engineering undergraduate students and supported by WIN and the Faculties of Engineering and Science, the first WUNC provided an exciting and inspiring look at the future of nanotechnology research and its place in industry and society.

The conference featured invited talks, including a keynote from Professor Mark MacLachlan (University of British Columbia) who presented on "New Photonic Materials from Nanocrystalline Cellulose". A panel of experts from industry discussed nanotechnology R&D and where job opportunities for future nanotechnology engineers can be found. Drawing inspiration from the invited talks, panels and posters, the conference concluded with a think-a-thon to bring ideas together and discuss innovations that could one day fundamentally change the world. Planning is underway for the second WUNC in November 2016.

WATERLOO INSTITUTE FOR NANOTECHNOLOGY GRADUATE STUDENT SOCIETY (WINGSS)

WINGSS brings together graduate students from across disciplines to promote social interaction and facilitate inter-departmental collaboration. Founded in 2014, WINGSS now has 60 members who organize social and scholarly events throughout the year. WINGSS Student Executives provide a collective voice for nanotechnology graduate students to participate in the development of policies related to the collaborative nanotechnology graduate program and offer insight into the needs and use of nanofacilities and services.
NanoOntario

WIN is a founding member of NanoOntario Inc. (nanoontario.ca) a fully incorporated not-for-profit organization that represents the interests of academic, government, industrial and finance community members in the development of nanotechnologies in Ontario. Dr. Arthur Carty is the Chairman and Alain Francq is the Treasurer.

JIANGSU-ONTARIO NANOTECH INNOVATION CENTRE (NIC)
SUZHOU, JIANGSU PROVINCE, CHINA

The Ontario Ministry of Research and Innovation and the Science and Technology Department of Jiangsu Province in China signed an MOU on October 7, 2015 to establish an Jiangsu-Ontario Nanotech Innovation Centre (NIC). This centre will connect Ontario and Jiangsu nanotechnology resources, strengthen bilateral collaboration in nanotechnology industries, integrate nanotechnology information databases, organize bilateral nanotechnology forums and expos, and actively promote mutual visits and collaboration among nanotechnology research organizations, innovation centres and businesses. NanoOntario Inc. and Nanopolis Suzhou Co. Ltd. will implement and operate the centre on behalf of Ontario and Jiangsu, respectively.

Carty and Francq led a delegation to Suzhou, China to attend the CHInano Conference & Expo on October 28-30, 2015, to officially open the NIC Office and participate in trade discussions.

NANOFACILITIES FOR EMERGING TECHNOLOGIES: INDUSTRY-UNIVERSITY SHOWCASE
MIKE & OPHELIA LAZARIDIS QUANTUM-NANO CENTRE,
UNIVERSITY OF WATERLOO | MAY 13, 2015

WIN hosted the first NanoOntario Industry-University Showcase held at the QNC on May 13, 2015. Attended by 100 participants, the event brought together industry, academia and government representatives to showcase state-of-the-art nanofacilities in Ontario, facilitate academic-industry partnerships and explore funding opportunities. Quantum NanoFab Director Vito Logiudice gave a talk on the facility, followed by tours of the QNC conducted by WIN, raising the profile of University of Waterloo nanofacilities.
The 8,000 square foot Quantum NanoFab is a shared facility between the Waterloo Institute for Nanotechnology (WIN) and the Institute for Quantum Computing (IQC).

The Class-100 cleanroom is an ultra-clean environment with less than 100 particles per cubic foot of air, maintaining the stringent environment required for the extremely complex and challenging task of nanofabrication. Over the past year, the number of registered users has grown to more than 120.

**The Quantum NanoFab offers three broad categories of fabrication processes:**

- Deposition, or growth, of different types of materials
- Patterning materials
- Etching to selectively remove materials as a function of a pattern.

The most recent addition is the 100 keV electron beam lithography system, a machine that allows researchers to reliably pattern structures down to only eight nanometers wide — the equivalent of approximately 80 atoms.

With access to a growing suite of state-of-the-art equipment, the Quantum NanoFab is attracting industry partners and even some University of Waterloo startups. The actual devices engineered in the Quantum NanoFab may be very small — however, their impact has the potential to be just the opposite.
“New discoveries in nanotechnology are dramatically enabled by the tools to see, measure and manipulate materials at the nanoscale.”

— ARTHUR J. CARTY

**QNC METROLOGY OBJECTIVES**

- Support multi-mission research projects with open-access instruments
- Educate and train students in cutting-edge techniques
- Provide user service and facilitate scientific discovery

**Tools:**

- TEM
- SAXS
- SEM
- AFM
- XRD
- FIB
- SQUID

**RESEARCH HIGHLIGHT**

TEM images of a typical (a) TiO$_2$ nanobelt, (b) corrugated nanowire (NW), (c) straight nanowire, and (d) decorated nanowire. Lower-right insets show the corresponding high-resolution TEM images, while the upper-right inset in (d) depicts the high-resolution TEM image of a nanocrystallite. Here, we demonstrate, for the first time, the controlled growth of 1D TiO$_2$ nanostructures with different morphologies and with incorporation of oxygen vacancy defects on a Si substrate by a single-step, catalyst-assisted pulsed laser deposition (PLD) method. Photoelectrochemical water splitting measurements under simulated sunlight show that the decorated nanowires exhibit one of the highest photoactivities in the visible region (>430 nm) reported to date, which represents 87 per cent of the overall photocurrent. The higher activity in the visible region can be attributed to more conductive TiO$_2$ nanostructures (i.e., with a larger amount of oxygen vacancy defects), and the enhanced charge transfer from the nanocrystallites to the core of the decorated nanowires.

**Reference:**


*Defect-rich decorated TiO$_2$ nanowires for superefficient photoelectrochemical water splitting driven by visible light*
**GLOBAL IMPACT**

**international**

**GERMANY**
**CENTER FOR NANO INTEGRATION DUISBURG-ESSEN (CENIDE)**

WIN Professor Kyle Daun invited CENIDE Scientific Director, Professor Christof Schulz to deliver a WIN seminar on February 15, 2013. During this visit, both institutions recognized they share similar visions and strengths, and expressed interest in developing a partnership in nanotechnology. As a result of the Daun and Schulz collaboration, Daun received a Humboldt Research Fellowship and will work with Schulz in CENIDE for 18 months.

Building on the partnership, WIN Executive Director Arthur Carty was invited to the Transatlantic Ruhr Partnership Tour in 2015 and met with Schulz at CENIDE to explore how to expand the partnership to other areas of WIN and sign an agreement promoting co-operation in research and development. Next steps include information exchange, visits by faculty and students and promoting joint activities and workshops.

**UNITED KINGDOM**
**UNIVERSITY OF BRISTOL**

The University of Bristol is one of the top-ranked institutions in the world. In June 2015, WIN welcomed a delegation of 10 faculty and graduate students from Bristol for a workshop in nanotechnology and quantum information research, led by WIN member, Professor Zoya Leonenko. Five research collaborations were identified in the areas of advanced materials, bionanomedicine, and drug and gene delivery systems. The second reciprocal WIN-Bristol workshop will be held at the University of Bristol.

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27** papers from WIN international collaboration in **2015**

19 international partners in ten countries
BRAZIL
WIN led a delegation to Brazil for the fourth annual Brazil-Canada workshop in nanotechnology in October 2015 at Brazil’s “Tech Week” event in São Paulo. This new approach combined academic research talks with the Tech Week industrial trade show and networking activities to foster research, innovation and commercialization between academia and industry. The workshop was co-organized by WIN and Brazil’s Ministry of Science, Technology and Innovation (MCTI), and included a reception at the residence of the Consulate General of Canada to Brazil. The Exhibition attracted over 70 representatives from government, industry, and research institutions from both Canada and Brazil. The workshop featured keynote speakers, an industrial panel and 30 talks in the areas of nanomaterials, nanocomposites, nanosensors and nanodevices. The Canadian delegation visited LNNano and CNPEM in Campinas for presentations, discussions and tours of the facilities, including the Sirius 3 GeV, 518m synchrotron light source. Over 25 Soochow students came to Waterloo in 2015, as Graduate Students in WIN’s 2+2 and 3+1+1 programs, as well as undergraduate internships. A group of five Soochow administrators worked at Waterloo in 2015 as exchange staff.

FRANCE
WIN faculty member Professor John Wen spent a six-month sabbatical working with Professor Nabiha Chaumeix, Director of Research at the National Centre for Scientific Research (CNRS) in Orléans, France. They performed cutting-edge research on characterizing the laser power range for igniting energetic nanomaterials. During his stay, Wen also worked with Professor Carole Rossi, a rising star in nanoenergetics from the University of Toulouse. Rossi delivered an invited WIN seminar at Waterloo on December 8, 2015 to initiate collaboration.

JAPAN
WIN faculty member Professor Holger Kleinke has published a paper entitled “Thermoelectric Properties of Ni_{0.05}Mo_{3.5}Sb_{5.4}Te_{1.6} with Embedded SiC and Al_{2}O_{3} Nanoparticles” in the European Journal of Inorganic Chemistry, as a result of the collaboration between WIN and National Institute for Materials Science (NIMS) in Japan and University of Bordeaux in France.
WIN is committed to creating opportunities for Waterloo to train the next generation of nanotechnology scholars. WIN and our international partners have designed a suite of joint education programs.
**WATERLOO-BRISTOL BILATERAL TRAINING PROGRAMS**

In 2016, a group of nanotechnology graduate students from the University of Waterloo will travel to the University of Bristol in the United Kingdom to participate in a training program to improve independent research skills, writing and communication ability, and introduce ways to effectively engage the media. This bilateral program will also bring graduate students from Bristol to Waterloo for advanced equipment training in the Quantum NanoFab cleanroom and fabrication procedures, and other metrology techniques at the QNC. WIN and the Bristol Centre for Functional Nanomaterials (BCFN) share similar objectives in the priority areas of nanotechnology and have complementary facilities and resources. It is expected that this joint education program will produce exceptional independent student researchers in both institutions in 2017.

**WIN-SUN DUAL DEGREE AND DOCTORAL EDUCATION PROGRAMS**

The WIN-SUN collaboration allows students from Soochow to come to Waterloo to participate in the joint education programs, including the 3+1+1 BSc/MSc, 2+2 PhD or the four-month research internship programs. Since 2012, over 40 Soochow students have participated in these programs and have produced an impressive list of publications in top academic journals and patents. In 2015 WIN welcomed six 3+1+1 students, one 2+2 PhD student and 10 students into the four-month research internship program.

**WARSAW SUMMER INTERNSHIP PROGRAM AT WATERLOO**

Six outstanding students for the University of Warsaw’s elite College of Interfaculty Individual Studies in Science and Mathematics (MISMaP) have visited WIN for a two-month summer internship program, since 2013. These bright and focused students are very productive during their time at Waterloo, resulting in several coauthored publications in top academic journals. In 2016, the WIN-Warsaw graduate internship initiative will be expanded to bring three exceptional MSc students from the MISMaP College for a three-month internship.
Every year, WIN awards dozens of Nanofellowships valued at CAD$10,000 to outstanding graduate students for their scholarly achievements.

**2015–2016 NANOFELLOWSHIP RECIPIENTS**

Parvin Adeli  
Sanam Atashin  
Erin Bedford  
Navid Bizmark  
Yu Chai  
Li Chen  
Dennis Curry  
Christopher Deimert  
Russel Fernandes

Fredrick Fu  
Nathan Grishkewich  
Gordon Hall  
Gyu-Chull Han  
Andrew Holmes  
Md Ariful Hoque  
Nicholas Lanigan  
Dong-Un Lee  
Timothy Leshuk

Matthew Li  
Stuart Linley  
Biwu Liu  
Anand Lopez  
Gregory Lui  
Nupur Maheshwari  
Pendar Mahmoudi  
Quanquan Pang  
Jesse Quinn

Shehan Salgado  
Brandon Seo  
Hamed Shahsavani  
Amirreza Shirani  
Bin Sun  
Colin Tittle  
Taylor Urquhart  
Xinyun Wu  
Demin Yin

36 nanofellowships awarded (2015-2016)  
8 rounds of nanofellowship competitions

276 nanofellowships awarded since 2008
The Vanier Canada Graduate Scholarship is a highly prestigious program, awarding $150,000 over three years to top doctoral students for their academic excellence, research potential and leadership. Professor Frank Gu was able to attract four Vanier scholars to conduct their doctoral research in his laboratory in the QNC, which speaks volumes about Gu’s mentorship and facilities at WIN.

Vanier scholars Mohit Verma (PhD ’14, Nanotechnology), Timothy Leshuk, Stuart Linley and Paul Chen (candidates for PhD in Nanotechnology) all graduated from Waterloo’s Nanotechnology Engineering undergraduate program straight into the PhD program, a leap that is only attainable by exceptionally high achieving students. During their undergraduate studies, they spent their co-op terms working in Gu’s lab on research projects which continued to be the focus of their research for their doctoral studies.

Verma was interested in ocular health and investigated the use of gold nanoparticles to detect harmful bacteria on contact lens. Today, Verma is a Postdoctoral Fellow at Harvard University working with world-renowned chemist, Professor George Whitesides. Paul Chen is interested in drug delivery and played a key role in developing prototypes of a nanodiagnostic platform to identify pathogens.

Leshuk and Linley are working on nano-enabled photocatalysts that harness the power of the sun to break down persistent contaminants in water, including naphthenic acid found in wastewater from oil sands. The treated water can be safely discharged into the municipal water system and the catalysts recovered and reused, without generating any waste. Leshuk and Linley, along with their mentor Gu co-founded a startup, called H2nanO to commercialize their renewable and low-cost nanotechnology for water treatment.

Verma, Leshuk and Linley were also awarded the WIN Nanofellowships for their groundbreaking research and scholarly achievements.
The WIN Distinguished Lectures and Seminar Series provide an opportunity for faculty and students to meet and interact with nanotechnology experts around the world, and drive research collaborations.

- Ferhat Aydinoglu (ECE)
- Robert Black (Chemistry)
- Remi Casier (Chemistry)
- Lindsey Daniels (Math)
- Brian Fernandes (Math)
- Kaveh Gharavi (IQC)
- Maria Pia Herrling (Chem Eng)
- Khaled Ibrahim (SYDE)
- Damin Kim (Chemistry)
- Madelaine Liddy (IQC)
- Lingzi Ma (Chemistry)
- Nupur Maheshwari (ECE)
- Ehsan Marzbanrad (MME)
- Nimer Murshid (Chemistry)
- Runjhun Saran (Chemistry)
- Luke Vanderzwet (Chemistry)
- Kier von Königslow (Physics)
- Demin Yin (ECE)

NANOTECHNOLOGY GRADUATE STUDENT SEMINAR SERIES

The WIN graduate student seminar series provides an opportunity for nanotechnology graduate students of WIN members to present and discuss their research, to help foster knowledge exchange and dialogue between researchers and across disciplines. This seminar series was initiated by WIN faculty member Professor Xiaosong Wang.
## Distinguished Lectures

<table>
<thead>
<tr>
<th>Name</th>
<th>Title and Affiliation</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robin D. Rogers</td>
<td>Canada Excellence Research Chair in Green Chemistry, McGill University, Canada</td>
<td>Innovation is the gateway to the biomass biorefinery and ultimately a sustainable bio-based economy</td>
</tr>
<tr>
<td>Kang L. Wang</td>
<td>Distinguished Professor and Raytheon Chair Professor in Physical Science and Electronics, University of California, Los Angeles (UCLA), United States</td>
<td>Spin-orbitronics for energy efficient systems</td>
</tr>
<tr>
<td>Lynden A. Archer</td>
<td>William C. Hoey Director and James A. Friend Family Distinguished Professor of Engineering, Cornell University, United States</td>
<td>Electrolyte design principles for lithium metal batteries</td>
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## Seminars

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<tr>
<th>Name</th>
<th>Title and Affiliation</th>
<th>Topic</th>
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<tr>
<td>Carlos Cesar Bufon</td>
<td>Head of the Laboratory of Functional Devices and Systems, Brazilian Nanotechnology National Laboratory (LNNano), Brazil</td>
<td>Hybrid organic/inorganic devices based on nanomembranes</td>
</tr>
<tr>
<td>Ning Chen</td>
<td>Scientist, Canadian Light Source; University of Saskatchewan, Canada</td>
<td>Opportunities for nanoscience research at the Canadian Light Source</td>
</tr>
<tr>
<td>Joanna Millunchick</td>
<td>Professor of Materials Science and Engineering, University of Michigan, United States</td>
<td>Atomic scale growth processes of compound semiconductor alloys</td>
</tr>
<tr>
<td>T. Pradeep</td>
<td>Professor of Chemistry, Indian Institute of Technology Madras, India</td>
<td>Affordable clean water using nanomaterials (Joint Water Institute-WIN seminar)</td>
</tr>
<tr>
<td>Antal Jakli</td>
<td>Professor at the Liquid Crystal Institute and Department of Chemical Physics, Kent State University, United States</td>
<td>Complex nanostructures of single component bent-core liquid crystal materials</td>
</tr>
<tr>
<td>Ismael Diez-Perez</td>
<td>Ramon &amp; Cajal Research Professor in Physical Chemistry, University of Barcelona, Spain</td>
<td>Probing concepts in single-(bio) molecule wires: bioengineering the protein/electrode interface</td>
</tr>
<tr>
<td>Aaron Wheeler</td>
<td>Canada Research Chair in Bioanalytical Chemistry, University of Toronto, Canada</td>
<td>Digital microfluidics for three dimensional cell culture and single-cell signaling assays</td>
</tr>
<tr>
<td>Dan Botez</td>
<td>Professor, University of Wisconsin-Madison, United States</td>
<td>High-coherent power, photonic-crystal mid-infrared quantum cascade lasers</td>
</tr>
<tr>
<td>Huan-Tsung Chang</td>
<td>Chemistry Professor, National Taiwan University, Taiwan</td>
<td>Analytical applications of photoluminescent nanomaterials</td>
</tr>
<tr>
<td>Nenad Markovic</td>
<td>Senior Chemist at the Materials Science Division, Argonne National Laboratory, United States</td>
<td>Electrochemical interfaces, electrocatalysis and green energy</td>
</tr>
<tr>
<td>Patrick Malenfant</td>
<td>Printable Electronics — Materials Thrust Leader, National Research Council of Canada, Canada</td>
<td>Nanomaterials for printable electronics</td>
</tr>
<tr>
<td>T.K. Sham</td>
<td>Canada Research Chair in Materials and Synchrotron Radiation and Chemistry Professor, Western University, Canada</td>
<td>Synchrotron solutions for the length scale science of matter and time</td>
</tr>
<tr>
<td>Carole Rossi</td>
<td>Research Director of the Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS-CNRS), University of Toulouse, France</td>
<td>Nanoenergetics, a new technological area through the integration of reactive nanomaterials into MEMS</td>
</tr>
<tr>
<td>Yuezhong Meng</td>
<td>Pearl-River Professor of Polymer Chemistry and Physics, Sun Yat-Sen University, China</td>
<td>Conversion of carbon dioxide into biodegradable plastics and other fine chemicals</td>
</tr>
</tbody>
</table>

*The WIN lectures and seminars, and WUNC conference are available for viewing online at WIN YouTube channel: youtube.com/WINanotechnology*
NEW FACULTY MEMBERS

Na Young Kim  Solid-state quantum simulators
Kevin Musselman  Functional nanomaterials
Germán Scaini  Time-resolved electron diffraction and microscopy
Adam Wei Tsen  Low-dimensional quantum materials and devices
Alfred Yu  Biomedical ultrasound

82 Faculty Members

19 Research Chairholders
On July 1st, 2015, four WIN affiliates were named to the Order of Canada, one of Canada’s highest civilian honours, in recognition for their outstanding achievement, dedication to the community and service to the nation.

WIN member Linda Nazar was named an Officer of the Order of Canada in honour for her contributions as a materials chemist on advanced battery systems for clean energy storage. Garry Rempel became a member of the Order of Canada for his contributions to the field of chemical engineering, notably for advancing research in rubber technology. WIN donors Ophelia Lazaridis and Douglas Fregin were also honored as a member of the Order of Canada.

**AWARDS**

Janusz Pawliszyn
14th most influential analytical scientist — *The Analytical Scientist “Power List 2015”*  
October 2015

David Cory
Fellow of the Royal Society of Canada — elected by peers in recognition of outstanding scholarly, scientific and artistic achievement.  
*September 8, 2015*

Zhongwei Chen
Natural Sciences and Engineering Research Council of Canada (NSERC) E.W.R Steacie Memorial Fellowship — in recognition of his work in developing new materials that make batteries and fuel cells smaller, lighter and longer-lasting.  
*February 16, 2016*

John Yeow
Fellow of the Engineering Institute of Canada — for his contributions in microsystems and nano devices for medical diagnostic and therapeutic instruments.  
*May 26, 2015*

Juewen Liu
Paper listed in *Langmuir* 30th anniversary virtual issue as one of the journal’s most important articles in surface science and colloid science.  
*August 2015*

**CHAIRS**

Canada Excellence Research Chair
David Cory — Quantum Computing

Canada Research Chairs
Zhongwei Chen — Advanced Materials for Clean Energy
Frank Gu — Advanced Targeted Delivery Systems
Raafat Mansour — Micro and Nano Integrated RF Systems
Linda Nazar — Solid State Materials
Janusz Pawliszyn — New Analytical Methods and Technologies
Pavle Radovanovic — Spectroscopy of Nanoscale Materials
Carolyn Ren — Lab-on-a-Chip Technology
Derek Schipper — Organic Material Synthesis
Germán Sciaini — Atomically-Resolved Dynamics & Ultrafast High-Resolution Imaging
John Yeow — Micro and Nanodevices

Ontario Research Chair
Siva Sivoththaman — Renewable Energy Technologies and Health

WIN Endowed Research Chairs
Raffi Budakian — Joint WIN/IQC Chair in Superconductivity
Zbig Wasilewski — Molecular Beam Epitaxy (MBE)

University of Waterloo Research Chairs
Pu Chen  
Mark Matsen  
James Forrest  
Michael Tam  
Norman Zhou
WIN MANAGEMENT AND ADMINISTRATION

Arthur Carty, Executive Director
Alain Francq, Managing Director
Lisa Pokrajac, Assistant Director, Research Programs
Caroline Brookes, Administrative Assistant
Ivy Tjendra, Office and Communications Co-ordinator
Jisu Kwon, Administrative and Financial Assistant

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C.N.R. Rao, National Research Professor and Honorary President & Linus Pauling Research Professor, Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), India
scholarly output

3,104 papers published since 2008 (cited 37,273 times)

521 papers published since in 2015

7 papers from industrial collaboration

27 papers from international collaboration
SELECTED WIN PAPERS IN 2015


» Liang, Xiao; Hart, Connor; Pang, Quan; Garsuch, Arnd; Weiss, Thomas; Nazar, Linda F.*, “A highly efficient polysulfide mediator for lithium-sulfur batteries”, Nature Communications, 6 (2015)


» Akhlaghi, Seyyedeh Parinaz; Zaman, Masuduz; Mohammed, Nishil; Brinatti, Cesar; Batmaz, Rasim; Berry, Richard°; Loh, Watson*, Tam, Kam Chiu*, “Synthesis of amine functionalized cellulose nanocrystals: optimization and characterization”, Carbohydrate Research, 409, pp461-469 (2015)


» Amoli, Behnam Meschi; Trinidad, Josh; Rivers, Geoffrey; Sy, Scrubbabel; Russo, Paola; Yu, Aping*: Zhou, Norman Y.*; Zhao, Boxin*, “SDS-stabilized graphene nanosheets for highly electrically conductive adhesives”, Carbon, 91, pp188-199 (2015)

* WIN member
° WIN International collaborators
≠ WIN industrial collaborators

Data collected from Thomson Reuters Web of Science
BY THE NUMBERS

financials

2008 - 2009
2009 - 2010
2010 - 2011
2011 - 2012
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Offic e
Operations
Salary