TORONTO REGION
ACCELERATE INNOVATION.

TORONTO REGION: THE LEADING CENTRE OF ADVANCED NANOTECHNOLOGY RESEARCH IN CANADA

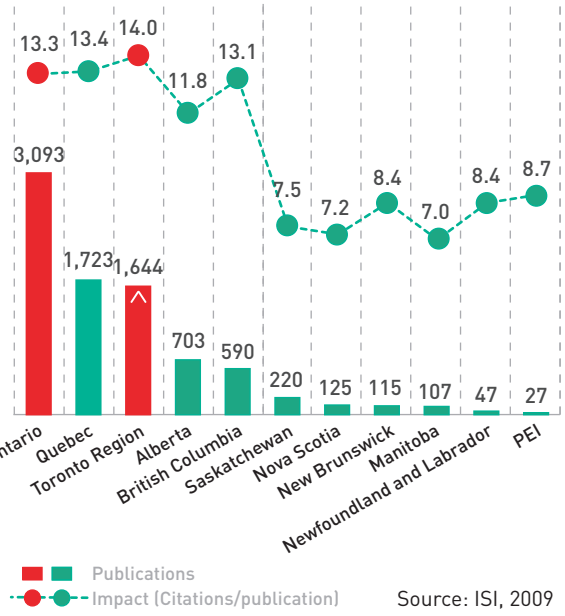
AT THE FOREFRONT OF A RAPIDLY EXPANDING SCIENTIFIC FRONTIER

Size matters. Nanotechnology, the science and technology of manipulating matter at the molecular level, transforms existing materials and devices to be smaller, faster, lighter, cheaper, and more energy efficient. These properties are fuelling research in many different fields including engineering, chemistry, electronics, and medicine.

Toronto Region universities are at the forefront of this rapidly expanding scientific frontier. McMaster University, University of Toronto and University of Waterloo alone produce 25% of the nanotechnology research conducted in Canada. The region also leads the rest of Canada in terms of scientific impact of nanotechnology-related publications. With 271 researchers across 19 institutions, the scientific impact of Ontario nanotechnology publications compares favourably to other North American and international regions. More than half (157) of Ontario's scientists conducting nanotech-related research are based in the Toronto Region.

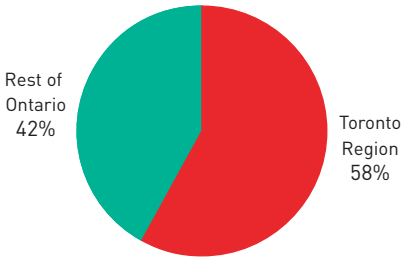
HIGH SCIENTIFIC IMPACT

Publications between 2000-2009



Source: ISI, 2009

271 INVESTIGATORS IN 19 INSTITUTIONS

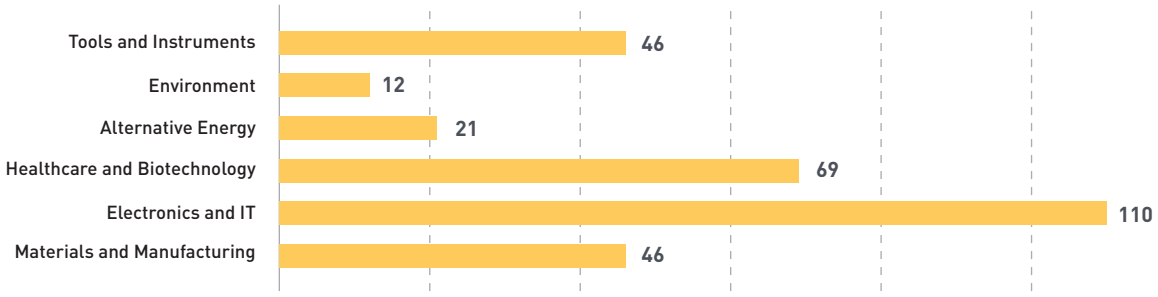


Source: NSERC, CFI, CIHR, 2009

BUILDING ON INDUSTRIAL STRENGTHS

Ontario is well-positioned to become a leader in niche areas that build upon its industrial strengths. Ontario scientists are actively engaged in research directed toward traditionally strong areas such as ICT, materials and manufacturing, and life sciences, as well as in rapidly emerging areas such as solid state lighting and solar photovoltaics. For example, a recently announced NSERC Strategic Network in Photovoltaic Innovations is headquartered at McMaster University, led by Rafael Kleiman, Canada Research Chair in MEMS Technology, and includes key researchers from all Toronto Region universities.

NUMBER OF NANOTECH SCIENTISTS BY MARKET SECTOR IN ONTARIO



Note: Scientists may be involved in more than one area

Source: NSERC, CFI, CIHR, 2009

CANADIAN CENTRE FOR ELECTRON MICROSCOPY

MCMASTER UNIVERSITY, HAMILTON

The **Canadian Centre for Electron Microscopy (CCEM)** operated by McMaster University's Brockhouse Institute of Materials Research houses two of the world's most powerful commercially-available electron microscopes, the Titan™ 80-300. The microscopes are located in specially-designed, state-of-the-art facilities to withstand even ultralow vibrations, noise and temperature variations. This unique electron microscopy centre is bringing together academic and industry experts and fostering international collaborations at the cutting-edge of materials science. It greatly enhances Ontario's research capability in materials for a broad range of applications, from electronics and photonics to health care and geoscience, as well as other disciplines whose advancement depends on obtaining structural information at unprecedented spatial and energy resolution.

McMaster University has an outstanding reputation for its basic and applied materials research that supports advanced manufacturing, steel and automotive industries, both in Canada and around the world. These resources add to McMaster's impressive collection of materials-related research facilities such as the **McMaster Steel Research Centre**, and the **Centre for Emerging Device Technologies (CEDT)**. The **Brockhouse Institute of Materials Research** develops, supports and coordinates all materials research at the university.

CCEM Scientific Director **Gianluigi Botton** holds the Canada Research Chair in Electron Microscopy of Nanoscale Materials. He has developed advanced electron microscopy and analytical spectroscopy techniques for exploring the composition, structure and bonding of nanostructured materials. He also pioneered methods in electron energy loss spectroscopy used to obtain bonding and chemical states of elements present in materials and relating the data to properties of engineering materials, coatings and interfaces in electronic and photonic applications.

Dr. Jamal Deen, professor of electrical and computer engineering, is regarded as a leading scientist in modelling, design and applications of advanced semiconductor devices. In his role as the Canada Research Chair in Information Technology, he develops next-generation electronics by exploring nanotechnology components for long-distance communication systems required for transmission of data, speech and video signals. His research is of great industrial importance as device manufacturers continue to embrace nanoelectronics and nanophotonics to support the increasing need to store and share information more efficiently.

"We are the first university in the world with a microscope of such a high calibre...The resolution of the Titan 80-300 Cubed microscope is remarkable, the equivalent of the Hubble Telescope looking at the atomic level instead of at stars and galaxies. With this microscope we can now easily identify atoms, measure their chemical state and even probe the electrons that bind them together."

- **Professor Gianluigi Botton**, Director of the Canadian Centre for Electron Microscopy, Canada Research Chair in Electron Microscopy of Nanoscale Materials

"The addition of the Titan 80-300 Cubed to the Centre's suite of microscopy instruments that include a Titan cryo-in situ solidifies Ontario's and Canada's lead in nanotechnology, and places us among the world's most advanced materials research institutions."

- **Mo Elbestawi**, Vice-President, McMaster University, Research and International Affairs

CENTRE FOR ADVANCED NANOTECHNOLOGY

UNIVERSITY OF TORONTO

The University of Toronto took an early leadership role in nanotechnology. In 1997, the university established Canada's first centre for nanotechnology research, the **Centre for Advanced Nanotechnology (CAN)**. CAN's team of interdisciplinary scientists, led by Professor **Harry Ruda**, established Canadian competence in nanoelectronic and nanophotonic research. Nobel laureate **John Polanyi** is a member of the centre's faculty.

The **Centre for Nanostructured Polymer and Inorganic Materials (CNPIM)** is also based at the University of Toronto. Founded in 2002 and supported by the Canada Foundation for Innovation, CNPIM provides exceptional infrastructure to scientists and industry partners for investigating properties of nano-, meso- and microstructured materials. Interdisciplinary efforts at the Centre focus on innovative research into novel polymer, inorganic, and hybrid nanostructured materials for a wide range of applications, from polymer materials for spinal cord repair to photonic crystal chips for optical communications.

The University of Toronto is home to several internationally-recognized nanotechnology researchers. **Professor Geoffrey Ozin**, Canada Research Chair in Materials Chemistry, is a pioneer in the field whose work spans studies of new classes of nanomaterials, mesoporous materials, photonic crystals and nanomachines. **Professor Chemistry Gilbert Walker** is the Canada Research Chair in Molecular Microscopy and Nanophotonic Devices. He heads BiopSys, a multi-year $5 million interdisciplinary research to develop and test bioplasmonic devices to diagnose lung cancer and leukemia faster. **Professor Mitchell Winnik** heads the **Centre for Nanostructure Imaging (CNI)** which operates of state-of-the-art scanning and scanning transmission microscopes that allow for structural characterization down to 0.14 nm. His group pioneered the application of nanotechnology techniques that provide information about events occurring within 10 Å to 100 Å of an interface.

WATERLOO INSTITUTE FOR NANOTECHNOLOGY

UNIVERSITY OF WATERLOO

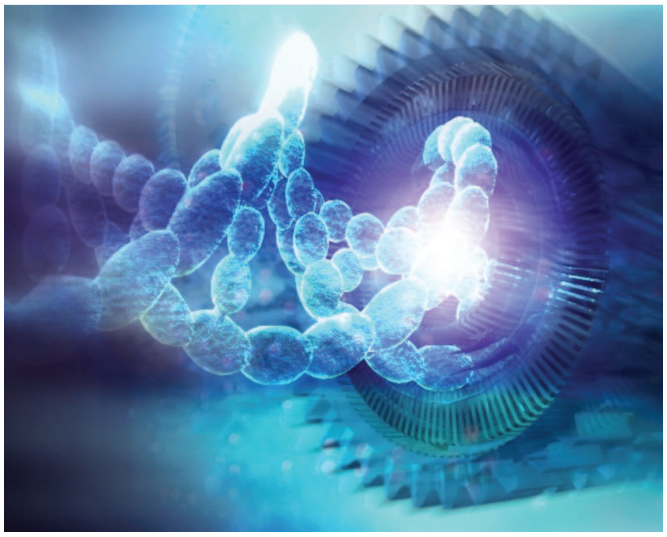
Established in 2008, the **Waterloo Institute for Nanotechnology (WIN)** is an interdisciplinary and collaborative research centre whose mandate is to coordinate nanotechnology initiatives taking place across the university. Drawing on more than 50 faculty members from eight departments at the University of Waterloo, the centre takes a 4-pronged approach to nanotechnology by providing world-class facilities, building outstanding research talent, nurturing the next generation of nanoscientists, and seeking national and international partnerships.

WIN is home to four flagship research facilities: **Giga-to-Nano Electronics laboratory; Waterloo Advanced Technology Laboratory (WATLab); Centre for Integrated RF Engineering (CIRFE); and Centre for Advanced Photovoltaic Devices and Systems (CAPDS)**. The intellectual capabilities and advanced facilities combine to provide the critical mass in four thrust areas: nanomaterials, nanoelectronics, nanoinstruments, and nanobiosystems.

The university has also responded to the increased demand for nanotechnology expertise by establishing Canada's largest co-operative undergraduate degree program in nanotechnology engineering. Unique in North America, the curriculum provides students with the opportunity to gain a sound foundation in relevant mathematics, physics, chemistry and engineering principles in more than 60 courses (with 29 core courses in nanotechnology) and 24 months of work experience over five years of study. In addition, a new collaborative, interdisciplinary MASc, MSc, and PhD graduate program allows students to gain a broad perspective on nanotechnology through course work and research within a community of scholars spanning seven different disciplines.

The new $160 million state-of-the-art **Mike and Ophelia Lazaridis Quantum-Nano Centre** is set to open in late 2010. It will house WIN along with the **Institute for Quantum Computing (IQC)** whose respective excellence in nanotechnology and quantum computing strengthens Waterloo as an epicentre for quantum information processing and development of nanoscale devices needed for enabling quantum computing systems.

The University of Waterloo has a rich pool of expertise in nano-materials for energy conversion, storage and delivery. **Linda Nazar**, a faculty member of the



> "WIN will attract outstanding new faculty, students and research personnel; foster new national and international partnerships enhance collaboration; and enable research at the forefront of science and engineering. The overall objective is to establish WIN as a global centre of excellence for nanotechnology and its applications."
>
> **Arthur J. Carty**, Executive Director
> Waterloo Institute for Nanotechnology

Department of Chemistry is the Canada Research Chair in Solid State Materials. Her long-time efforts to develop new materials for energy storage and conversion may enable the innovation necessary to build cost-effective and environmentally friendly batteries for renewable power sources and vehicles. Her studies of the underlying solid-state chemistry and structure-property relationships in metal oxides and metal phosphates have led to multiple patents and breakthrough discoveries in the field, such as using sulphur-carbon composites to store three times the energy of lithium ion batteries.

Professor **Siva Sivoththaman** in the Department of Electrical and Computer Engineering is widely-regarded as an expert in photovoltaic (PV) energy conversion, semiconductor devices, and related fabrication methods. He is the director of the **Centre for Advanced Photovoltaic Devices and Systems (CAPDS)**, a world-class research facility with dedicated infrastructure for PV materials and device R&D. As the Ontario Chair in Renewable Energy Technologies and Health, his work will address health and safety concerns in the manufacturing and use of new technologies and provide scientific data about potential health impacts of renewable energy.

UNIVERSITY OF GUELPH

The Toronto Region is the third largest food manufacturing region in North America, behind the clusters in California and the Chicago area. As the third largest Canadian manufacturing sector, it plays a significant role in the economic health of Ontario and Canada.

Guelph University, in particular, is positioning itself as Ontario's leader in food nanotechnologies. A large, collaborative project, funded by **the Advanced Foods and Materials Network** (AFMNet) and led by Professor John Dutcher, is studying nanotechnology-based approaches for the understanding of complex problems involving bacteria and bacterial biofilms on surfaces. The team is using state-of-the-art experimental and computational techniques to explore nanoscale interactions, structure and dynamics and study the effectiveness of novel anti-biofilm agents. **Milena Corredig** in the Department of Food Science holds the Canada Research Chair in Food Nanostructures and is probing the behaviour of food structures in order to optimize the delivery of nutrients, with an emphasis on dairy technology. Professor **Loong-Tak Lim** is developing "intelligent" food packaging by using electrospun nanofibers from biodegradable sources as the basis for packaging materials to extend the shelf life of liquids. This research has the potential to meet the global demand for high-quality and smart food packaging.

TRRA
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