miam

McGill Institute for Advanced Materials

Promoting and supporting the field of advanced materials at McGill

MIAM ANNUAL REPORT
2011-2012

Director: Prof. Andrew Kirk

Administrator: Rowena Franklin

MCGILL INSTITUTE FOR ADVANCED MATERIALS

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Director's Message

Question: How many different items of research equipment are the supported by the McGill Institute of Advanced Materials?

Answer: depending on exactly what you count, around thirty (twelve of these are surface and materials characterization tools and the reminder are nanofabrication tools in the McGill Nanotools Microfabrication laboratory).

As you will see from this report, the equipment that forms the distributed MIAM Characterization Facility, is being used to an even greater extent than last year (which was the first full year of operation). Fees provided by users are all returned to the facilities in order to pay for the technical staff which support the equipment and to cover maintenance and consumables.

Despite the continued healthy growth in facility usage, the MIAM facilities remain critically dependent on the continued financial support of the university (the Provost's office and the Faculties of Science and Engineering) and in the current challenging university budget context it is more important than ever that you, our users, provide us with as much data on papers produced, students trained and grants awarded as a result of these tools. These are all essential metrics to help get renewed funding.

I would like to express my gratitude to all of the technical and academic staff who work so hard to keep the equipment running and available to users, despite such unexpected interruptions as the massive flood that the Wong Building, and other parts of campus two months ago!

If you have any suggestions for additional equipment, or thoughts on how to help us provide better access or service, please do not hesitate to get in touch.

Prof. Andrew Kirk,
MIAM Director & Interim Dean of the McGill Faculty of Engineering

In this Issue

Executive Summary

In this newsletter, we are pleased to report that MIAM currently has 61 academic members, distributed across the Faculties of Science, Engineering, Medicine and Dentistry. In addition 42 students are enrolled in the NSERC CREATE program in Integrated Sensor Systems, which is administered by MIAM.

Usage of the MIAM Characterization facility tools has almost doubled since last year's report., with an average usage of 233 hours per month (in comparison to 142 hours per month last year). Several of these tools are now brining in sufficient income to be able to support the technicians that undertake training and maintenance, which was a long-term goal for the Characterization Facility. The Nanotools Microfabrication Facility continues to go from strength to strength. Usage has stabilized at just over 7,000 hours in total, but the number of PIs has increased from 42 to 50, representing a reassuring broadening of the impact of the facility. Nanotools also hosted the Standing Committee on Finance of the House of Commons this fall. With the success of Prof. Grutter in obtaining CFI funding for the Nanotools II project, the facility will be further improved and expanded in the coming years.

MIAM members reported having produced 309 journal articles, 8 books and 12 chapters in the last year. Users of the facilities reported at least 79 peer reviewed articles as being due to the facilities, and a total of $7.6 M in new grant funding.

The number of HQP being trained in the facilities continued to increase, with 107 reported for the Nanotools facility last year. The facilities are also increasingly being used for organized training activities. In addition to the very popular hands-on course in Nanobiotechnology which Professor David Juncker has offered for several years, a new Microfabrication course was created for the Integrated Sensor Systems (ISS) CREATE program and will shortly be offered for the second time. Several training courses also make use of the equipment of the Characterization Facility.

Finally the ISS CREATE program continues to build on its success in previous years, providing training to students from four different area universities in the broad area of sensor technologies and systems.

Mission, Objectives and Goals

The McGill Institute for Advanced Materials (MIAM) was created in 2001 with the objective of promoting and coordinating research and graduate training in advanced materials at McGill. MIAM is jointly operated by the Faculties of Science and Engineering, with a growing involvement of researchers from the health sciences, including Medicine and Dentistry.

MIAM currently has 61 members, including 26 from the Faculty of Science,30 from Engineering, four from Medicine and two from the School of Dentistry. MIAM members are highly productive members of the McGill and international research community, and we hope to further promote their effectiveness and creativity by encouraging collaboration and providing high quality, cutting edge instruments and facilities.

In 2006, MIAM assumed responsibility for operation of the McGill Nanotools Microfabrication Facility (NMF, which now contains equipment valued at around $12M). This facility has a full time technical staff of four professional associates. The facility enables a wide range of research activities for many users, both inside and outside McGill, and represents a major investment in time and funding on the part of MIAM. MIAM also now operates a $5.8M Characterization Facility (distributed across several locations) which provides researchers with access to wide range of advanced surface analysis tools. There are five full time and one part time professional staff members distributed around campus who organize and maintain the MIAM Characterization equipment so that they can be used by the broader community while other instruments are run mainly by professors and students.

As part of the MIAM mandate to provide training, MIAM administers a $1.6M grant from NSERC under the CREATE program to run a unique training program in Integrated Sensor Systems. This program now boasts 42 graduate and undergraduate students.

After reviewing this year's survey of MIAM members, staff and users, we look forward to continuing to increase the activities in all three areas through more staff facilitation of facilities use and expansion of our facilities' capabilities as well as expanding the promotion and training for both graduate students and staff. As part of this we will be hosting a regular information series on our facilities' tools and staff expertise. We look forward to see you at our upcoming events.

MIAM Activities and Events

The 2011-2012 year has been quite a busy one for the MIAM facilities and programs.

The Nanotools Microfab (NMR) was host to the fifth one week Hands-on Workshop in Micro and Nanobiotechnology in February 2012 and the first annual hands-on Introduction to Microfabrication workshop in May 2012. The NMR also instituted monthly user meeting the first Thursday of every month, held an annual Microfab user meeting and poster session in April 2011 and presented the facility at the prestigious Standing Committee on Finance in the house of comments in October. The NMR was also involved in several new funding initiatives, including applications for operations funding and several research and training grants.

The Characterization Facility continued to develop their user access, user committees and financial systems throughout this second year of operations. This included new booking and reporting procedures, improving training for new users and improving data collection procedures for the MIAM tools. In addition, the new ISS workshop Introduction to Surface and Materials Characterization for Sensors provided new opportunities for students to learn about the methods and capabilities of several of the MIAM Characterization Instruments.

Lastly, the CREATE-ISS training program was pleased to introduce a number of other new technical and professional training workshops during summer 2012 including Project Management, Process Control and to assist the ISS graduate students in their second and expanded Sensors Summer School last May.

ISS Masters student Daisy Daivasagaya gives a presentation to the other ISS students on her 2012 exchange to Columbia University.

Publications, Grants and HQP

In 2011-2012 MIAM members produced 309 journal articles, 8 books and 12 book sections. MIAM members also received 16 separate awards and honors including CRC chairs, International fellowships, teaching awards and other distinctions. Members also reported another $**1.2M** in new grants based on MIAM member collaborations.

Users of MIAM facilities reported new grants of a **total value of $6,440,884** and at least 79 peer reviewed publications and 10 issued or filed patents directly dependent on facility access. The facilities themselves have won external funding and grants for upgrades in the amount of $548,710. The MIAM Facilities will also be integral to an additional $3,700,000 for the university expected next year as a result of FQRNT *Regroupements Strategiques* renewals and two new NSERC CREATE programs.

> *MIAM equipment and collaborations directly enabled grants of over **$4million** in 2010-11 and over **$8 million** in 2011-12*

While HQP has not yet been measured for the Characterization facility the various tools were used by up to 148 laboratories in at least 15 different departments and 4 external institutions during the 2011-12 year.

In the MIAM Microfab, on the other hand, PIs reported 107 students from 50 laboratories were trained in this year, and workshops introduced as many as 38 others to the procedures and equipment available.

In addition MIAM's ISS program has provided unique inter-university professional and technical training in nano and micro sensor systems for at least 10 ISS undergraduate and 49 graduate students. While individual workshops provided by the ISS program allowed as many as 42 additional students and McGill staff new learning and resource opportunities.

MIAM Members 2011-2012: arrivals, departures and announcements

ISS PhD students pose in front of the McGill Macdonald Harrington building on their way to the 2012 new student welcome reception.

We would like to welcome new member Prof Jeff Gostick, Assistant Professor in Chemical Engineering since 2010. Prof Gostick specializes in engineered and non-conventional porous materials; fuel cell and battery electrodes; porous microstructure characterization; pore-scale modeling; multi-phase transport phenomena; capillary properties. Prof. Gostick is also a user of the MIAM XRD.

In June 2012 MIAM hired a new research assistant Dr Lihong Shang to help in the Wong Building MIAM characterization Facility, especially the XPS. Dr. Shang is now working part time and can be contacted via the MIAM website for assistance and advice on the Wong facility tools. Welcome Dr. Shang.

We would also like to congratulate Dr. Matthieu Naninni, Microfab Manager and MIAM Director Prof. Andrew Kirk on the births of their beautiful daughters: Charlotte and Julianna Trinity.

MIAM Members

Faculty of Engineering

Name	Department	Field of Research
Prof. Francois Barthelat	Mechanical Engineering	Mechanics of materials, biomimetics, experimental mechanics
Prof. Mathieu Brochu	Mining and Materials Eng.	Nanostructured materials consolidation; solar cell electrode fabrication
Prof. Mourad El-Gamal	Electrical & Computer Eng.	MEMS sensors and actuators and wireless sensor networks
Prof. Marta Cerruti	Mining and Materials Eng.	Phenomena between inorganic surfaces and biological molecules
Prof. Lawrence Chen	Electrical &Computer Eng.	Fiber and integrated optics for communications and sensing
Prof. Vamsy Chodavarapu	Electrical & Computer Eng.	Integrated Sensor Microsystems and Nano-/Bio- Materials
Prof. Sylvain Coulombe	Chemical Engineering	Synthesis of nanostructures and nanofluids
Prof. Richard Chromik	Mining and Materials Eng.	Multiscale mechanical and tribological properties of materials
Prof. George Demopoulos	Mining and Materials Eng.	Green energy nanomaterials and clean technology
Prof. Raynald Gauvin	Mining and Materials Eng.	Quantitative x-ray microanalysis; characterization of electron diffusion
Prof. Pierre-Luc Girard-Lauriault	Chemical Engineering	Plasma deposited thin organic coatings for biomedical applications
Prof Jeff Gostick	Chemical Engineering	Porous materials; capillary properties; fuel cell and battery electrodes
Prof. Reghan J. Hill	Chemical Engineering	Complex behavior, soft matter & nanotechnology in chemical eng.
Prof. Pascal Hubert	Mechanical Engineering	Development of multi-functional polymer nanocomposites
Prof. Musa R. Kamal	Chemical Engineering	Micro and nano-structured polymer systems
Prof. Anne Kietzig	Chemical Engineering	Biomimetic surface engineering
Prof. Andrew Kirk	Electrical &Computer Eng.	Integrated nanophotonics
Prof. Larry Lessard	Mechanical Engineering	Design, Analysis & Manufacturing of Composite Materials & Structures
Prof. Milan Maric	Chemical Engineering	Controlled radical polymerization for nano-scale materials.
Prof. Zetian Mi	Electrical &Computer Eng.	Semiconductor nanostructures, III-nitrides, nanophotonics
Dr. Sam Musallam	Electrical & Computer Eng.	Development of neural prosthetics
Prof. Showan Nazhat	Mining and Materials Eng.	Biomaterials for tissue engineering and drug delivery
Prof. Sasha Omanovic	Chemical Engineering	Functional electrochemically active materials
Prof. Damiano Pasini	Mechanical Engineering	Cellular materials for tissue scaffolding, biomedical devices, and hybrid structures
Prof. David Plant	Electrical & Computer Eng.	Fiber Transmission Systems, Silicon Photonics, Optical Interconnects
Prof. Nate Quitoriano	Mining and Materials Eng.	Semiconductor growth and devices at the nanoscale and beyond
Prof. Alejandro Rey	Chemical Engineering	Computational, structural & functional material science, thermodynamics
Prof. Thomas Szkopek	Electrical & Computer Eng.	Nanoelectronic semiconductor materials and devices
Prof. Jun Song	Mining and Materials Eng.	Mechanics and physics of nanoscale materials modeling and simulation
Prof. Srikar Vengallatore	Mechanical Engineering	Advanced materials for micro/nanosystems (MEMS/NEMS)

Faculty of Dentistry

Name	Department	Field of Research
Dr. Jake E. Barralet	Dentistry	Development of bioceramics for tissue repair or delivery materials & devices
Prof. Marc D. McKee	Dentistry	Biomineralization in bones, teeth and pathologic calcification

Faculty of Medicine

Name	Department	Field of Research
Prof. David Juncker	Biomedical Engineering	Nanobioengineering, microfluidics, proteomics
Prof. Jay L. Nadeau	Biomedical Engineering	Photophysical nanomaterial & protein design for biosensing
Prof. Satya Prakash	Biomedical Engineering	Mathematical tools in continuous-state systems & metrics and logics
Prof. Maryam Tabrizian	Biomedical Engineering	Nanofabrication of cell-substrate/ biomolecular interactions; biointerfaces

MIAM Members

Faculty of Science

Name	Department	Field of Research
Dr. Mark P. Andrews	Chemistry	Photonic/electronic materials and devices; Raman microscopy
Dr. Christopher John Barrett	Chemistry	Self-Assembled Light-Harvesting Materials.
Prof. Amy S. Blum	Chemistry	Novel nanostructured devices and materials through self assembly
Prof. Ian S. Butler	Chemistry	Properties of inorganic compounds; solid-state chemistry
Prof. Aashish Clerk	Physics	Theoretical quantum electronics & quantum nanoscience
Dr. Gonzalo Cosa	Chemistry	Biophotonics/biosensors, luminescent materials
Dr. Adi Eisenberg	Chemistry	Characterization of nanoscale aggregates
Prof. Guillaume Gervais	Physics	Low-temperature quantum nanoscience
Prof. Martin Grant	Dean of Science	The formation of structure and patterns in nonequilibrium systems
Dr. Derek G. Gray	Chemistry	Preparation and properties of cellulose nanocrystals
Prof. Peter Grutter	Physics	Nanoelectric & biochemical tools, information processing &data storage
Prof. Hong Guo	Physics	Transport theory in mesoscopic & nanoscopic systems; nano materials physics
Prof. Michael Hilke	Physics	Quantum nano electronics
Dr. Patanjali Kambhampati	Chemistry	Ultrafast laser spectroscopy and nanoscience
Dr. R. Bruce Lennox	Chemistry	Structure/property relationships of interfaces and nanomaterials molecules
Dr. Audrey Moores	Chemistry	Nanoparticles as catalysts for green chemistry
Prof. Dmytro Perepichka	Chemistry	Synthesis of new properties in organic materials, nanostructures
Dr. Linda Reven	Chemistry	Self-assembled nanoparticles, macro and small molecule stuctures
Prof. Walter Reisner	Physics/ Science	Nanofluidics for single-molecule manipulation and analysis
Dr. David Ronis	Chemistry	Equilibrium and nonequilibrium problems in condensed complex systems
Prof. Bradley Siwick	Chemistry	Experimental condensed matter physics; materials science; chemical physics
Prof. Hanadi Sleiman	Chemistry	Supramolecular & DNA chemistry, synthetic polymers, biomimetics
Prof. D. Mark B. Sutton	Physics	Time evolution of non-equilibrium systems
Prof. Hojatollah Vali	Anatomy & Cell Biology; Earth & Planetary Sciences; Dentistry; FEMR	Biomineralogy; tissue engineering; biomaterials
Dr. Theodorus van de Ven	Chemistry	Innovative cellulose products, bioactive paper & nanomaterials
Prof. Paul Wiseman	Physics & Chemistry	Biophysics, fluorescence fluctuation methods, nonlinear microscopy

MIAM Associated Professional Staff

Name	Department	Position
Mr. Don Berry	MIAM	Technologist, MIAM Nanotools-Microfab
Mr. Lino Eugene	MIAM	Research Assistant, MIAM Nanotools-Microfab
Mr. Jun Li	MIAM	Equipment technologist, MIAM Nanotools-Microfab
Dr. David Liu	FEMR	Staff Scientist, Facility for Electron Microscopy Research (FEMR)
Dr. Andrey Moiseev	Chemistry	Research Associate (Electron Paramagnetic Resonance facility)
Dr. Fred Morin	Chemistry	Manager, NMR Facility
Dr. Matthieu Nannini	MIAM	Manager, MIAM Nanotools-Microfab
Dr. Florence Paray	Mining and Materials	Manager, Wong Building MIAM Characterization Facility
Dr. Nadim Saadeh	Chemistry	Manager, Mass Spectroscopy Facility
Dr. Lihong Shang	Mining and Materials	Research assistant, Wong Building MIAM Characterization Facility

MIAM Member Awards and Honours

MIAM would like to issue a special congratulations to all of the members whose fine work has been honoured in 2011-2012

Prof. Alejandro Rey

2012 Sturgeon Lecture Award, British Liquid Crystal Society

Stanley Mason Award, Canadian Society of Rheology, June 6, (2011).

Best Poster Award, Canadian Society of Rheology : "Acousto-spinodal decomposition of compressible polymer solutions: Earlier stage", with Gonchech Rasouli, Workshop on Rheology, Montréal QC, Canada, June 6-7, (2011)

Prof. Nate Quitoriano

Suzhou Venture week Honorarium.
This award is to honor excellence in research and development. It is provided by the Suzhou Investment Group.

Prof. Lawrence Chen

Fellow, Optical Society of America.
Only 10% of the total membership who have served with distinction in the advancement of optics are eligible for being elected to the class of Fellow, the new position comes with many responsibilities and distinctions.

Dr. Maryam Tabrizian

International Fellow in Biomaterial Science and Engineering in 2011 by the World Biomaterials Society.
This is a international grant to recognize excellence and expertise in a field. She is a Member of the organizing committee for: micro and nanoegineering in medicine meeting sponsored by IEEE and other numerous influential engineering committees.

Prof. Damino Pasini

Research award fellowship for Experienced Researchers from the Alexander von Humboldt Foundation (Germany).
This award allows the recipient to carry out a long-term research project (6-18 months) they have selected at a research institution in Germany.

Prof. Paul Wiseman

J. D. Jackson Award for Excellence in Teaching (Physics) 2012.
This Award recognizes exemplary teaching in the field of physics.

Dr. Audrey H Moores
Science Communication Fellowships for Green Chemistry, 2011.
This award is for post doctoral fellows and junior faculty with active research programs related to Green Chemistry. Advancing Green Chemistry in partnership with Environmental Health Sciences

Prof. Adi EisenBerg

Recipient of the 2011 CIC medal from the Chemical Institute of Canada, Montreal, Canada Chemistry Conference.
This award is presented as a mark of distinction and recognition to a person who has made an outstanding contribution to the science of chemistry or chemical engineering in Canada.

Dr. Jake E Barralet
Canada Research Chair in Osteoinductive Biomaterials.
Canada's government is investing in science and technology and giving recognition to a generation of researchers who are advancing discovery and innovation in exciting new directions.

Prof. Richard Chromik

Faculty of Engineering Outstanding Teaching Award.
In recognition of exemplary teaching skills and reception.

Prof. David Plant

2013 Killam Fellowship
The Killam Fellowships. provides an opportunity for exceptional undergraduate students from universities in Canada and the United States to spend either one semester or a full academic year as an exchange student in the other country

MIAM Member Research Highlight:

Prof. Zetian Mi, Department of Electrical and Computer Engineering et. al.

MIAM Members Zetian Mi, Thomas Szkopek, Ishiang Shih, Guillaume Gervais, Kirk Bevan, Hong Guo, and Pat Kambhampati and their group members have been working together for a few years to find a practical solution to reduce the energy consumption, and to make high efficiency lighting sources and other electronic and photonics devices using nanowire structures. These semiconductor nanowire structures are synthesized in Prof. Mi's GaN Molecular Beam Epitaxy (MBE) laboratory.

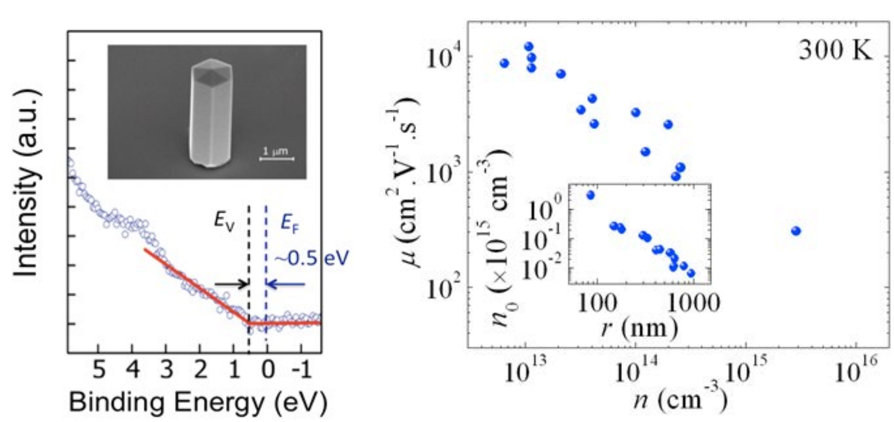
From drilling wood to get fire, to the modern LED lamps, the lighting technologies have evolved a long way in the past thousands of years. Behind the evolution of lighting technologies lies an important driving force: increasing the luminous efficiency. If the lighting efficiency for general illumination is increased from the current ~5-20% to 50%, the global electricity consumption is expected to be reduced by more than 10%. The current approach for achieving high efficiency LED lamps relies on the use InGaN quantum wells, which, however, has been fundamentally limited by the difficulty in achieving high efficiency green and red LEDs. To address this grand challenge, Prof. Mi and his group have developed InGaN/GaN dot-in-a-wire nanostructures and have further demonstrated phosphor-free white LEDs with record internal quantum efficiency. To further improve the device performance as well as to achieve ultrahigh-speed electronic, photonic, and biosensing devices on a Si platform, they have further investigated the epitaxial growth and characterization of InN nanowire structures, which is arguably one of the least investigated, yet most important materials in III-V compound semiconductors. They have addressed three major challenges related to InN, including the lack of intrinsic InN, uncontrolled surface properties, and lack of p-type doping.

Methods and Results

In contrast to previous reports on tapered InN nanowires, Prof. Mi and his students found that with the use of a self-catalytic epitaxial growth process, the quality of InN nanowires can be enhanced significantly (see the inset of Fig. 1(a)). Moreover, they found that the valence band spectrum measured on such InN nanowires by X-ray photoelectron spectroscopy in MIAM characterization facility suggested the achievement, for the first time in the world, intrinsic InN. Shown in Fig. 1(a), the near-surface Femi-level was measured to locate 0.4 to 0.5 eV above the VBM, suggesting the absence of surface electron accumulation (for a bandgap of 0.65 eV). Meanwhile, the free carrier concentration is estimated to be as low as ~1013 cm-3 (see the inset of Fig. 1(b)). This near-surface Fermi-level and free carrier concentration is essentially close to the intrinsic Fermi-level and intrinsic carrier concentration, respectively, if taking electron effective mass me* = 0.05 m0, and mh* = 0.65 m0. In addition, an extremely high electron mobility value was measured. Illustrated in Fig. 1(b), the room temperature electron mobility can be as high as ~104 cm2/V·s, approaching the theoretically predicted value for pristine InN. The results they found are in direct contrast to the characteristics of n-type degenerate InN nanowires grown by conventional methods and to a great extent resolved the debate on many fundamental physical properties of this technologically important semiconductor nanowires.

Furthermore, they found that the surface charge properties of InN nanowires, including the formation of 2DEG and the optical emission characteristics can be precisely tuned through controlled n-type doping; and such tuning of the surface charge properties can be well captured by the theoretical calculation, which also explains the presence of 2DEG on the conventionally tapered InN nanowires. They also demonstrated, for the first time, p-type doping in InN, which is critical to many practical device applications, including more efficient LEDs and lasers in the near-infrared wavelength range.

This work is being supported by the Natural Sciences and Engineering Research Council of Canada and the *Fonds de recherch sur la nature et les technologies*.



Left: Valence band spectrum of intrinsic InN nanowires. SEM image of a single InN nanowire is shown in the inset.
Right: The derived electron mobility as a function of free carrier concentration, and the free carrier concentration as a function of nanowire radius (inset).

The McGill Nanotools Microfabrication Facility

Here we present highlights of the detailed Nanotools annual report prepared by Academic Director Prof. Peter Grutter in August 2012.

Research, Usage and Training

A clear trend is observable in all the data comparable to previous years: growth has stabilized at a high level. The McGill Nanotools Microfabrication Facility (NMR) has reached steady state operation.

Income from user fees increased 18% to $262,731 in the fiscal year 2011-2012 For a second year in a row, the NMR is recovering all operating expenses from user fees. The University and NanoQuebec support the cost of manpower at 100%. Average user fees amounted to $37.5/h.

After 4 years of strong growth nearly all outputs quantifiable with reasonable effort show a stabilization of usage in 2011-12. Total usage is currently at 7004h, an increase of 1% compared to 2010-11. The total number of PIs using the Microfab was 50 PIs compared to 42 in 2010-11. Fourteen of these, used it for more than 100h (versus 13 in 2010-11). One hundred and seven students worked in the Microfab this year (17% more than in 10/11), resulting in 52 publications (57 in 10/11), 8 patents (6 in 10/11), and 1 start-up (Sensoreal Inc). Forty four students graduated with a project that had a major Microfab component (52 in 10/11), while 5 external companies used the Microfab (3 in 10/11).

The data also shows that the McGill Nanotools Microfab continues to be core to the research of many, mainly recently hired, faculty in Engineering, Science and Medicine at McGill. The outside user base and usage is increasing slightly; with increased marketing by NanoQuebec we anticipate some additional growth in future years. We continue to observe that companies are interested in the whole 'package' including the PIs, HQP and access to excellent facilities. Indeed most companies access the McGill Nanotools Microfab via collaborative mechanisms such as NSERC Strategic projects, CRD or in other partnership agreements with McGill researchers.

The 5th installment of the Hands-on Nanobiotechnology lecture and lab course was offered from Feb 20-24, 2012, attracting 26 students (11 from outside of McGill). This year, the Nanotools Microfab also hosted the 1st installment of the new ISS Introduction to Microfabrication hands-on workshop from May 9-16, 2012. Eleven students attended, including two from outside the ISS program.

New Grants and Funding

Given the competitive funding climate a remarkably high amount of new grants worth $3,925,476 were acquired directly by the NMR PIs, in addition to $3,700,000 as a result of FQRNT *Regroupements Startegiques* renewals and two new NSERC CREATE programs with important Microfab justification and research components. This is a great increase from the $2,669,150 of new grants reported in 2010-11).

Very important for the long term sustainability of the NMR operation was winning peer reviewed, competitive support for NMR manpower from NanoQuebec: $140,000per annum for two years. The McGill Nanotools Microfab is now part of the Quebec Nanotechnology Core Infrastructure and this positions the McGill Nanotools Microfab well for renewal of all NanoQuebec infrastructure support in 2013.

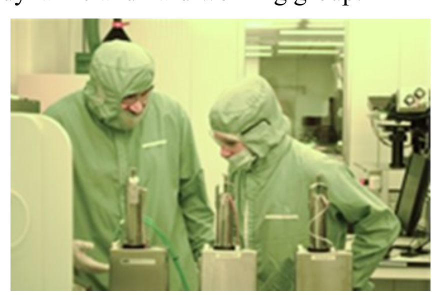
The submitted CFI VII 'Nanotools II' proposal will substantially increase our capabilities, in particular for rapid prototyping and biomedical applications and is expected to lead to growth of life science users once implemented. We are currently establishing partnerships with the MNI as a bridgehead to attract life science and biomedical researchers to the Microfab.

Thanks

Finally, it is noteworthy to point out the excellent team work of our NMR staff: every day on average four different processes are performed by the users! This is a constant challenge to our staff in terms of equipment maintenance, operations stability, safety and training. The manager and staff form a highly motivated, dynamic and hard working group.

ISS Student Ann-Lauriene Haag shows friend Jasmin how to suit up for mean room work.

View of the wafer bonder chamber interior. On the chuck: a structured glass wafer anodically bonded to a silicon wafer.



A batch of wafers are entering the oxidation furnace.

Key Achievements and Improvements in the Nanotools Microfab

Improvements to the Microfab
A major success for the Microfab was obtaining $140,000 p.a. for 2 years from NanoQuebec and becoming a core part of the Quebec Nanotechnology Infrastructure. This will allow us cover all manpower costs and to expand our efforts to provide services to the micro-nano & bio community even as McGill reduces its support in the coming years. The NanoQuebec fund was opened at the end of December and a business plan was developed for the micro-nano bio community which is currently being implemented.

After extensive consultation with the Microfab user community as well as other researchers at McGill a CFI LOF for a total of $11.3M was submitted in April 2012 for the **Nanotools II**. This follow up proposal of the original Nanotools CFI requests a fast prototyping suite, growth and characterization equipment needed to advance research, development and training. Competition results were released in November 2012 and we are pleased to announce the awarding of and Leading edge Fund CFI grant in the amount of $10 861 200 for the Microfab which will be highlighted in next year's report.

Lastly, 6 pocket E-beam evaporator from Angstrom Engineering was purchased with NSERC RTI funding and fully commissioned in 2011/2012.

News and Events
The annual Microfab user meeting was held 15 April 2011 with more than 50 participants. In the spring of 2012 no meeting was organized due to many individual interactions necessary with many NMR users to develop the CFI call VII Nanotools II proposal.

We started a series of monthly lunch user meetings every first Thursday of the month for students to discuss details of particular processes they developed. The aim of these meetings is to build and sustain the Microfab community, facilitate personal interactions, enable the exchange of information, and provide a forum for consultation between the Microfab team and users. Policies and procedures are discussed (and if necessary subsequently adapted).

Figure: D. Juncker giving a presentation via Skype on nanobio research to the Standing Committee on Finance. Brian Jean (conservative caucus) and Justin Trudeau (liberal caucus) inspecting microfluidics devices fabricated in the McGill Nanotools Microfab by the Juncker group.

The 5th installment of the Hands-on Nanobiotechnology lecture and lab course was offered from Feb 20-24, 2012. This year's course drew 26 participants, with 15 coming from McGill and the other 11 from Concordia, U de Montreal, Sherbrooke, and U of Ottawa, including 2 faculty members from McGill. Participants received basic instruction on microfabrication and each made their own wafers in the clean room. Microfluidic techniques and microcontact printing were demonstrated in the lab, as well as brainstorming sessions to help them design devices specific for their research. The keynote speaker was Prof. Hatice Altug, of Boston University, who showcased exciting research in the in the field of photonic nanosensors.

For the complete list of tools in the Nanotools Microfab

please visit

www.mcgill.ca/miam

A new Hands-on workshop providing students with personal experience in the Microfab was also instituted by the ISS Training Program. The 1st Introduction to Microfabrication Workshop was taught by Prof. Srikar Vengallatore, Microfab Manager Matthieu Nannini and Technician Mr. Jun Li. The workshop spanned a full week in May and introduced students to silicon microfabrication techniques by allowing each team to build and test their own cantilever capacitor.

The Standing Committee on Finance of the House of Commons was hosted on October 5th. We explained some of our research, discussed financial issues and gave a hands-on tour of Juncker's nanobio facilities.

In 2011-12 the following new policies were developed, communicated and implemented. The general philosophy guiding these policies is to provide transparent and fair access to all users (major and casual, academic and industrial) and to nurture the vision of a shared, safe Microfab community where all users share responsibility, information and training.

Major New Policies
A new User Agreement, to be signed annually and afterhours access, including new weekends policies were updated.

Other policy changes including user fees can be found at mnm.physics.mcgill.ca/content/.

Nanotools Microfab Outcomes: Usage

In 2011-12 the Microfab generated 7004 billable hours, a slight 1.5% increase over last year's 6300h (note, the 2010-11 fiscal year had 11 months only, thus usage prorated to 12 months would amount to 6900h) and a 6% increase from 2009-10. This is substantially higher than a little more than 2300 billable hours we had in 2008-09, showing that growth is now stabilizing.

The 50 PIs from 2011-12 sent a total of 107 students to work in the Microfab, compared to 42 PIs who sent a total of 91 HQP in FY 2010-11 – a 19% increase in the number of PIs and 17% increase in the number of HQP trained in the Nanotools Microfab. On average, each HQP spent nearly 65h (76 h in 2010-11) in the lab.

We have sustained the number of major users at 14 (11 last year), including one user with more than 1500h. A major user is defined as a PI who use the Microfab more than 100 h per year. An additional 3 dozen internal and external PIs comprise minor or occasional users.

These numbers demonstrates that the user base of the Microfab is now broad and that it will ensure sustainability.

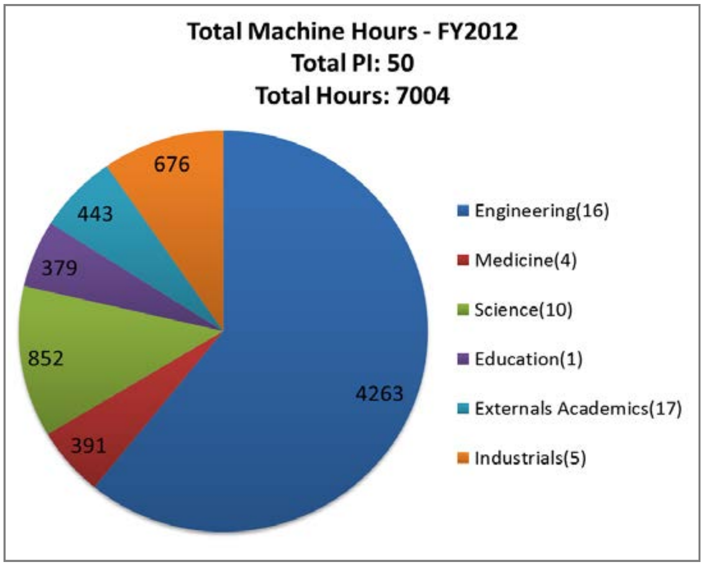
Usage breakdown according to faculties

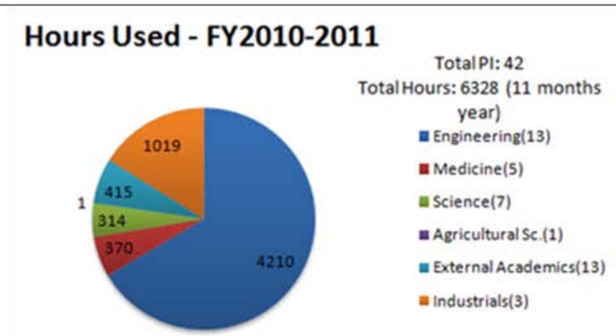
The total number of PIs increased slightly by 20%, mainly due to members from Engineering and Science.

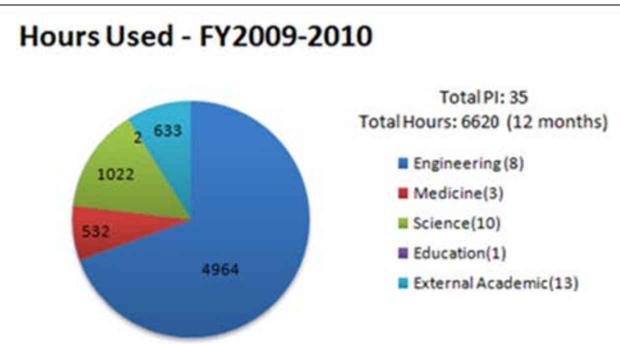
The major users in terms of hours came from the faculty of Engineering, with over 4000 hours booked in the Fab for each of the last 3 years. This use is now spread over a larger number of PIs, with fewer hours per group.

Medicine, Science and external users each have about 10-20% of the usage by engineering with a fairly stable and substantial group of PIs. Usage from Agriculture and Engineering represent single PIs which may not be useful for forecasting, but external academics continue to comprise a significant group and represent 17 PIs from seven different institutions around Quebec, Ontario and from the USA.

While industrial usage decreased, the number of users actually increased from 0 in 2009, 3 last year and 5 in 2011-12. The decrease in usage seen can be mostly explained by the very high usage by one company, Aerovirus Technologies, in 2010-11.







HQP Usage

The total number of Highly Qualified Personnel (HQP) trained in the Microfab increased by 18% from 91 last year to 107 in 2011-12, thus increasing slightly after a 42% increase last year. Roughly half these HQP are engineering students.

It is noteworthy that for a 240 workday year (48 weeks of operation), assuming an 8 hour day and a total of 7004h billed hours, on average there are 3.7 HQP in the Microfab at all the times. This translates to 4 different processes being executed on a given day in the Microfab, a major challenge in terms of support and scheduling of equipment.

A user in the Nanotools Microfab rinses a graduated cylinder in preparation for an upcoming experiment.

Nanotools Microfab Outcomes: Publications, HQP and Grants

After 4 years of strong growth, outputs from the Nanotools Microfab have begun to stabilize in 2011-12. In total , the Microfab has produced or assisted in the training of 107 HQP (91 in 10/11), in 52 publications (57 in 10/11), 8 patents (6 in 10/11), 42 invited talks, and one start-up (Sensoreal Inc., created by Roozbeh Safavieh from the Juncker group).

This year, 44 HQP graduated with a project that had a major Microfab component (52 in 10/11) and 5 external companies used the Microfab (3 in 10/11). An additional 37 students received specialized training in the two hands-on Microfab workshops.

New grants worth $ 3,925,476 ($2,669,150 in 10/11) were acquired directly by the fab PIs, in addition to $3,700,000 as a result of FQRNT *Regroupements Strategiques* renewals and two new NSERC CREATE programs.

Publications (including Patents and Disclosures)

In 2011, at least 52 peer reviewed publications and 8 issued or filed patents resulted from work with an intensive Microfab component (some of the minor Microfab users did not provide an annual report). This is a leveling off of the trend observed in the past few years: After nearly 200% increase from 21/7 publications/patents in 2008 to 41/2 in 2009 and a 13% increase to 57/6 publications/patents in 2010, publications and patents are now stable.

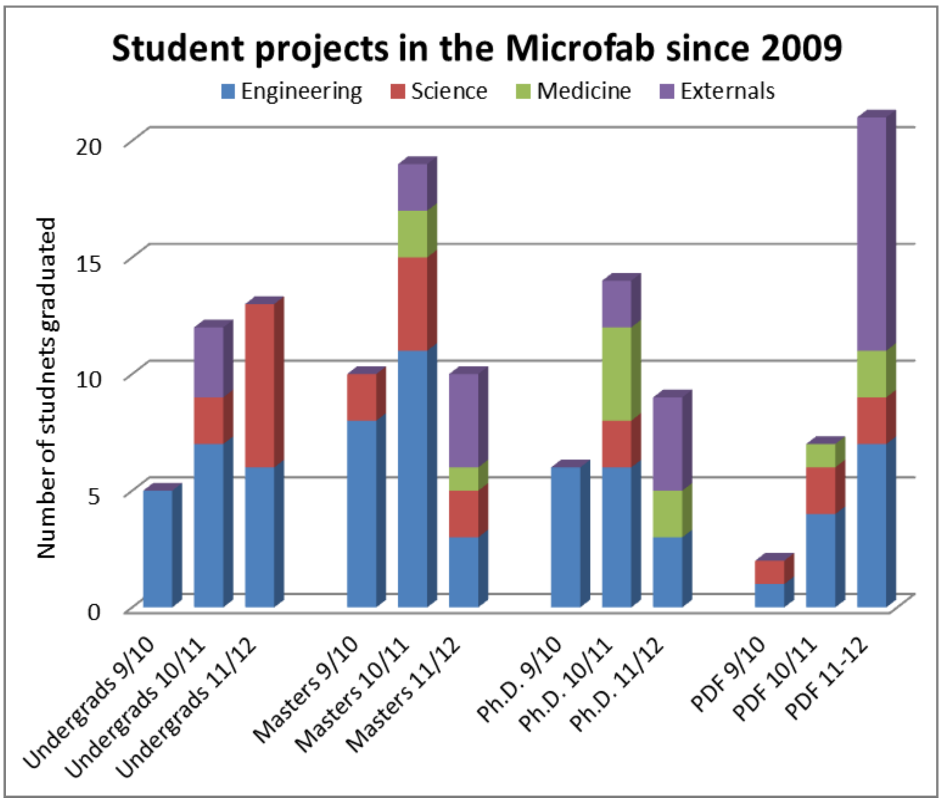
Note that publications, for annual consistency reasons, were only counted in a given calendar year, whereas all other data is from June 2011- May 2012.

HQP and training

The total number of HQP trained in the Microfab has also stabilized at 107 compared to 91 in 2010-11, 64 in 2009-10 and 57 (2008-09). Again a large, stable number of HQP graduated with a major component of their work being performed in the Microfab: 44 compared to 52 in 2010-11 (see the figure right for details). These numbers are underestimates, as not all PIs provided a report.

The quality of training offered was exemplified by Michael Menard, who graduated from A. Kirk's group in 2009 and was appointed as an Assistant Professor at UQAM in 2011.

As well, this year 38 students received additional hand-on training in the Microfab in the 2 one week hands-on workshops offered. The increasingly popular Hands-on Workshop in Micro and Nanobiotechnology has now ben joined by a new ISS Introduction to Microfabrication workshop, to introduce users with and without Fab experience to new techniques and technologies for the lab.



Research Grants acquired due to access to fab

The total of new individual grants and contracts directly linked to the fab (excluding Discovery Grants) had a value of $3,925,476 - an increase of more than 50% from $2,669,150 in 2010-11 (and approximately 200% from $1,339,826 in 2009-10). Of this, $428,200 was directly acquired for the fab (through an NSERC RTI Equipment grant and the Quebec Nanotechnology Infrastructure program (NanoQuebec). An additional total of $3,700,000 not included in the total above were acquired by 2 new CREATE programs in Neuroengineering and Nanobiomachines as well as a FQRNT *Regroupement Strategique* (INTRIQ), all three with major fab components. The distribution across faculties is similar to last year: 52% from engineering, 22% from science and medicine each and 3% from outside of McGill.

In 2009-10 the PIs of grants linked to the Microfab were almost exclusively from the faculty of engineering. Thus the trend to a more even distribution across faculties first noted in 2011 has continued this year.

Microfab Nanotools Outlook and Objectives for 2013

Last year's objectives were largely achieved. Manpower funding was increased with the requested NanoQuebec grant. Upgrades to the NMR infrastructure will be enabled with the procurement of the Nanotools 2 CFI grant. Operations continue to be responsive to user needs and requests, including for example, the recent development of access policies for the weekend. Only the proposal for business development staff to increase external outreach has been discarded, after peer review by the NanoQuebec proposal. However, Nano-Quebec has now opened a position with this specific mandate for 2012.

In 2012-13 the McGill Nanotools Microfabrication Facility objectives are:

- **Funding:** with the announced reduction of direct financial support by McGill we need to develop a long term financial plan.

An essential part will be the expansion of services to the life science community, which will enable larger and more stable user income. Our success in the current CFI VII competition will be a key element in addition to current discussions with the Montreal Neurological Institute on expanding services.

- **Infrastructure:** Implement the CFI requested upgrade of the Nanotools infrastructure.
- **Usage:** increase the usage by researchers from the life sciences by hiring dedicated manpower funded from current NanoQuebec support.
- **Operations:** improve microfab operations at the administration, tool maintenance and training level in terms of efficiency and effectiveness.

Overall, we expect the current stabilization trend to continue in 2012-2013, while we continue to improve services and equipment.

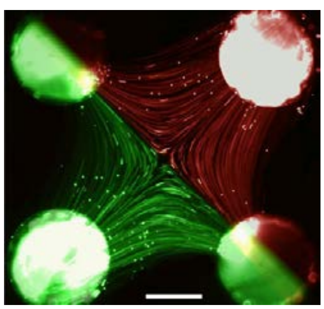
MIAM Microfab Nanotools Success Story:

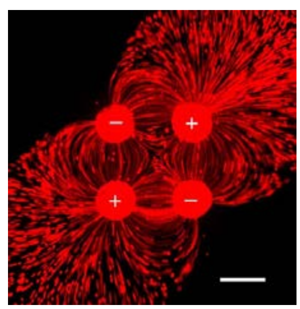
Prof. David Juncker, Department of Biomedical Engineering

The Biomedical Engineering research group of Professor David Juncker, a MIAM member since 2006, has been making waves in 2012. His paper, '*Microfluidic quadrupole and floating concentration gradient*' has been a blinding success, highlighted in more than 60 new and scientific website notably on Futurity, Nature Asia Pacific, Science Daily, Medical Device Daily, and PhysOrg. The lead student on this project, PhD candidate Mohammad Qasaimeh was also awarded the ***FRSQ etudiant-chercheur etoile*** for May 2012 based on this work.

The Microfluidic probe project started in 2005. The idea was to make gradients of multiple chemicals as well as shear-stress free gradients to expose single cells to various chemicals without affecting them otherwise. Since microfluidic devices offer precise, small-scale methods of delivering fluids, this method became the focus of their efforts. In 2007, a team including David Juncker' s group and his colleagues with the Microfab, E-beam and SEM MIAM tools began work on a microfluidic quadrupole.

A microfluidic quadrupole was, until now, only a theoretical outcome of microfluidic hydrodynamics. In a microfluidic quadropole fluid streams from four points interact creating a stable concentration gradient over a microscopic area, in a process similar to balancing electrostatic forces.





(Left) Experimental image of a MQ when formed by injecting and aspirating liquids with tracer beads via two injections (plus sign) and two aspirations (minus sign) apertures. Path lines were captured by the long-term exposure of the flowing fluorescent tracer beads. Whereas we adopt the same symbolism than for electrical charges, the '+' and '−' signs correspond to purely fluidic sources and sinks. Scale bar is 400 μm.

(Right) Fluorescence micrograph showing path lines in a MQ using 2 μm red and green tracer microbeads injected through the top right and bottom left apertures, respectively, into a 50 μm gap filled with liquid, and aspirated back through the other two apertures. Scale bar is 200 μm.

The microfluidic quadrupole developed by the Juncker Group was formed by simultaneously injecting and aspirating fluids from two pairs of opposing apertures in a narrow gap formed between a microfluidic probe and a substrate. By changing the fluid flow rates the concentration gradient could be quickly and precisely changed, in a setup that is designed to minimally disturb organisms, tissues, and cells. Such an apparatus could give researchers a system for exposing cells to signaling molecules, for instance, and watching cells' reaction right in the dish.

Bringing the concept from idea to reality was a major endeavor. Setup for this delicate system needed to be very precise and Junker commended the team well on their efforts, especially Dr. Gervais (McGill professor of Physics and MIAM member) who provided theoretical input, and Mohammad who as first author conducted the experiments and wrote up the results. Junker maintains that the most effective means to overcome obstacles was "Perseverance, perseverance, perseverance". This perseverance paid off well as the team published a high impact paper laying the foundation for a whole new area of experimental and theoretical applications.

Currently the team is working on the biological application of the microfluidic quadrupole. They would like to extend it to manipulation of single neurons, as well as measurements of chemicals excreted by single cells. On the technological side, the team expects to expand the quadrupole into a microfluidic multipolar setup.

The MIAM Characterization Facilities

2011-2012 was the second year of operations for the MIAM Characterization Facilities. The Characterization Facility consists of eleven different advanced surface and materials characterization tools housed in four different departments and faculties across the McGill campus.

With help from the faculties of Chemistry, Mining and Materials, the Goodman Cancer Center and Dentistry, the Characterization tools have been made accessible to the McGill Community and to external academics. This year several industrial users have also used these tools.

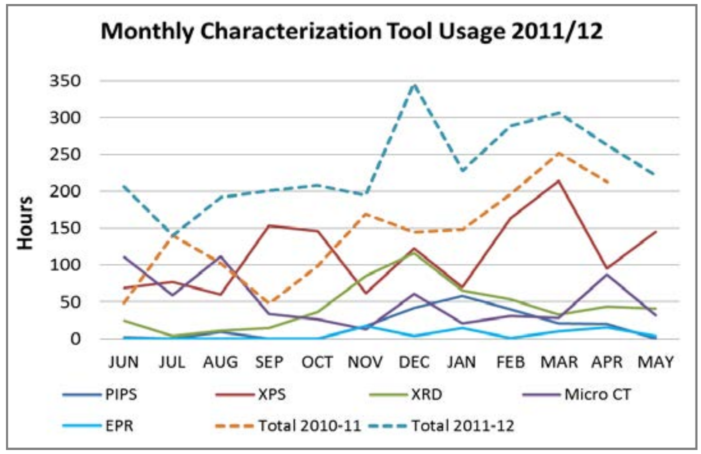
The MIAM Characterization Facility is **open access.** To discuss a project using Characterization Facility tools, or to make a booking please **visit the MIAM website**.

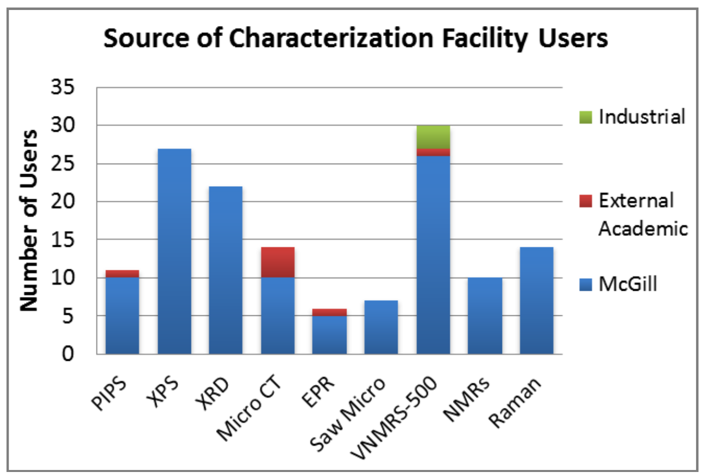
Characterization Facilities: Total Usage

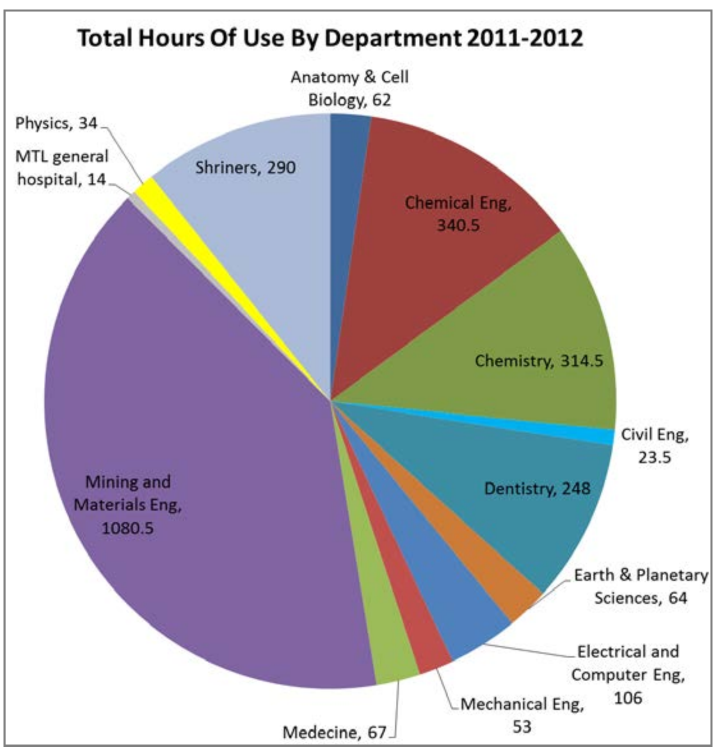
There is an improvement in the data available for this year. All of the departments were able to furnish some data on the usage and operational costs of their equipment.

While the data is not fully comparable between as data collection was not fully established the first year, usage of the Characterization tools has increased. Reported usage has nearly doubled from 142 to 233 hours per month. More of the tools have been operational and in use throughout the year and total hours of use appear to have increased over the course of the year.

Although the monthly and hourly usage data is not available for all tools, including for the 3 MIAM Mass spectrometers in Chemistry, the tool managers reported 2847 total hours of use for just the PIPS, XPS, XRD, Micro CT and EPR. The largest users a appear to be in Mining and Materials Engineering, where most of the tools reported are housed there. Other major users include Chemical Engineering, Chemistry and Dentistry, but there do appear to be significant users in several other departments and faculties around McGill, including in Medicine and the MUHC hospital network. Users, defined by professor laboratories show that most tools do have a wide appeal, and are not being monopolized by single professors.







Overall most users appear to be from within McGill, and specifically from within the departments housing the tools for the data available. This is partly because the utility of the tools was a factor in the choice of location, but since the tools are not yet at full capacity, it does appear that increased awareness of the MIAM Characterization facility may be warranted to ensure that the tools are most valuable to the scientific community.

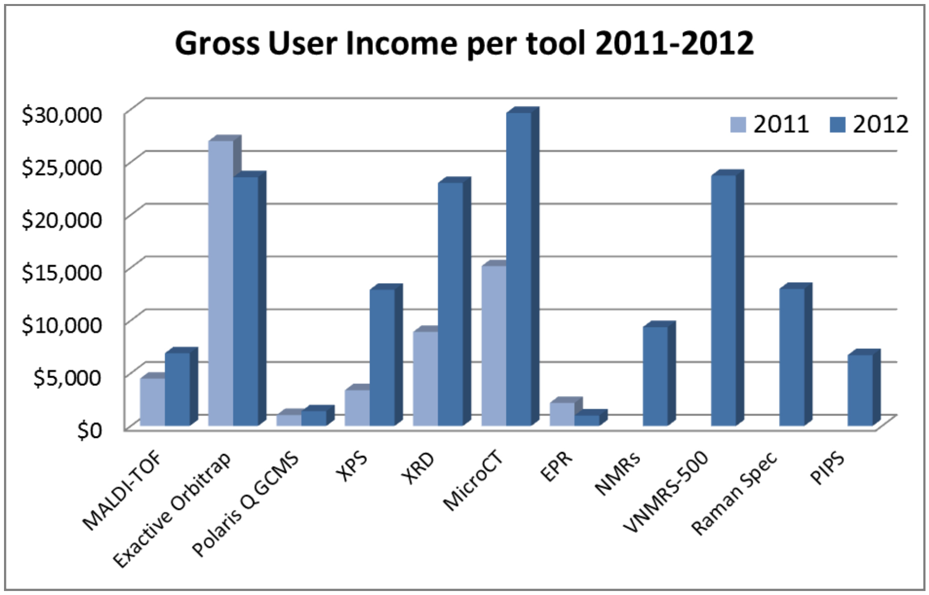
Outcomes: Publications, Grants and HQP

According to data requested from users the Characterization Facility was integral to the publication of at least 27 papers and two patents.

Users also reported 10 new research and operations grants received in 2011-2012 which were dependent on access to Characterization Facility resources. These grants had total value of **$2,515,408 over 5 years**, or 600K of new external funding to McGill in just 2011-2012.

These data may well be significant underestimates as well, as not all users responded to requests for data.

Equipment upgrades and financial analysis

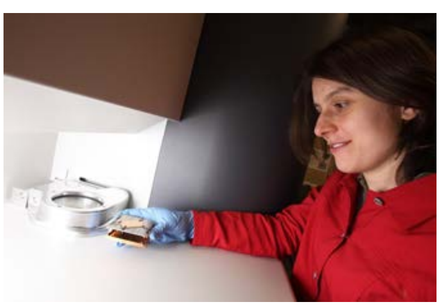


Analysis of the income and expense data provided shows that overall the Characterization Facility has made 86% of its operational expenses (excluding staff costs) or 56% of total expenses in user fees in this financial year. All tools continue to operate in part due to in-kind and overhead contributions by the departments which house them: Chemistry, Mining and Materials, The Cancer Research Centre and Dentistry.

Comparison of data available last year shows that nearly all tools with available data show that the income from user fees increased significantly from 2010-2011 to 2011-2012. One exception is the Exactive Orbitrap Mass Spectrometer which decreased slightly. This may have been due to the fact that is was out of order for a month more than the year before.

Almost all the MIAM Characterization tools reported increased revenues from user fees, and we are pleased to report that the tools in the Wong Building were able to bring in sufficiently increased revenue to be able to hire an additional technician in June 2012 to assist in the maintenance and operation of the instruments. This will be particularly beneficial for users of the XPS which requires considerable expertise for smooth operation.

MIAM is also pleased to announce the addition of several new spectroscopy resources including CasaXPS spectra analysis software and several specialized surface analysis and polymer analysis resources for the XPS.



Prof. Marta Cerruti loads a sample into the X-Ray Photoelectron Spectroscopy unit (XPS) to measure elemental composition, and chemical and electronic states within the material

Tim Gonzalez demonstrates how the Raman microscope can be used for to study vibrational, rotational, and other low-frequency modes in a system to identify chemical bonds

We are also pleased to announce that the Confocal Raman System has now been supplemented with a stand alone Confocal Photoluminescence (PL) unit from Horiba Jobin-Yvon valued at over 200K for only $120510.00 (including tax), with thanks to NSERC RTI application led by Professor Andrews, $5K from MIAM and $8Kof supplementary funding from MIAM members Kambhampati ($2K), Butler ($3K), Sleiman ($2K) and Andrews ($1K). Prof. Andrew has also generously supplied new microscope objectives to improve performance and capability of total value by separate funding.

The new unit will join the Confocal Raman Microscope in the new optics laboratory upgraded by the Department of Chemistry in March 2012.

Characterization Facility Instruments

Instruments	Abbrev.	Instrument capabilities
Chemistry Department Tools		
Brucker Electron Paramagnetic Resonance Unit	(EPR)	detection and analysis of free radicals from chemical species
Fourier Transform Infrared Spectrometer	(FTIR)	provides an infrared spectrum of absorption, emission, photoconductivity or Raman scattering of a solid, liquid or gas
Autoflex III® Matrix-Assisted Laser Desorption/Ionization Time-of Flight Mass Spectrometer	(MALDI-ToF)	mass spectral characterization of large synthetic polymers and biomacromolecules such as nucleic acids, proteins and glycans
Exactive Plus Orbitrap Mass Spectrometer	(ESI/APCI-MS)	high resolution/high accuracy mass analysis of small and large molecules in liquid with the capability of molecular formula identification
Polaris Q Ion Trap Mass Spectrometer	(GC-MS)	identification and separation of volatile organic compounds and direct powder analysis by EI and CI
Nuclear Magnetic Resonance Spectrometer	(NMR)	detailed information about the structure, dynamics, reaction state, and chemical environment of molecules
Confocal Raman Microscope and the	(Raman)	the study of vibrational, rotational, and other low-frequency modes in a system to identify chemical bonds
Confocal Photoluminescence unit (on order)	(PL)	a non-contact, nondestructive method of probing the electronic structure of materials through photo-excitation
Mining and Materials Department Tools		
Bruker Powder X-Ray Diffractometer	(XRD)	non-destructive analytical techniques which reveal information about the crystallographic structure, chemical composition, and physical properties of materials
X-ray Photoelectron Spectroscopy Unit	(XPS)	quantitative spectroscopic surface chemistry analysis
Skyscan MicroCT (microtomoraphy or computed tomography) System 1172	(MicroCT)	comparative morphology, anatomy, 3D histology, soft-tissue visualization
FEMR, Dentistry and Goodman Cancer Center Tools		
Gatan Precision Ion Polisher	(PIPS)	TEM sample preparation techniques; ion beam thinning
Saw Microtome	(Saw Micro)	specially designed for the cutting of extremely hard and brittle embedded materials like bone, mineralogical samples or industrial materials
Skyscan MicroCT (microtomoraphy or computed tomography) System 1178	(Small MicroCT)	viewing devices and materials in-vitro and to for internal views of smaller material samples.

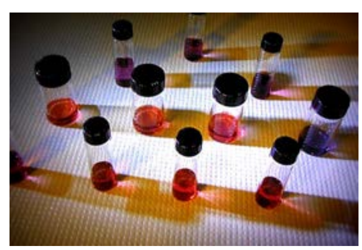
The Upcoming Year

Last year the MIAM Characterization Facility managed to increase income from user fees to allow for a much needed increase in technical staff for the Wong Building instruments.

MIAM was also able to procure and supplement member and external funding from an NSERC RTI to improve the Confocal Raman System with a unit capable of confocal photoluminescence which should be installed and tested this year.

This year the Chemistry optics laboratory also intends to implement an online system for user reservations and fee recovery for the Confocal microscopy system. An online system is also an ongoing goal for the Wong Building MIAM instruments.

A few units also still require improvements to the record keeping, to allow full comparisons on use and utility. The data we have so far indicates that there is still room to improve awareness and procedures, but that these tools are already proving to be a valuable addition to the McGill research community.



MIAM Training Activities

The NSERC-CREATE Integrated Sensor Systems Training Program

The NSERC-CREATE Training program in Integrated Sensor Systems (ISS) is an inter-university program centered at the McGill Institute for Advanced Materials (MIAM) designed to develop the next generation of Canadian experts in integrated sensor systems. ISS includes teams from four Montreal-region universities: McGill University, Ecole Polytechnique, INRS and Université de Sherbrooke.

The ISS Program is now in its 3rd year of the 6 year initiative funded by the National Science and Research Council of Canada's *Collaborative Research and Training Experience* program. The NSERC-CREATE program "supports training of teams of highly qualified students and postdoctoral fellows through the development of innovative training programs that encourage collaborative and integrative approaches, address significant scientific challenges associated to Canada's research priorities, include the acquisition of professional skills, and facilitate the transition of new researchers from trainees to productive employees in the Canadian workforce."

To implement this initiative MIAM was provided $1.6M from NSERC plus $580k from the four participating universities to develop a multidisciplinary technical and professional skills training program which advances expertise in broad range of application areas: biomedical sensing: diagnostics and drug discovery; aerospace and automotive; consumer electronics and environmental sensing.

Unlike many CREATE programs, ISS accepts students from any laboratory schools working on relevant technologies at the four partner schools. Places in the program and student funding are awarded annually on a competitive basis.

ISS Program Director Andrew Kirk welcomes students at the Internship/Exchange info-session

The ISS Program provides a value of up to $2,500 per graduate student and an average of $1,200 per undergraduate student in hands-on technical skills training, interdisciplinary research exposure related to integrated sensor systems and in professional and industrial skills training to aid in the smooth transition of graduates to the workforce. The ISS program also promotes research collaboration through travel awards of up to $5,000 for graduate exchanges and internships.

The create ISS program accepts the best candidates with the following:

- Excellent academic and research potential
- A strong interdisciplinary and/or inter-laboratory approach
- Commitment to attend training activities and workshops for an industry or research career

Projects must focus also on the design, fabrication or testing of sensor devices, the development of materials that are required for sensors, the processing of signals obtained from sensors, sensor integration and packaging. Special emphasis is placed on the research involving minimization, packaging and the use of micro and nano technologies for sensing.

ISS also provides 50% stipends in the form of ISS Masters Awards and ISS PhD Fellowships Awards for selected students (up to $10,500 for 2 years for PhD & $8,650 for 2 years for Masters).

We also accept a limited number of undergraduates each summer to for paid work on preapproved projects in sensors and increase interest in research and graduate studies.

ISS Program and Outcomes

To build experimental and theoretical skills, the ISS program has created a number of new hands-on workshops, including Surface Chemistry, Microfabrication, Surface Analysis and Sensor Integration (including signal processing and packaging). In addition the ISS program has provided access for students to an existing workshop on Soft Lithography. Each workshop is typically 2-4 days in length. These three workshops cover all the stages of the sensing chain.

To improve professional skillsets, we have developed and implemented three new workshops in Project Management, Process Control and Intellectual Property.

By Fall 2012, the ISS program had provided training and lectures by 46 different invited academics, industry members and representatives and other experts on a wide variety of topics spanning the entire value chain of sensors research from laboratory techniques to marketing.

Activities like the Sensors Summer School and Undergraduate posters session provide students a chance to share their latest results and methods with each other. As well ISS students also reported at least 23 local inter-laboratory collaborations (60% of which were encouraged or facilitated by the program) and 11 research exchanges and internships made possible, at least in part by ISS funding.

These exchanges included trips to MIT, the University of California and Harvard Medical School in the US, and places as far flung as the University of Shanghai, China and Tohoku University in Japan.

Management and Governance

Students in the ISS program receive additional training on top of their regular degrees, which is managed by the Student supervisor and the students advisory committee according to the home university's regular practice.

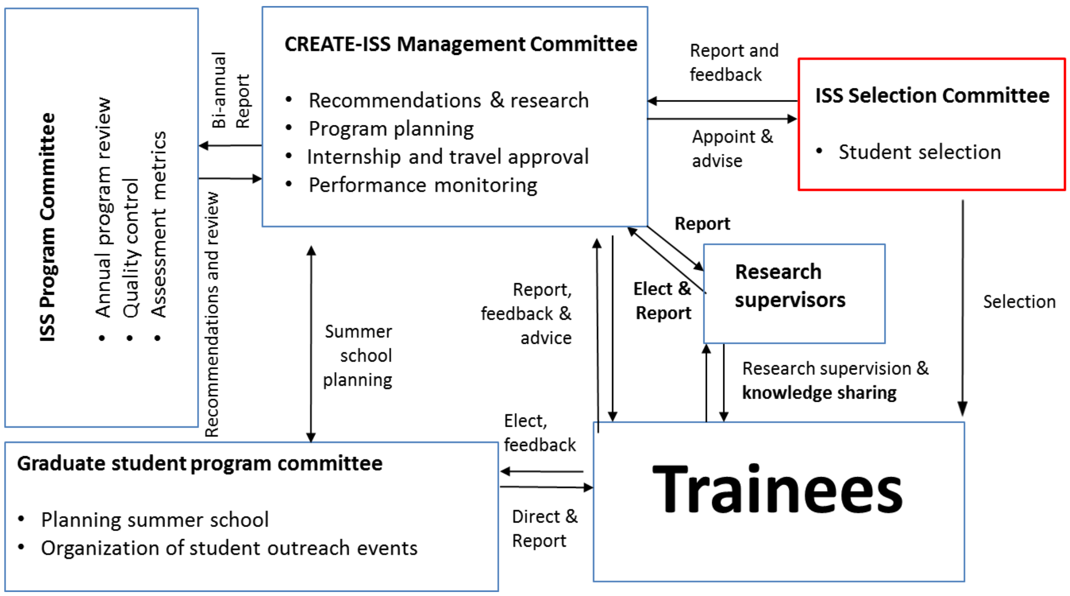
Regular activities of the ISS Training Program are designed and implemented by the CREATE Management Committee. This committee consists of representatives from all four participating schools, from Industry and from McGill graduate studies Teaching and Learning Services. The Management committee makes day to day decisions on how to implement the proposal accepted by NSERC and on how to further the goals of the program. These decisions are implemented primarily by the MIAM administrator, and by the ISS director, Prof. Andrew Kirk.

This plan is overseen by the Program Committee, who include local and international academic and industry members, and a representative of the trainees. In 2011 the Program Committee met for the first time and made a number of recommendations. These included improvements to student selection by increasing industry input in selection process, which was done by inviting an industry HR specialist for feedback on new applicants and by improving student on fit with the program mission by improvements to the application form. The Program Committee also suggested improvements in student tracking and in industry feedback on the program which are being implemented.

In addition, this year the CREATE-ISS Program welcomed a number of new members and collaborators.

To streamline the selection process and ensure its integrity, the Management Committee which sets policy and procedures was separated from the group that reviews and ranks students for acceptance and awards. This Selection Committee was formed by a number of professors (at least one from each school), as well as a representative from graduate studies and an external HR specialist from one of the program's industry partners, Teledyne DALSA.

The complete organization chart of the ISS Program as of 2012 can be seen below.



ISS Technical Training Activities: Seminars and Workshops

In 2011-2012 CREATE-ISS held a number of new seminars and workshops to introduce and explore the intricacies of sensor technology and research.

For the second year, the Sensors Seminar Series hosted invited speakers from around the Montreal area from industry and several local universities. Topics covered in the ten bimonthly seminars included MEMS manufacturing, biochemical and photonic sensing, sensor energy harvesting, electronic nanosensors, accelerometer design and others from both academic and industry members.

In addition to the Surface Chemistry for Sensors Workshop introduced in 2011and the existing , ISS held the first Surface and Materials Characterization workshop which introduced students to the field and included a hands-on comparison of the main surface characterization techniques, including X-Ray Photoelectron Spectroscopy (XPS), Scanning Electron Microscopy (SEM) and Raman Spectroscopy. This workshop, organized by Prof. Gerrard -Lauriault of McGill's Department of Chemical Engineering was very well received and will be repeated this year. Post-course surveys indicated nearly universal agreement that the course was excellent, well organized, and gave a good introduction to the subject.

The ISS program also increased the hands-on training available in the Microfab with the addition of an Introduction to Microfabrication Workshop focusing on techniques for silicon microfabrication. Developed by Prof. Vengallatore of ECE and the Microfab staff. This workshop gave students personal experience in the Microfab.

Lastly, the Juncker Lab held its ongoing Hands-on Workshop in Micro and Nanobiotechnology during the Spring break, advancing knowledge in microfabrication, soft lithography, and microfluidics, as well as the surrounding biotechnology. Ten ISS students attended.

Business and Professional Skills Training

This year the ISS program introduced several new workshops in professional skills including an intensive four day Project Management short course by Prof. Dufault from the Université de Sherbrooke, an instructor with over 20 years experience in Project Management.

The ISS Program put on a special iteration of the Canadian Intellectual Property Office (CIPO) and the Intellectual Property Institute of Canada's case study session with special guest speakers on their experiences in patenting sensors.

ISS was honored to host Mr. M. Louis Forest, Photo Engineer & Microfabrication technology development expert at Teledyne DALSA Semiconducteur for a one day workshop on Process control and statistical analysis where students learned how to bring a concept to prototype and then to full scale production.

As well, once again the ISS Program partnered with the McGill Graduate and Postdoctoral Studies' and Teaching and Learning Services' "SKILLSETS" Professional Development for Graduate Students program, to provide undergraduates and non-McGill graduate students in the ISS Program access to several pre-existing short courses and workshops, basic business skills, several workshops in communication skills, including teaching, teamwork facilitation skills and communication of research with non-experts, as well as an academic ethics workshop.

Lastly, the ISS provided students with assistance in developing CVs, procuring internships and exchanges with resources, assistance and funding. ISS students also had the opportunity to meet with local business and academic leaders.at several networking events.

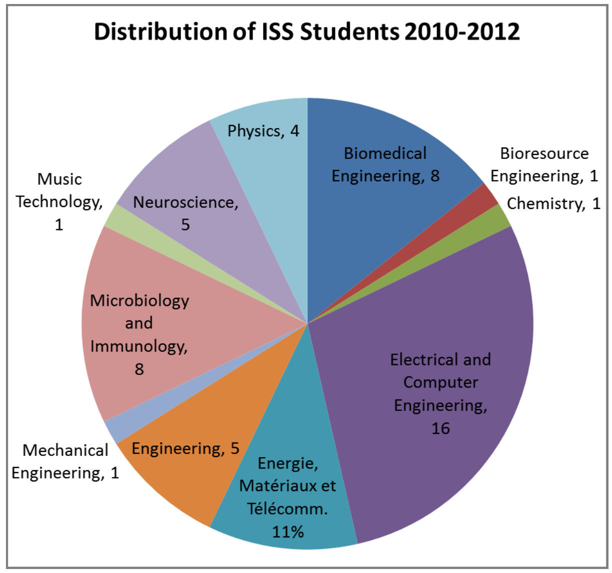
ISS Students

As of 2012, the ISS program has included 10 Undergraduate students, 8 Masters students and 31 PhD students, including 32 recipients of partial stipends. During the spring application call, a further four masters students and seven PhD students were accepted to start in Fall 2012.

The majority of ISS students (56%) are still from McGill, but applications from the other schools are increasing, with 24% of ISS students now hailing from Sherbrooke, 11% from INRS and the addition of four new Polytechnique students for 2012.

As seen in the pie chart ISS students come from a wide range of disciplines, including the physical, biological and engineering sciences. A large number of these project also overlap, including 23 graduate projects in which students reported collaborations with another discipline.

The current students are quite productive, having already submitted at least 15 refereed articles, 27 technical reports and 1 patent and presenting at 24 conferences.



Student Feedback

The first and second cohort have now reported on their experiences and have a number of interesting things to say about the NSERC-CREATE ISS Program. The average ISS graduate student had completed 7.1 events, short-courses or workshops in June 2012. Ten students had participated in internships and exchanges.

84% of student agreed that the ISS program would be useful in their future career and 63% that it had helped them in their current research. 90% of respondents thought that the ISS Program provided unique learning opportunities. 60 percent stated that they had had unique opportunities for collaboration and 77% had unique networking opportunities.

A minority of students (30%) found that the ISS program delayed their graduation. To improve this we have made modification to the program to both assist students in appropriate planning to finish on time, and to allow more choice in the activities required.

Quotes from students:

•I benefit the most through the intensive hands-on workshop since it gives me the opportunity to gain some experience in areas I am not familiar with.

•I find professional development workshops (such as Project Management) are of the top importance for myself. My involvement in the organization of Summer School in 2011 and 2012 has given me experience in organizing large-scale events, communicating with sponsors, preparing the materials and advertising.

•I have learned a lot from exchanging ideas with other students and profs through seminars and workshops.

•Above all, the ISS Program gave me the unique opportunity to do an exchange … where I gained new technical background as well as insightful new collaborators.•

The CREATE-ISS Sensors Summer School

The ISS Students' Graduate Student committee produced the 2nd annual Sensors Summer School on May 3-4, 2012 in the Lorne Trottier Building. This year the Summer School was sponsored by NanoQuebec and NanoExplore in additional to funding from MIAM and the NSERC-CREATE ISS program.

The students added a half day Career Day to the program. This new session covered a variety of topics including how to prepare for the job market and career opportunities for scientists and engineers. Invited speakers included several local academics: Prof. Linda Cooper (dept of Chemistry); M. Ed. Richard Zereik, Associate Director, of Services for Students and Dr. Lenore K. Beitel (dept of Human Genetics) as well as Dr. Julien Sylvestre from IBM Canada.

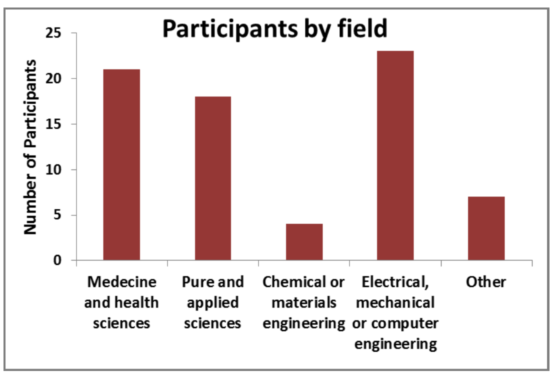
Day 2 was focused on current research in the field of sensors with talks from academics and ISS students in a variety of fields and a poster presentations competition. Topics ranged from microelectronic packaging techniques to quantum dot bioprobes.

Special guests were invited from throughout Canada and Europe including: ISS students were honored at the attendance of well-known presenters Prof. Y.Sun, University of Toronto "*Micro Sensors for Characterizing Biological Cells and Nanomaterials From Solid-State to Polymeric Devices*"; Prof. K. Takahata, University of British Columbia "*Micromachined Sensors Enabled by Alloys, Gels, and Carbon Nanotubes*"; Prof. Yatsenko, National Space Agency of Ukraine "*Perspectives of Sensor Technologies - Information, Intelligence and Applications*"; Prof. J. A. Paradiso, MIT "Connecting with the Emerging Nervous System of Ubiquitous Sensing" and Prof. U.Krull, University of Toronto "*Integrating Quantum Dot Bioprobes with Microfluidics and CMOS Technology to Achieve Rapid Nucleic Acid Assays.*"

The event succeeded in attracting people from a large number of areas in sensors research from outside the program. Fifty-two people attended Day 1 activities and 60 people attended Day 2 activities (with 74 unique registrants in total) including nearly 40 non-ISS participants from the participating universities of McGill, Université de Sherbrooke, Polytechnique and INRS.

Of these the majority (64) were graduate students however there were also 18 undergraduates and a few post-doctoral fellows and faculty present. Furthermore, there was representation from a wide variety of fields in science and engineering. Overall, the event was very successful with a 28% increase in registration from the previous year, when a total of 58 people registered. Also compared to the first summer school, there was a 35% increase in the number of those registered from outside the ISS program indicating an increasingly successful advertising campaign.

Members of the ISS Graduate Student Program Committee Sandie De Bonnault and Esen Sokullu man the registration table at the 2012 CREATE-ISS Sensors Summer School.



For more details on ISS Graduate Committee Events please see the student website:
www.create-iss.org

ISS Program: Plans and Objectives for 2013

In 2012-2013 the ISS program intends to improve the current workshop offerings through review of student and instructor feedback. We also plan to increase the workshop roster by adding a workshop in Entrepreneurship.

There are also plans to improve the ISS workshop and Summer School registration system by using an external registration client for fee and data collection.

Discussion with the Program Committee has also led to proposed improvement to the student application process by developing a better formula to assess and rank potential candidates, a change in the procedure for undergraduate projects, and new application forms for funding renewals for current students. These new processes will be implemented in the Spring 2013 application call.

As mentioned previously review of previous data and discussion with students has led us to modify the program requirement to allow more choice in student workshops. These changes will be implemented when the new cohort arrives in 2013.

The ISS program is also looking forward to increasing its industry network through networking, outreach and awareness campaigns to improve internship and networking opportunities for the members of the program.

Lastly, we look forward to saying goodbye to the majority of our first cohort of ISS graduate students, and to providing them with a new certificate and activity report which documents the many skills they have gained.

ISS Students and Projects

UNDERGRADUATE STUDENTS

Name	School	Research Project
Andrei Dan*	INRS	Development of aptameric nanobiosensor
Damian Marek*	McGill	Chalcogenide microresonator sensors
Florence Shahabi*	McGill	Label free microfluidic screening method for monoclonal antibody pairs
Greta Thompson-Steckel*	McGill	Development of a neuronal mechanotransduction sensor to examine the relationship between extracellular matrix substrate and adhesion strength
Jana Chaaban*	McGill	Fabrication of Graphene Devices
Luc Maurais*	Sherbrooke	Characterization of CMOS single photon avalanche diode arrays
Mike Wei*	McGill	Nanofluidic Based Epigenetic Screening
Samuel Parent*	Sherbrooke	Characterization of CMOS readout electronics for single photon avalanche diode arrays
Tevy Chan*	INRS	Development of phage-based nano-theranostic (therapeutic and diagnostic) platform
Wayne Yang*	McGill	Fabrication of graphene microwave resonators

MASTERS STUDENTS

Name	School	Research Project
Adiel Mallik	McGill	Use of microfluidic probe and perfusion chamber with Brainbow organotypic brain slices to generate a visual map of neural remodeling after hippocampal damage
Daisy Daivasagaya	McGill	Centrifugal DNA Fragment Sorter for High-Throughput Cancer Diagnostics
Grant Ongo	McGill	Diagnostic for Rapid Detection of Methicillin-Resistant Staphyllococus Aureus
Robert Welch*	McGill	An electrochemically integrated microfluidics system for parallel microcantilever and nanowire-based biosensing
Sharifun Nahar	INRS	Multiplexed biosensing platform for routine screening of new-born babies against herpes simplex viruses
Sherman Hung	McGill	Energy harvesting and energy storage for wireless networks of integrated sensor systems
Vincent-Philippe Rhéaume	Sherbrooke	Integrated light sensor based on single-photon avalanche diodes (SPADs)

PhD STUDENTS

Name	School	Research Project
Adel Merdassi	McGill	New Epi-Sci SiC process technology for Neuro MEMS, BioMEMS, HarshMEMS
Ali Salehiomran	McGill	Spread-Space heterodyning Near-Field optical CDMA Technique for Free-Space Optical Communication Systems
Amir Foudeh	McGill	Pathogen detection using SPR integrated digital microfluidics
Andre Dompierre	Sherbrooke	Design and fabrication of an integrated piezoelectric vibration energy-harvesting MEMS system
Benoit-Louis Bérubé	Sherbrooke	Research and development of a single photon avalanche diode in CMOS 3D integrated circuit technology for positron emission tomography and computed tomography
Carolina Brum Medeiros	McGill	Wireless Saw temperature sensor assessment
Esen Sokullu	INRS	Theranostic platform for MRSA detection and treatment comprising array of deep probe optical waveguide
Evgeny Kirshin	McGill	Microwave breast cancer detection: advanced signal processing and device prototype
Gaston Contreras Jimenez	INRS	Ultra-sensitive hand held CMOS based optical biosensor for the detection of toxins in water
Gina Zhou	McGill	Disease alert threads: threads as a microfluidic platform for low cost infectious leishmania sensing
Huiyan Li	McGill	3D hydrogel droplet co-localisation microarray sensor system for multiplexed profiling of breast cancer biomarkers

ISS Students, Projects and Supervisors

PhD STUDENTS CONTINUED

Name	School	Research Project
Joe Gerald Jesu Raj	INRS	Synthesis, Optical Properties and Applications of Metal Based Complexes as Biophysical Probes and Chemical Sensors for High Sensitive Detection of Biologically Important Molecules
Julia Del Re	McGill	Examination of the Influence of Local Environment on Single Molecule Conductance
Li Zhao	Sherbrooke	Integrated sensing and actuating arrays for damage detection in aerospace structure
Mohammadali Safavieh	INRS	Development of rapid low-cost biosensing platform and Lab-on-a-chip for the detection of urinary tract infections and antibiotics susceptibility analysis
Muhammad Diaa Baiad	Polytechnique	Surface plasmon resonance sensors with Bragg grating for new medical applications
Muhammed Cheema*	McGill	Application of the ring-down spectroscopy to microcavities for biosensing
Nandkishor Dhawale	McGill	Development of autonomous pull-type sampling system and fabrication of an embedded soil phosphate sensor to determine phosphate activity parameters though and agriculture on-the-go
Osvaldo Arenas	Sherbrooke	Experimental study of electrical and thermal behavior of power GaN Field effect transistors
Ottoleo Kuter-Arnebeck	McGill	Design , microfabrication and characterization of hollow and fluid filled micro-resonators
Pascal Newby	Sherbrooke	Fabrication of porous SiC and characterization of its thermal, mechanical and structural properties; application to thermal insulation in sensors
Peyman Y. Moghadam	Sherbrooke	Optimization piezoelectric sensor/actuator for guided wave generation
Reda Elshafey	INRS	Development of a brain tumor gene profiling lab-on-a-chip system for personalized medicine
Sandie De Bonnault	Sherbrooke	Development of miniaturized photonics biosensor based on surface plasmon resonance
Sebastien Ricoult	McGill	Axonal Migration and Turning of Neurons Investigated though Surface-bound Digital Nanodot Gradients
Seyed Ali Malek Abadi	Sherbrooke	Micro-machined THz Transmission lines:nano-sensors and Nano-antennas applications
Shimaa Eissa	INRS	Aptameric biosensor for cyanobacteria detection
Simon Hamel	Sherbrooke	Conception et fabrication d'un system de pile a combustible brohydryde en convection naturelle
Teresa Simão	INRS	Building an in vitro diagnostic tool for early Alzheimer's disease detection
Tohid Fatanat Didar	McGill	Design and fabrication of an Adhesion-based microfluidic Lab-on-chip biosensor platform for detection, isolation and sorting of cells
Yucai Wang	McGill	Implantable micromachined capacitative sensors to monitor compartment pressures in lower limb

SUPERVISORS

Name (Prof.)	School
Amy S Blum	McGill
Andrew Kirk	McGill
David Juncker	McGill
Dominic Deslandes	Sherbrooke
Francois Boone	Sherbrooke
Frederico Rosei	INRS
Jean-Francois Pratte	Sherbrooke
Luc Frechette	Sherbrooke
Marcelo M. Wanderley	McGill
Martin Rochette	McGill
Maryam Tabrizian	McGill
Michael Hilke	McGill
Milica Popovich	McGill
Patrice Masson	Sherbrooke
Paul Charette	Sherbrooke
Peter Grutter	McGill
Daniel Guay	INRS
Raman Kashyap	Polytechnique
Richard Arès	Sherbrooke
Sadegh Vishkaei, Mahta	INRS
Serge Charlebois	Sherbrooke
Shiv O Prasher	McGill
Srikar Vengallatore	McGill
Thomas Gervais	Polytech
Tim Kennedy	McGill
Tsuneyuki Ozaki	INRS
Vamsy Chodavarapu	McGill
Viacheslav Adumchuk	McGill
Walter Reisner	McGill
Yves-Alain Peter	Polytechnique

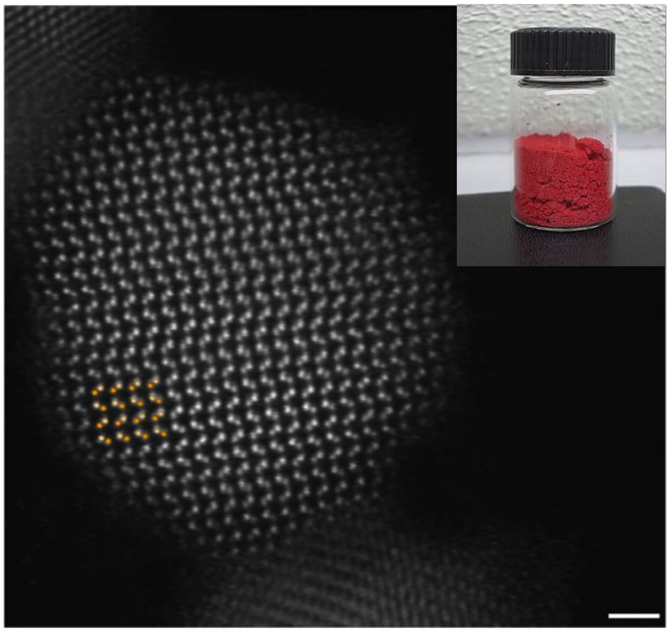
** program completed*

MIAM Member Research Highlight:

Prof. Pat Kambhampati and Mr. John Saari, Department of Chemistry

Long standing MIAM member Prof. Kambhampati has developed a successful niche in nanoscience by tapping his expertise in spectroscopy to understand the physics of semiconductor nanocrystals. Since the discovery of the first colloidal nanocrystal, synthetic advancements have exploded bringing about an array of all imaginable varieties of nanocrystals. Most recently, Dr. Kambhampati, as a trained spectroscopist, brought fresh light into the effort to understand the excitonics of the quantum dot Cadmium Selenide in an article, "*Terahertz Bandwidth All-Optical Modulation and Logic Using Multiexcitons in Semiconductor Nanocrystals*", recently published in the high impact American Chemical Society journal: **Nano Letters.**

Dr. Kambhampati was working on quantum dot research when Ryan Cooney came to Kambhampati with a strong interest in nanoscience. When Dr Cooney joined Dr Kambhampati' s lab as a graduate student he and another graduate student Dr. Sam Sewall began investigating various pump-probe signatures of Cadmium Selenide through a myriad of spectroscopic techniques to understand the physics of the compound. Through advancement and development of spectroscopic instrumentation and techniques, they were able to delve more deeply into the study of semiconducting nanostructures than ever before. Both Saari and Kambhampati want their research to provide excitonic materials to advance computer technology an understanding of the exitonics of semiconductor nanocrystals could eventually build an altogether new platform for all-optical signal generation and processing, leading the way to new technology and more intricate computer systems.



A CdSe nanoparticle with atomic resolution. It is a projection image of the nanoparticle where darker atomic columns represent Se columns while the brighter columns are Cd (atomic structure has been partially overlayed to highlight the atomic arrangement). Scale bar is 1nm. Thanks to Robert Hovden, Wikipedia Commons.

Upper Left: Cadmium Selenide, in jar. Wikipedia Commons.

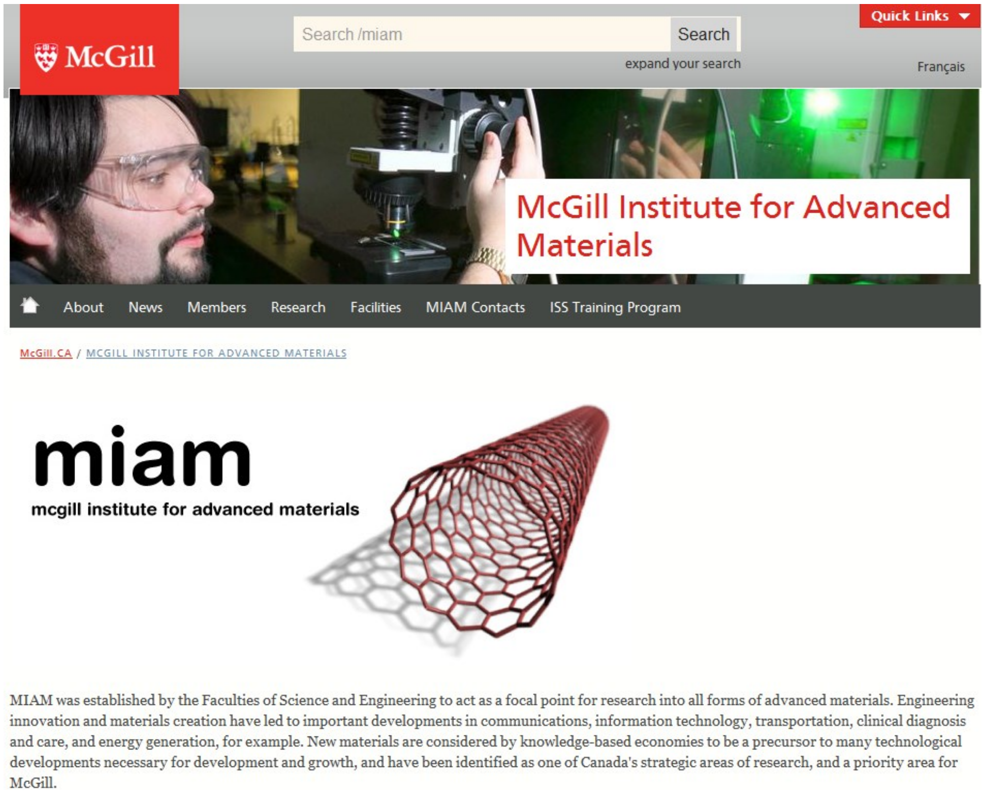
Saari and Kambhampati envision the development of more complicated and efficient logic gates in future experiments. Logic gates are types of "switches" that perform logical decision based on inputted arguments. Other potential projects are developing cascading logic gates and the implementation of wave guides. Jon Saari, one of the group's PhD candidates, explained that one of the most exciting aspects of the experiments is the fact that innovations made in the lab are not only novel and innovative but important and potentially applicable. The unique optical properties of semiconductor nanocrystals suggests they could someday be a platform for novel optical transistors.

This year, the team was able to publish an article showing for the first time that control of multiexciton populations produces high speed modulation of stimulated emission. They showed that modulation rates approached 1 THz, which brings the vision one step closer to reality by demonstrating that all-optical logic using these nanocrystals comes in two forms: an AND gate, and an inverter. This presents a key step forward for all optical signal processing.

The research conducted by the Kambhampati team comes through careful investigation of the excitonic structures via femtosecond pump-probe spectro-scopy. An exciton is a bound state of an electron and an electron hole which are attracted to each other by Coulombic force. Excitonic structures are composed of components in this state.

The amount of effort required by the sheer depth and complexity of the experiment means that the experiments themselves are inherently dependent on incredible teamwork and coordinated effort. The multidimensional nature of nanoscience invites contributions from the various chemical and physical disciplines, from synthesis to spectroscopy. The intersection of Physics, Chemistry and electrical engineering provides a challenge only solved through cooperation, especially through the initiatives of students. In the near future, the team hopes to begin work in the MIAM Nanotools MicroFab Facility to further explore the fundamental properties of semiconductor nanostructures.

The MIAM Website



Information on MIAM, its members, facilities and the ISS program can all be found at www.mcgill.ca/miam.

On it you will find links and contacts regarding the MIAM Characterization facility Tools, The MIAM Microfabrication Facility website, complete lists of MIAM members and ISS network connections along with research and contact information and other resources useful to people interested in the activities, specialties and training offered by MIAM.

MIAM also now has an RSS feed which you can connect to your cell phone, homepage or email provider to hear the latest MIAM and ISS announcements., including upcoming workshops, seminars, deadlines and networking events.

Notes

Contributions by: Andrew Kirk, Peter Grütter, David Raji, Songrui Zhao, the 2012 ISS GSPC Committee and Rowena Franklin

Faculties of Engineering and Science

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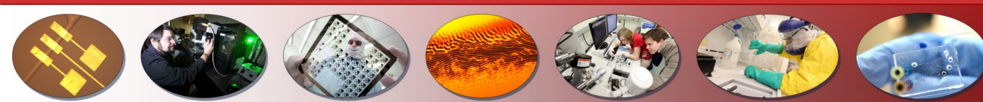

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MIAM was established by the Faculties of Science and Engineering to act as a focal point for research into all forms of advanced materials. Engineering innovation and materials creation have led to important developments in many areas including communications, information technology, transportation, clinical diagnosis and care, and energy generation. New materials are considered by knowledge-based economies to be a precursor to many technological developments necessary for development and growth, and have been identified as one of Canada's strategic areas of research, and a priority area for McGill.

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