miam

McGill Institute for Advanced Materials

MIAM ANNUAL REPORT
2010-2011

Director: Prof. Andrew Kirk

Administrator: Rowena Franklin

NOVEMBER 2011

miam

THE MCGILL INSTITUTE FOR ADVANCED MATERIALS

MIAM ANNUAL REPORT 2010-2011

Director's Message

This year has been a very exciting one for MIAM. The NSERC-funded Integrated Sensor Systems (ISS) CREATE Training program has completed its first year of operation, providing a first cohort of 19 graduate students and three undergraduate students from McGill, Sherbrook, Ecole Polytechnique and INRS with hands-on workshops and seminars to enhance their research and their professional skills.

The new MIAM Characterization Facility is now operating fully, giving researchers access to a suite of surface science tools that were not previously available at McGill, including X-Ray photoelectron spectroscopy (XPS) and MicroCT.

The Nanotools laboratory continues to go from strength to strength, with an ever-increasing number of users and the facility is now recovering its operating costs from user fees (while the university continues to fund the highly professional staff who operate it).

Most recently we received the very welcome news that thanks to the efforts of the Nanotools Director, Professor Peter Grutter, the Nanotools Facility will once again receive operating funding from NanoQuebec for the next two years. At the Federal level, under the leadership of MIAM, the four Montreal-region nanofabrication facilities and NanoQuebec also submitted a combined proposal to NSERC for very significant funding via the Major Resource Support program and a site visit it expected early in 2012.

We are also very excited to welcome 21 new members to MIAM, from departments across the university, and look forward to supporting their research in nanoscience and nanotechnology.

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

Annual Report format change

After focusing on the maintenance and upgrading of its facilities for several years, MIAM is pleased to be increasing its visibility at McGill and abroad.

One change we are making is the creation of this new Annual Report publication, which will provide a yearly update on the activities, capabilities and facilities of the institute.

This report will also allow MIAM to highlight the broad range of skills, specialties and talents of the MIAM members. This includes a new section listing member research areas (p. 6, 7) and annual focus articles on members and their latest exciting research results (p. 9, 16 & 20).

We hope you enjoy the new format of the MIAM Annual Report.

Inside this issue:

Executive Summary

In 2010-2011 the McGill Institute for Advanced Materials (MIAM) expanded by adding a number of new members from several different departments and faculties at McGill. The new members add significantly to the research strength of MIAM, with activities in nanoscience, nanotechnology and nanomedicine. Our members also received a range of awards this year, including several international awards. Members of MIAM reported the publication of almost 250 research articles, with over 80 publications and patents reported as being directly enabled by MIAM facilities. In addition, our members also reported being awarded over $4M in new grants and contracts that are directly linked to MIAM facilities.

The recently installed MIAM Characterization Facility completed its first year of operations, bringing significant new materials science capabilities to MIAM and McGill, including X-Ray photoelectron spectroscopy and Raman spectroscopy. Thanks to the user fees obtained, the Characterization Facility is now on its way to being financially self-supporting.

The Nanotools facility also reported increased usage this year, both in terms of hourly use and in the number of principal investigators (now at 41). Several new tools were also installed in the Nanotools facility this year, including light interferometric surface profiling, a contact aligner and a parylene coater. A successful proposal was made to Nano-Quebec for operating funds for Nanotools, and the facility will receive $140k per year of funding for the next two years.

The NSERC CREATE Training Program in Integrated Systems (ISS) completed its first year of operations, providing training to 22 graduate and undergraduate students from McGill, Sherbrooke, Ecole Polytechnique and INRS. The ISS program enabled the creation of several new hands-on workshops which are now also being made available to other students and increased collaboration between the four partner universities in this important area. Finally, MIAM moved into newly renovated offices on the ground floor of the Frank Dawson Adams Building.

Mission and Objectives

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.

MIAM assumed responsibility for operation of the McGill Nanotools Microfabrication Facility (NMF, which now contains equipment valued at around $12M) in 2006. 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. Some instruments are mainly run by professors and students, and there are also three full time professional staff who organize and maintain certain equipment.

As part of the MIAM mandate to provide training, MIAM has recently obtained 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.

MIAM currently has 61 members, from the faculties of Science, Engineering, Medicine and Dentistry. MIAM members are highly productive.

According to a survey of MIAM members, staff and users, we look forward to increasing the activities in all three areas through more staff facilitation of facilities use and expansion of our facilities' capabilities as well as increased promotion and training for both graduate students and staff.

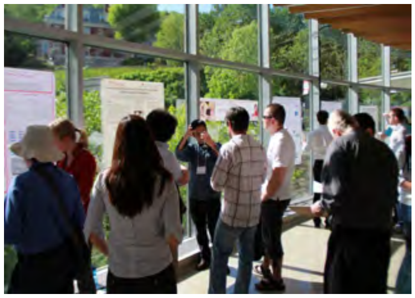
As part of this we will be hosting a regular information series on our facilities' tools and staff expertise. We look forward to see you at our upcoming events.

MIAM Activities and Events

2010-2011 was an interesting year for the institute. Following the modification of the MIAM governance structure in 2009, MIAM has renewed its commitment to training and promotion of the field of advanced materials.

MIAM held a Members Meeting last November where Prof. Kirk presented the 2009 Annual Report, the new MIAM Bylaws and discussed the institute's future mission and objectives.

This was followed by an exposition to mark the official opening of the MIAM Characterization Facilities. Speakers from all sections of MIAM facilities made short presentations on the research potential of the various new (and older) tools. Attendance was very high, with standing room only!



Students and guests review the ISS Summer School Poster competition entries in the Macintyre building in July 2011.

The first NSERC-CREATE Integrated Sensor Systems Training Program graduates students started their program last January. In 2010 we accepted 19 graduate students, and provided partial student stipends to nine. We also accepted 3 undergraduate students for Summer 2011 research projects.

The ISS Program also introduced several new Hands-On workshops, including one in Sensor Integration presented by Professor Zeljko Zilic, and one in Surface Chemistry developed by Engineering Post-Doc Dr. Philip Roche.

The bimonthly ISS Seminar series was well attended by both ISS students and others in the McGill and inter-university community.

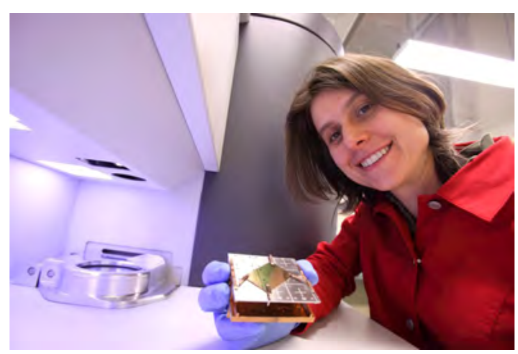
We look forward even more MIAM and ISS events, including a new Microfabrication workshop, a Surface Characterization short-course and the continuation of seminars in sensor systems, the transfer of research to industry and other advanced materials related topics.

New Members 2011, Arrivals and departures:

This year MIAM is pleased to add several more academics working in advanced materials across the university to its membership. Please welcome:

- Francois Barthelat (Mechanical Engineering)
- Amy Szchumacher Blum (Chemistry)
- Mathieu Brochu (Mining and Materials)
- Ian S. Butler (Chemistry)
- George Demopoulos (Mining and Materials)
- Marta Cerruti (Mining and Materials)
- Vamsy Chodovarapu (Electrical and Computer Engineering)
- Richard Chromik (Mining and Materials)
- Pierre-Luc Girard-Lauriault (Chemical Engineering)
- Anne Kiezig (Chemical Engineering)
- Zetian Mi (Electrical and Computer Engineering)
- Sam Musallam, Dr. (Electrical and Computer Engineering)
- Showan Nazhat (Mining and Materials)
- Sylvain Coulombe (Chemical Engineering)
- Nate Quitoriano (Mining and Materials)
- Dmyrto Perepitchka (Chemistry)
- Bradley Siwick (Chemistry)
- Hanadi Sleiman (Chemistry)
- Walter Reisner (Physics)
- Thomas Skopek (Electrical and Computer Engineering)
- Jun Song (Mining and Materials)

As well, there have been several changes to the technical staff in the MIAM Facilities. In the MIAM Nanotools-Microfab, technologist Pierre Huet has moved on, and two more members have joined the team: John Li the new equipment technologist and Lino Eugene, research assistant.



New member Prof. Marta Cerruti shows off the use of the new Characterization Facilities' XPS machine which provides quantitative spectroscopic surface chemistry analysis.

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. 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, multiscale mechanics, multiobjective optimization
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.	Development & application of nanostructured 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

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
Dr. Matthieu Nannini	MIAM	Manager, MIAM Nanotools-Microfab
Dr. Nadim Saadeh	Chemistry	Manager, Mass Spectroscopy Facility
Dr. Florence Paray	Mining and Materials	Manager, Wong Building MIAM Characterization Facility
Dr. Andrey Moiseev	Chemistry Dept	Research Associate (Electron Paramagnetic Resonance facility)
Don Berry	MIAM	Technologist, MIAM Nanotools-Microfab
John Li	MIAM	Equipment technologist, MIAM Nanotools-Microfab
Lino Eugene	MIAM	Research Assistant, MIAM Nanotools-Microfab

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 the past year:

Adi Eisenberg

Recipient of the 2011 CIC Medal from the Chemical Institute of Canada, Montreal, Canadian 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.

Alejandro Rey

Fellow, Royal Society of Chemistry (FRSC UK), April 9, 2010.

The RSC recognizes the substantial career contributions in nominating outstanding scientists as Fellows. Their contributions reflect a maturity of experience in fields involving a wider application of chemical science.

Jay Nadeau

Nominated for Canada's Top 40 Under 40, Fall 2010

Larry Lessard

SPE Composites Division -DOW Chemical Composites Educator Of the Year 2011.

The Composites Educator Of the Year is someone in the educational field who has made a significant contribution to the training of students in the composites area

Maryam Tabrizian

Fellow of the Biomaterials Science & Engineering (FBSE), 2011 (distinction)

demotes national recognition and international respect of his/her comprehension of professional issues and accomplishments as a scientist or engineer in the field of biomaterials science and engineering.

Guggenheim Follow in Biomedical Research, 2010 (Award)

Guggenheim Fellowships are intended for men and women who have already demonstrated exceptional capacity for productive scholarship or exceptional creative ability in the arts.

Musa R Kamal

International Award, Society of Plastics Engineers (SPE), Boston (April 2011)

The International Award is the highest honor bestowed by the Society of Plastics Engineers. It recognizes lifetime achievements in the fields of polymer science or polymer/plastics engineering.

Sylvain Coulombe

Carrie M. Derick Award 2010 for Excellent in Graduate Teaching and Supervision, McGill University

To acknowledge outstanding contributions by members of the administrative and support staff of the University for service to Graduate and Postdoctoral Studies.

Zetian Mi

Young Investigator Award from the 27th North American Molecular Beam Epitaxy ConferenceBreckenridge, Colorado on September 26-29, 2010

for contributions to the development of high-performance quantum dot lasers on GaAs, InP, and Si. The NAMBE Young Investigator Award recognizes individuals who have made significant contributions to the science and technology of MBE or enabled by MBE by the age of 35 and show promise of future leadership in the field.

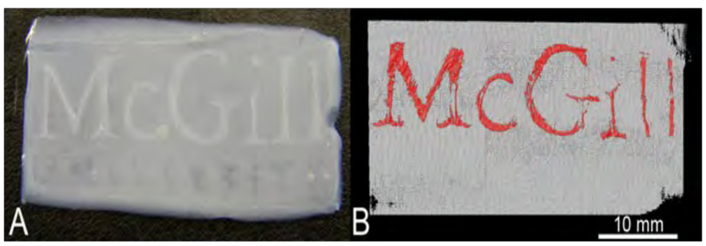
Invited to present at Bravo "Excellence in Research 2010", McGill University

MIAM Facilities Research Highlight:

Prof. Showan N. Nazhat, Department of Mining and Materials Engineering

New MIAM Member Showan Nazhat has been using the MIAM Nanotools-Microfab facility in his biomaterials research since he joined the McGill Faculty of Engineering in 2006. In 2011, his studies in plastically compressed fibrillar collagen hydrogels garnered an NSERC Discovery Accelerator Supplement of $120,000 over three years "*to accelerate progress and maximize the impact of* ***superior research programs...contributing to groundbreaking advances****.*"

In the project published in *Biomaterials* in 2011: "*Real time responses of fibroblasts to plastically compressed fibrillar collagen hydrogels*", Nazhat's team set out to validate a newly developed methodology in tissue engineering; Nazhat and his team; Chiara Ghezzi, Benedetto Marelli and Naser Muja used the MIAM Sky-scan 1172 micro-CT to investigate how plastic compression affects cells seeded in a dense collagen gel.



A cell seeded gel (B) was embossed on top of an a cellular gel. 3D reconstruction provides proof of concept by selectively highlighting the presence of cells (red) along a specific pattern. Figure taken from Ghezzi CE, et al., Real time responses of fibroblasts to plastically compressed fibrillar collagen hydrogels. Biomaterials (2011), doi:10.1016/j.biomaterials.2011.03.043

Collagen gels are of potential use in multiple medical applications, including in tissue replacement, but the construct is normally too weak for clinical use. Processes like plastic compression, where a mechanical force is used to expel most of the gel water content can make a regular collagen gel dense enough for clinical use, but the effects on cells seeded in the gel matrix have not been fully explored. X-ray computed micro-tomography analysis of the labeled cells allowed Nazhat's group to measure how compression affected cell distribution in the matrix.

Prof. Nazhat hopes that further advances in the hybridization of collagen hydrogels will generate physiologically relevant materials for rapid output in tissue engineering. Possible applications include regeneration of mineralized tissues like bone, muscular-skeletal systems, cartilage and any other collagen based bodily tissues.

Methods and Results:

The team used several different methods to fully characterize the effects of PC. CLSM analysis or confocal laser scanning microscopy allowed the team to characterize the distribution of calcein-AM labeled cells in the matrix before during and after compression. Their analysis revealed that during PC cells progressively increased in density in the gel without cell loss and lateral displacement due to the fluid flow.

Analysis of lactate dehydrogenase levels (intracellular enzyme which is released by damaged or dead cells) and of CLSM for calcein-AM fluorescence and EtBr-1 DNA over 48 hours revealed that compression appears to actually improve cell viability compared to cells in regular highly hydrated collagen gels over the short term. AlamarBlue^{TM} reduction analysis and several other techniques confirmed that this advantage persists for up to a week and did not affect cell metabolic activity significantly.

In a striking demonstration of the predictability of 3D distribution in PC collagen scaffolds, Nazhat's team developed a method to label cells with phosphotungstic acid and to selectively incorporate the cell population in a silicon mould in the shape of the McGill logo on the surface of a gel. They then used the MIAM Micro-CT to view the results in 3D after 1 and 7 days. From the image developed (*right*), you can see how cells grew uniformly within a defined volume despite the "application of an unconfined compressive stress" on the gel. This proves that PC is a cell-friendly, efficient and controllable process for scaffold production in tissue engineering even with structures of different dimensions and geometries.

Publications, Grants and HQP

In 2010, MIAM members produced **202 publications** and **43 conference proceedings**.

As well, at least **77 peer-reviewed publications** and **7 issued or filed patents** resulted from work made possible by MIAM equipment or collaborations (some Members did not provide an annual report).

MIAM equipment and collaborations enabled grants of $4, 037, 435 in 2010-2011

The detailed titles, authors and references can be found in the Annual Report Appendix A & B on the MIAM website at www.mcgill.ca/miam.

The total value of new grants and contracts obtained by members in 2010-11 and which are directly linked to MIAM equipment and collaborations had a value of **$4,037,435.** These included funds from varied sources including Genome Quebec, FQRNT, CIHR, NSERC and EPA.

These grants were well distributed across the faculties of Medicine, Science and Engineering, compared to last year when the primary recipients came from engineering.

Facilities

The McGill Nanotools Microfabrication Facility

Here we present highlights of the detailed Nanotools annual report prepared by Academic Director Prof. Peter Grutter in June 2011.

Fiscal year 2010-2011 only lasted 11 months. Nevertheless, the income from user fees was $207,265 (an increase of 14% from 2009/10)!

For the first time since inception, the McGill Nanotools Microfab is recovering operating expenses from user fees. The University continues to support the cost of manpower at 100%. Usage on a 12 month basis is 4% up compared to 2009/10 to 6900h (6300h in the 11 month fiscal year).

In 2010/11 the McGill Nanotools Microfab has also upgraded its equipment, implemented a new reservation system, updated the facility website, and implemented several major policy and fee structure changes.

There were 41 PIs using the Microfab, with 3 users using it for more than 1000 h, 11 more than 100 h, and 27 less than 100 h. A dramatic 50% increase in publications compared to last year is observed (57 papers, 6 patents in 2010/11).

Industrially-linked research grants have increased from 8 to 10 and the number of graduated students with Microfab experience from 28 to 52. The PIs acquired a total sum of more than 2.7M$ (1.3 M$ in 2009/10) in new grants and contracts directly linked to the Microfab! Particularly noteworthy is a new NSERC CREATE in Neuroengineering (PI R.B. Lennox and 9 others), the second Microfab enabled CREATE grant after the one in Integrated Sensor Systems obtained by A. Kirk (PI) and 9 others in 2009/10. We thus expect the current income, usage and output to increase next year. We will need to increase the manpower in the Microfab to continue offering the same high level of services and equipment availability offered in the past year.

The MIAM Nanotools-Microfab Etch/Deposition room. Acid wetbenches on the right, on the left a user is cleaving a sample on the table.

A clear trend is observable in all the data: the majority of users are from engineering, as is the research output. This is a reflection of the fact that only engineering has faculty members with an exclusive, major focus on microfabrication.

For science and medicine faculty members, access to the Microfab is important and is in many cases crucial for their research; however, they are not major users in terms of time or money spent in the Microfab.

This all points to a more intensive use of the McGill Nanotools Microfab, which is clearly becoming central to many, mainly recently hired, faculty in Engineering, Science and Medicine.

Our outside usage has also grown dramatically, in particular industrial usage (although this is mainly due to one company, Aerovirus). The collected data presented in this report shows that we also have many old and new companies using the McGill Nanotools Microfab. The trend observed in 2009/10 is continuing: most of these companies access the McGill Nanotools Microfab via collaborative mechanisms such as NSERC Strategic projects, CRD or in other partnership agreements with McGill researchers.

We conclude that companies are interested in the whole ‘package’: PI, HQP and access to excellent facilities.

New Tools and Equipment

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

Tools

- A parylene coater (Specialty Coating Systems – Lab Coater)
- A vacuum oven for wafer priming and image reversal processes (Yield Engineering Systems)
- A contact aligner (OAI 200)
- A probe station with 4 micromanipulators (Micromanipulators Co., Inc.)
- A white light interferometer microscope (donated by Prof. Fujinaga, Faculty of Music)
- The Canon Stepper was deemed obsolete and dismantled in Aug 2010

Key Achievements and Improvements– Nanofab

New Reservation System

In October 2010, we decided to retire our old reservation system and replaced it with a more sophisticated software suite. This suite was developed by microfab managers for microfabs, and has been adopted by a large number of microfabs, both small and large, in North America. What makes it even more attractive is that it is open source and actively maintained by the community, which guaranties its long term support and availability.

This system brought us the following key improvements and capabilities:

- Allows users to check whether equipment is available or in use by others
- Reports equipment problems and serious shutdown conditions
- Allows quick checks of the operational status of each piece of equipment and creates detailed reports of problem/shutdown conditions and their resolution.
- Optionally, collect and save run data during processing.
- Maintains lists of qualified users on each piece of equipment.
- Allows certain users to have special privileges on specific pieces of equipment.
- Generates detailed laboratory usage information including equipment reservations, equipment usage, staff and training activities, and equipment problems and shutdown condition. It thus provides key data for billing and effective management of the facility.
- Specifies the projects that each user is approved to work on, and the account corresponding to that project.
- Subscription to monthly charged services such as storage locker facilities, monthly cardkey access charges, etc.
- Provides an option to interlock equipment
- Offers a reporting engine that supports online (html/xml), Excel, and PDF formats. Additionally, flexible role-based report access is supported to manage and control information available to users.

Microfab manager Matthieu Nannini characterized thin film optical properties using a spectroscopic ellipsometer.

Annual Meeting

The annual Microfab user meeting was held 15 April 2011 with more than 50 participants. The keynote speaker was Prof. Luc Frechette (Sherbrooke), who spoke on 'Creating a continuum for innovation in microtechnology'. This was followed by open discussions with the Microfab users on issues concerning operation and equipment. In particular, the need for new tools, and the possibility of acquiring these tools in the upcoming CFI VI were discussed. A poster session was also organized, and the award for the best poster was presented to H. Nguyen.

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).In 2010/11 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.

- New user fee structure ($50 per hour; capping of TMAH etch, acid bench use at $50)
- After hour access to Microfab (buddy system, no HF, OK from fab staff)
- Consequences for not signing in for using equipment.

Website Update

A new public web site matching the look-and-feel of McGill theme was implemented by the Microfab manager. The Microfab manager also initiated the acquisition of a TV screen, strategically positioned in the lobby of Rutherford Physics, to advertise the facility.. This screen is shared with the Physics Department.

Assessments

Finally, an annual evaluation of all Microfab staff was performed. The process consists of a self evaluation followed by an evaluation by the supervisor, as specified in the job description.

All the initiatives listed above were a joint effort by the AC and the Microfab operation staff, in particular the Microfab Manager.

For the complete list of tools in the Nanotools Microfab

please visit

www.mcgill.ca/miam

Major new policies

Fee Structure

The current pricing structure is as follows (updated June 1st 2010 and March 1st 2011):

- The Facility Fee is 50 $/hour (was increased on June 1, 2010 to achieve a balanced operating cost budget).
- Starting April 2011 onwards, the cost of the TMAH bench, the two acid benches and the Blue Fisher Oven will be capped to 50$ if used more than one hour.

View of several tools: from front to back: stereo microscope, critical point dryer, stylus profiometer, optical microscope, thin film reflectometry.

- A 15% consumable surcharge is be added to Facility Fees on equipment requiring consumables. (e.g. photo resist, sputtering tool, etc).
- $ 1.50 per nm of deposited precious metal (Au, Pd, Pt) is charged instead of the usual 15% consumable surcharge. This applies to the ebeam evaporator and the sputterer and is adjusted to the cost involved in buying the precious metal target.

Soft Cap:

The new pricing structure is based on a single hourly base-rate per student:

1. Single PI/ 1-3 students –For each student (1-3), the PI will be charged the full Facility Fee for the first 25 hours of the month. For subsequent use, each hour will be charged at 25% of the Facility Fee for the remainder of the month.
2. Single PI / 4 students or more - For PIs with 4 or more students working in the fab the PI will be charged the full Facility Fee for the first 50 hours logged collectively by all his/her students per month. For subsequent use, each hour will be charged at 25% of the Facility Fee for the remainder of the month.

Note that the number of students per PI is defined as the number of students who used the Microfab in a given month.

Industrial users:

The Facility Fee for industrial users is $100/hour plus consumables and the McGill overhead charges.

As in the past, we will have to continue to charge a 1.5% overhead on all bills (this is clawed back by the Provost).

Billing periods:

There are 12 billing periods per year (monthly billing).

The new pricing applies to all academic users (McGill or non-McGill). Any other additional service such as technical support, engineering etc. is invoiced at an hourly rate of $60.

Fab misuse

Penalties for breaking the rules: With increased usage, the policy with respect to non-adherence to rules pertaining to safety, environment, tool mistreatment or usage of tools without signing in to CORAL (upon which billing is based) needed to be applied. Observed infractions include equipment mishandling (e.g. leaving resist residues in the spin coater or ramping up the voltage too fast on the ebeam writer), safety (e.g. safety equipment not worn or bottles not labeled), environment (disposal of acids and solvents!) or after-hours usage of equipment.

If a serious infraction is discovered (e.g. via random checks of video surveillance tapes), the Microfab manager discusses the issue with the users and the Microfab director. The aim is to initiate a change of behavior. In addition, the following rules apply without exception:

- Suspension of access for two weeks for 'basic' infractions, as decided by the Microfab. Director (after talking to all the parties involved).
- Suspension of access for four weeks if there is a major impact on other users (e.g. down time of a crucial tool). In 'major' cases, it is the committee that makes the decision after due process (i.e. talking to all parties involved with the aim of ensuring that the rule breaker was correctly identified). Safety and environment are major offenses.
- Repeat offense leads to a doubling of the suspension time.
- Public announcement of penalty for offense as deterrent. (posted on the Microfab user list without name of offender)

Outcomes: Publication, HQP and Grants

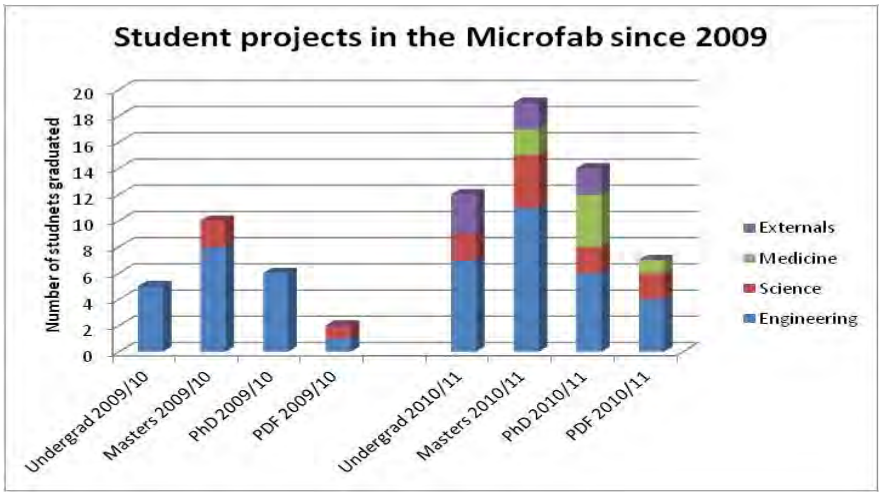
Nearly all outputs quantifiable with reasonable effort show a dramatic increase as compared to previous years. 91 students worked in the Microfab (64 in 09/10), 57 publications (41 in 09/10), 6 patents (2 in 09/10), 52 HQP graduated with a project that had a major Microfab component (28 in 09/10) and 3 external companies used the Microfab (8 in 09/10).

Highly Qualified Personnel

The total number of HQP trained in the Microfab has continuously increased from 57 (2008/09), 64 in 2009/10 to 91 in 2010/11.

What is remarkable is the large number of students who graduated with a major component of their work being performed in the Microfab (see figure, right). Both the total number of students working in the lab, and the number of faculties represented in the Fab have increased significantly in the past year.

Again, these numbers are underestimates, as not all PIs provided a report.



NSERC RTI funding awarded for a new electron beam deposition system for nanotools

Thanks to a proposal submitted to the NSERC Research Tools and Instruments (RTI) program by MIAM Director Andrew Kirk, and with essential input by many MIAM members at McGill and colleagues at Concordia, we have been awarded $150,000 towards the purchase of a new electron beam evaporator system for the Nanotools Facility. This new tool, which is currently being purchased, will permit the deposition of metallic and dielectric films with precisely controlled thicknesses. It represents a significant advance on our current deposition capabilities and will significantly accelerate a large number of research programs.

The availability of this new equipment will lead to (among others): improved optical biosensors that can measure exquisitely small concentrations of molecules, photovoltaic materials of higher efficiency than is currently possible, advanced nanoelectronic devices that may one day replace silicon transistors, nanomechanical structures that can scavenge energy from the environment and devices that can lead to a better understanding of skeletal development disorders.

Publications

In 2010/11, at least 63 peer reviewed publications and 6 issued or filed patents resulted from work with an intensive Microfab component (some of the minor Microfab users did not provide an annual report).

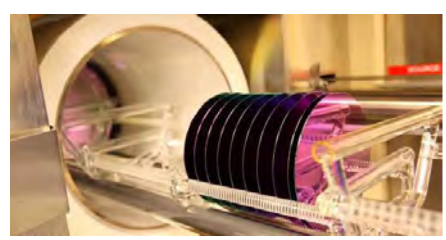
This is a major increase compared to 41/2 in 09/10 and 21/7 in 08/09 for publications/patents.

Appendix A gives the detailed titles, authors and references.

Research Grants acquired due to access to fab

The total of **new** grants and contracts directly linked to the fab had a value of **$ 2,669,150** - an increase of more than 100% from $ 1,339,826 in 2009-10**.**

The distribution across faculties is more even, in contrast to 2009/10, when the PIs of these grants were almost exclusively from the faculty of engineering.



(A batch of wafers are entering the oxidation furnace

The MIAM Characterization Facilities

As this is the first year of operation for many of the MIAM Characterization Facilities tools, a unified reporting structure is still being developed. Full data on usage is therefore not available.

As accessible, the data for the use of the Facilities are described, in some cases, estimates are used in lieu of recorded data.

Oleksandre Ivasenko and Andrey Moiseev inspect the electron paramagnetic resonance machine (EPR). The EPR is used in the detection and analysis of free radicals from chemical species

Tool List

The MIAM Characterization Facility consists of eleven different advanced surface and materials characterization tools housed in four different departments and faculties across the McGill campus.

Tools	Location
Brucker Electron Paramagnetic Resonance (EPR)	**Otto Maass (SS1 47)**
Fourier Transform Infrared Spectroscopy (FTIR)	**Otto Maass (SS1 35)**
Matrix-Assisted Laser Desorption/Ionization Time-of Flight Mass Spectrometer (MALDI-ToF)	**Otto Maass (SS1 36)**
Nuclear Magnetic Resonance (NMR)	**Otto Maass (SS1 47)**
Bruker Powder X-Ray Diffractometer (XRD)	**MH Wong (2060)**
Gatan Precision Ion Polisher	**FEMR (Ruth 407)**
Raman Microscope	**Otto Maass (225)**
Saw Microtome	**Dentistry**
Skyscan MicroCT 1172	**MH Wong (2060)**
Skyscan MicroCT 1178	**Goodman Cancer Centre (318)**
X-ray Photoelectron Spectroscopy (XPS)	**MH Wong (1280)**

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 Finances

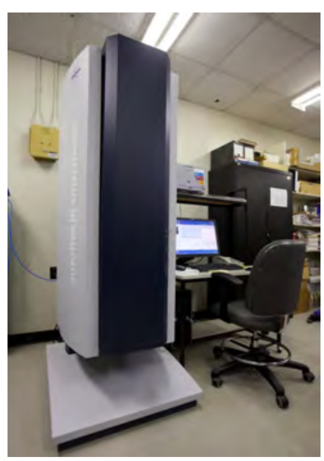
Preliminary fees to cover costs such as technicians, maintenance, consumables and usage have been set for almost all of the Characterization Facility tools. Some of these were set at low rates to evaluate demand and raise awareness of the tools' usefulness. Full details of the fee structures for each piece of equipment can be found on the MIAM website.

This far, several of the Characterization Facilities' tool are bringing in significant income: nearly $57, 000 in total since installation.

Their home departments– Chemistry and Mining and Materials are also still making significant in kind contributions to technician pay, overhead and upkeep.

(Above) Departmental electronic engineer (Chemistry) Richard Rossi adjusts the settings for the NMR (at left).

The NMR can provide detailed information about the structure, dynamics, reaction state, and chemical environment of molecules.



The Autoflex III® MALDI-ToF (right) is useful for detailed protein/peptide characterization, and polymer analysis as well as cutting edge high resolution MALDI imaging, glycan analysis or high-throughput microbiological molecular identification

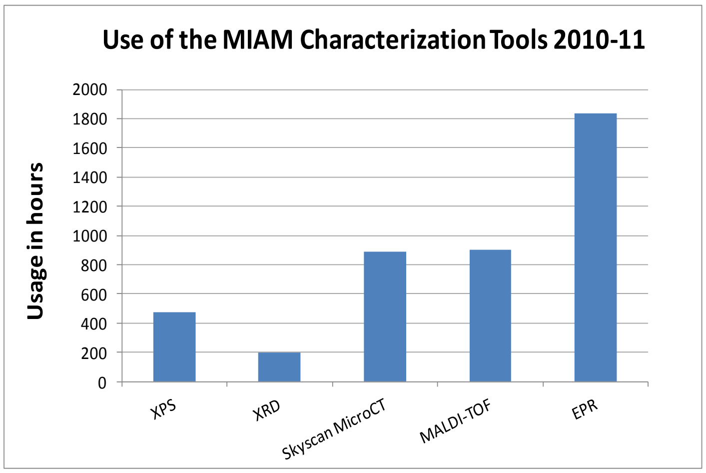
Characterization Facilities: Total Usage Breakdown

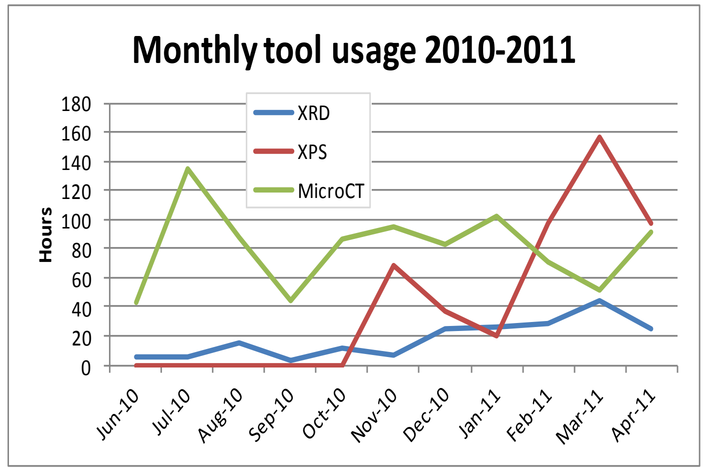
According to the current records, the Electron paramagnetic resonance spectroscopy (EPR) machine is currently getting the most use, and appears to be running near capacity. The large MicroCT and MALDI laser desorption ToF have also both been quite busy. The X-ray photoelectron spectroscopy unit (XPS) has not been in regular use for the whole period, running full time from October 2010. Thus the XPS may be more important next year.

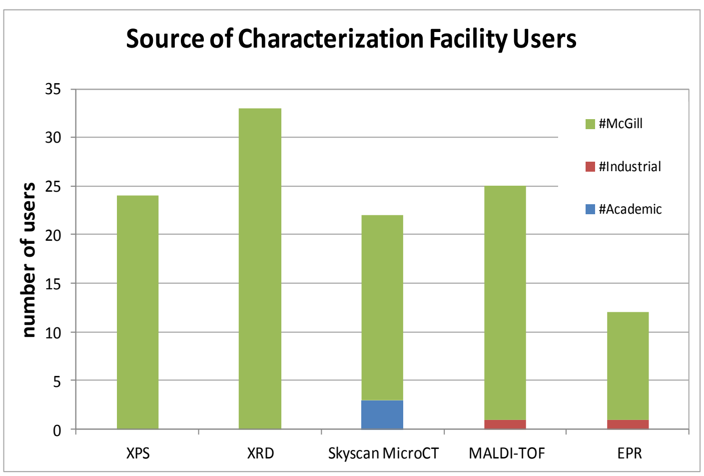
Monthly data is only available from some tools, but both the XRD and XPS have shown increases in use over the year.

The monthly data from the XPS shows an increase in use to over 100 hours per month after Feb 2011.

High usage in some months necessitated a change to the booking policy for the MicroCT and XPS in order to improve access for users. These changes included soft caps for yearly pass holders and new booking rules.







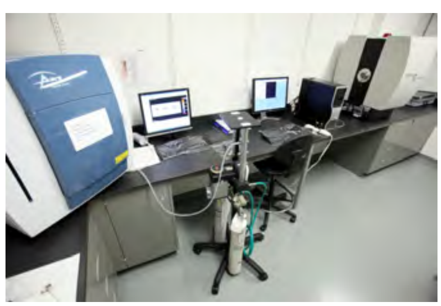
Most of the usage for the Characterization facilities tools is from within McGill.

At least 35 individual academics and their students have used the facilities' major tools for their research.

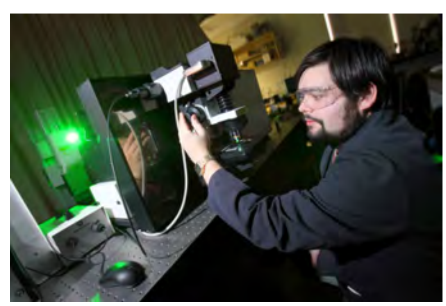
These users originate in multiple departments including Chemistry, Physics, Medicine, Human genetics, Surgery/ Biomedical Engineering, Dentistry, Microbiology and Immunology; Mining and Materials, Civil, electrical and Computer, Applied Mechanics, Chemical Engineering.

A small number of other institutions including academics from Polytechnique and INRS, and Slingshot Product Development Group, USA have also begun using the facility.

The X-Ray diffractometer (XRD) performs non-destructive analytical techniques which reveal information about the crystallographic structure, chemical composition, and physical properties of materials



The Skyscan MicroCT (right) can be used to view devices and materials in-vitro and to for internal views of smaller material samples.



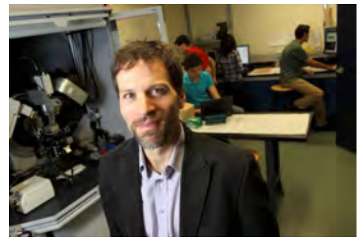
Tim Gonzalez demonstrates how the Raman microscope can be used for to study vibrational, rotational, and other low-frequency modes in a system to identify chemical bonds

The Upcoming Year

This year we plan to institute a more unified reporting structure of usage and financial information. In general we anticipate the amount of income generated by the Characterization tools to increase. Many of the tools have not been open to general use for a whole year, as yet.

Although full data on costs is not yet available, tools are not yet generating sufficient income to cover costs. Some will also either need additional technician support, (e.g. the XPS, MicroCT and XRD) or the purchase of service contracts (Micro CT, XRD) in 2011-2012. Usage and services fees may also be reevaluated based on new usage and cost data.

In addition, the MIAM Facilities website will be undergoing continual review and revision to improve the clarity and usability. A central online booking system for some of the tools will be assessed.



Research highlight:

Prof. Mark McKee, Faculty of Dentistry

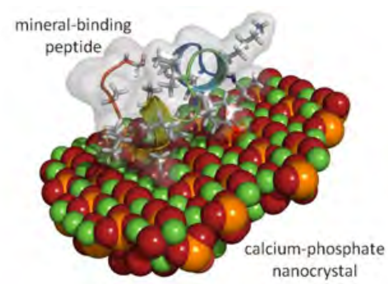
Prof. Marc McKee of the Faculties of Dentistry and Medicine was one of the inaugural members of MIAM, acting on the advisory committee (from 2004-2008) to MIAM's first director Jorge Vinals.

McKee's current research focuses on mineralization of bones and teeth. These hard tissues are considered the original, classic 'biomaterials' because of their nanocomposite, organic-inorganic hybrid structure consisting of matrix proteins including collagen fibrils "cemented" by calcium-phosphate nanocrystal growth within this biologic scaffold. Mores specifically, his group studies how proteins and small peptides bind to the surfaces of the nanocrystals that make up bones and teeth and how they regulate normal and abnormal growth of the crystals. The subject is highly interdisciplinary linking engineering, geology/mineralogy and biological sciences.

They now know that among the scaffolding matrix proteins of bones and teeth (mostly collagen) there many other proteins with a variety of complex functions. McKee's research group focuses on a subgroup of these – a family of mineral-binding proteins – generally using high-resolution techniques that include electron microscopy and computational simulations, as well as MIAM Characterization Facility equipment to study the exact molecular nature of both synthetic and tissue-extracted crystals and proteins prior to performing binding studies. He is a regular user of the MIAM XRD which is the "gold standard method to characterize minerals," the FTIR and the MIAM Micro CT in the Wong building. These tools allow him to analyze organic and inorganic interactions with very high resolution at the ultrastructural and atomic level.

One of McKee's findings in this area is that the phosphate groups of proteins are essential to calcium and crystal binding. He is using this information on phosphorylated proteins and the enzymes that process them to biomimetically engineer mineralizable new bone and tooth grafting substitutes; these could ultimately be used to correct bone and tooth defects after fracture/trauma and after surgeries including bone resection following cancer tissue destruction and certain cancer treatments.

This recent project has involved partnering with fellow member Prof. Showan Nazhat in Mining and Materials (see p. 7) and Prof. Mari Kaartinen (Faculty of Dentistry) on a project to use the this knowledge of proteins and peptides to prepare bioengineered collagen gels for mineralization within bone tissue. Together, they are working on biochemically crosslinking proteins (including enzymes) into collagen gels that promote calcification. This creates a scaffold with a tethered protein at specific sites where the goal is to selectively mineralize the parts of the scaffold that are inserted into bone, thus "biocementing" them into place. One can easily envisage this as a way to attach bioengineered ligaments into bone at their two extremities.



Computational simulation of a bone protein peptide domain bound to the surface of a calcium-phosphate (hydroxyapatite) crystal found in bone.

The same mineral-binding knowledge of how peptides and proteins bind to nanocrystals in the body is being used to target drugs(enzyme replacement therapy) to patients with soft skeletons and teeth.

McKee has worked with a Montreal-based biotechnology company to develop and test a designer "fusion protein" that targets an enzyme (in hypophosphatasia patients lacking this enzyme) to bones and teeth using a mineral-binding terminal peptide that binds to the nanocrystals after injection into patients and promotes bone and tooth calcification.

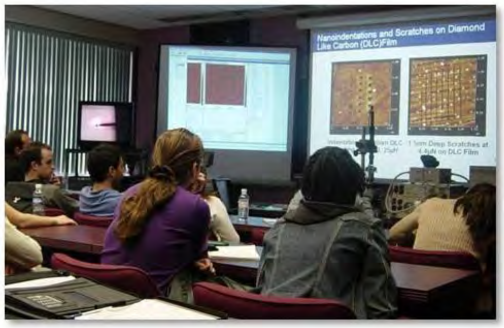
MIAM Training Activities

The NSERC-CREATE Integrated Sensor Systems Training Program

The first year of the NSERC-CREATE Integrated Sensor Systems Training Program has been a busy one: The first students were accepted and began activities in January 2011. The program also offered 3 Undergraduate Summer Research Awards in May 2011 and accepted the second cohort of graduate student for Fall 2011. Training activities developed for the program included several new hands-on workshops, a seminar series and a student run Summer School.

Public outreach and events have increased awareness of the challenges of integrating and commercializing systems amongst students. According to a survey of the first cohort, the program has already provided unique learning, networking and collaboration opportunities. Comments by the first cohort indicated that ISS has facilitated the development of an expanded research network for students. 37% indicated that ISS Seminars had opened new avenues in their research.

On average, 58% of students agreed or strongly agreed that the program has helped them progress in their research. Seven of 19 students also expressed that the seminar series had introduced new avenues for their personal research, while half had found that the program had helped them adapt their research to industry needs.



Students learn about sensors

Overall, the majority of students agreed that the workshops and short courses would be useful for their future careers. 74% requested more frequent training activities.

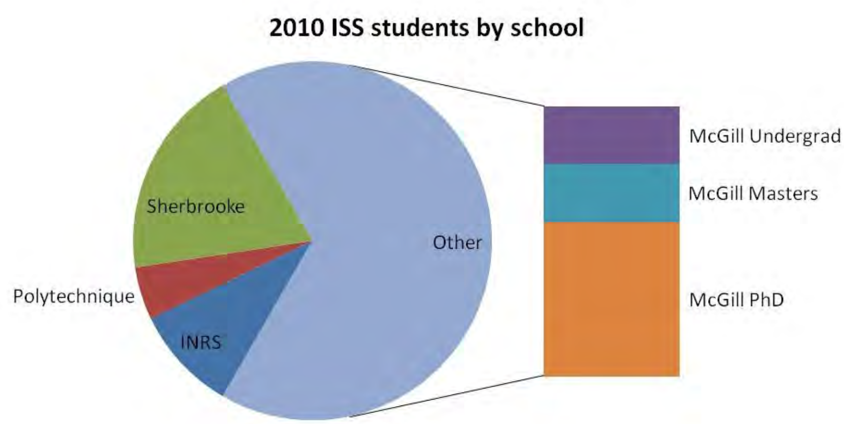
Finally a core aspect of the ISS program is to build a community of researchers in sensor systems by providing to the best eligible students, regardless as to whether their supervisors were part of the original co-investigator team.

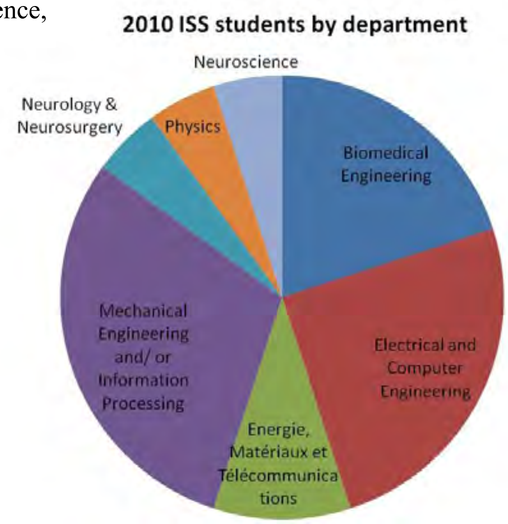
ISS Students and Awards

2010-2011 Trainees: In October 2010, the ISS Program accepted **19 graduate students** (3 Masters and 16 PhD) to start program activities in January 2011. Of these, 3 Masters and 6 PhD students were offered between one and three year 50%. All graduate student participants were offered travel funding to facilitate internships and exchanges, in addition to coverage of workshop and course fees. The group were a mixture of Science, Engineering and Medicine students from all 4 participating universities.

ISS Graduate students pose with program administration at the 2010 cohort Student Orientation event in January.

Three **undergraduate students** also joined the program in Summer 2011. These students were offered stipends for 3 month Summer research projects and will participate in this year's activities.





Seminars, Workshops and Events

The ISS program organized a new **bimonthly Sensors Seminar Series** starting in January 2011 to provide students exposure to a wide variety of sensor related topics. Attendees of the seminar series were presented with topics in a broad range of sensors related topics and speakers from McGill, INRS and Sherbrooke University.

Participation in the series in Winter 2011 was high. Six seminars were offered and nearly 3/4 of ISS students attended at least 4 sessions. A significant number of non-ISS students have also attended, and several of these later joined the ISS Program.

Speakers have or will include academic, government and industry researchers and managers.

In Summer 2011, the ISS program developed and offered two new 2-day **hands-on workshops** "Sensor Integration" and "Surface Chemistry. These were attended by 12 and 17 students respectively. Students surveys indicated that the workshop was a "good introduction to the subject" (AVG>4.3/5).

Several ISS Students also assisted in developing and facilitating an existing one week workshop in Microlithography, put on in conjunction with another McGill interdisciplinary training Program: the CIHR Systems Biology Training Program in February 2011. 53% of ISS students attended.

The CREATE-ISS Sensors Summer School

The organization of the summer school, which is planned and managed by the ISS students provides important experience in organizing large events as part of a team.

The ISS Students nominated a Graduate Student committee who, with assistance from an academic advisor and the ISS Administration put on the first **annual Sensors Summer School** on July 3, 2011 **with sponsorship by Teledyne DALSA Semiconductor, MIAM,** and the **NSERC-CREATE ISS Program**.

This event consisted of 4 local, national and international guest speakers from industry and academia, a student presentation competition and poster session. Invited speakers included: Dr. Michael Thompson form the department of Chemistry at the University of Toronto, Ontario with "*Sensor systems for clinical diagnostics*"; Prof. Stephen Arnold from the department of Applied Physics and Chemistry at Polytechnic Institute of New York University, NY spoke on "*Whispering Gallery Mode Label-free Opto-fluidic Sensing of Virus One at a Time*"; Mr. Luc Ouellet, VP for Technology Development at Teledyne DALSA, introduced *"The new micro innovation center at Bromont"*, and Mr. Zhao Lu from CMC Microsystems in Kingston, Ontario presented "*Microfluidics and biosensor systems*".

Guests enjoy refreshments at the CREATE-ISS Summer School poster competition.

The Summer School was well attended with over 60 participants and nearly 50 graduate students.

For more details please see the student website:

www.create-iss.org

Business and Professional Skills Training

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** normally reserved for McGill graduate students. These included a 10-week short course in 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.

Discussion has also begun regarding increasing access to several pre-existing courses in professional skills at Université de Sherbrooke. We are also looking toward the development of several ISS specific courses in Project Management, Entrepreneurship, IP and Process control.

Members Amir Foudeh (top), Mohamad Diaa–Baid (front) and Esen Sokullu (right) of the ISS GSPC organizing committee pose with Dr. Andrew Kirk (Director) and Rowena Franklin (co-ordinator) and invited speakers Stephen Arnold and Michael Thompson .

Management and Governance

The NSERC-CREATE Training program in Integrated Sensor Systems is 6 year initiative funded by the National Science and Research Council of Canada's Collaborative Research and Training Experience To implement this initiative MIAM was provided $1.6M from NSERC plus $580k from the four participating universities: McGill, Sherbrooke, Ecole Polytechniques and INRS with the objectives of :

•Developing a multidisciplinary training program

•Promoting the job-readiness of students

•Developing professional skills for graduate students

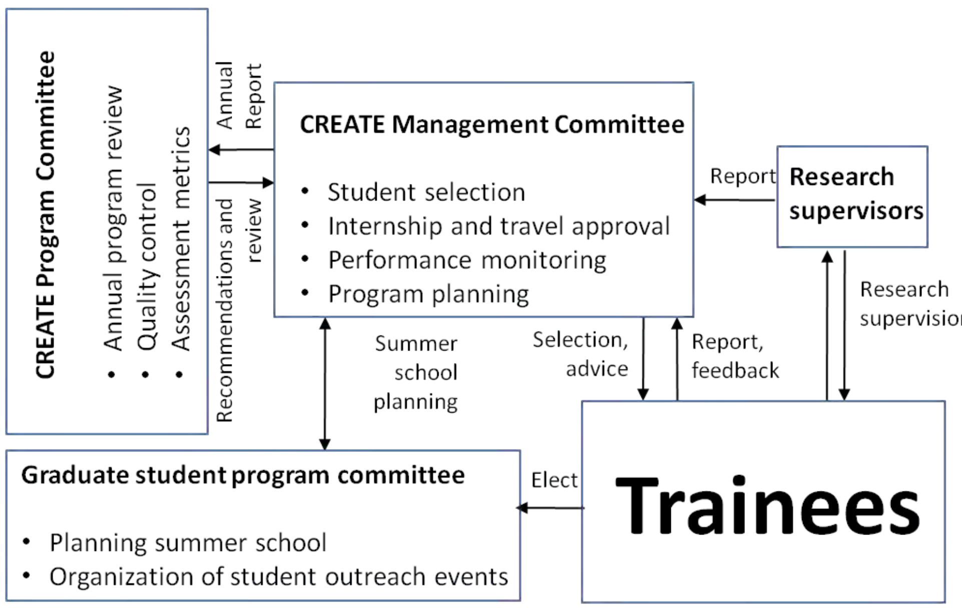
•Advancing expertise in broad range of application areas: Biomedical sensing: diagnostics and drug discovery; Aerospace and automotive; Consumer electronics and Environmental sensing.

•Training more than 100 students over six years

•Creating a community of sensors researchers

Regular activities of NSERC-CREATE ISS Training Program are designed by the CREATE Management Committee. This committee consists of representatives form 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. Student in the 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.



The Upcoming Year

Students:

In September 2011 we accepted **19 more graduate students** (4 Masters and 16 PhD), with undergraduate recruitment planned for next spring. Research stipends of 2 years duration were offered to all Masters and 7 of the PhD students. As well, two of the 2010-entry PhD students who had previously been offered travel funding only were offered stipends. So far, all students have accepted their offers.

Over the course of the program we estimate that the program will meet or exceed target numbers of trainees.

Training

Sixteen out of 19 students felt that the ISS Program workload had not delayed or impeded the completion of their degree. We therefore look forward to increasing the number of activities offered in the coming year.

We plan to implement a 1-2 day short-course in Entrepreneurship and Intellectual Property in Winter 2012. In the next year we also plan a 2-3 day Surface Characterization Workshop, and as proposed specifically by our industrial partners, a one day Process Control short-course. Planning and organization for a 12hour Microfabrication Workshop Series, and a 2-day Project Management short-course are already underway.

This is on top of repeats of last year's Soft Lithography and Microfluidics course, and Surface Chemistry workshops and Summer School

New Offices

MIAM has moved into its new permanent office space in the Adams building, in room 6C on the first floor!

MIAM will be joined by the administration from the Institution for Sustainable Engineering (ISEAD), and The McGill Institute for Aerospace Engineering (MIAE).

The MIAM Administrator Ms. Rowena Franklin is available during normal office hours to direct your questions about MIAM events and activities and about the NSERC CREATE ISS Program.

Please feel free to drop by!

Research Highlight:

Prof. Guillaume Gervais Physics, Thomas Szkopek and Zetian Mi, ECE

MIAM Members Thomas Szkopek (ECE), Guillaume Gervais (Physics) and Zetian Mi (ECE) have formed a unique collaboration between Science and Engineering with the goal to create near-perfect and "defect free" hybrid devices made out of both semiconductor and superconductor materials. These materials are all-McGill made using the Prof. Mi's unique Molecular Beam Epitaxy (MBE) Laboratory and the MIAM Nanotools-Microfab facility.

The team, presently funded for the project by NSERC, FQRNT the Canadian Institute for Advanced Research, aims at developing hybrid devices of unprecedented cleanliness and quality. This study, made possible by the recent advances achieved in Prof. Mi's MBE laboratory, aims at developing a prototype designed for the so-called "Majorana physics", a key theoretical prediction in Physics which could lead to important breakthroughs in the area of topological quantum computations.

This field of research has recently attracted a lot of attention due to Microsoft's creation of the institute Station-Q in Santa Barbara, and institute that Gervais attends all bi-annual meetings. While the team has not yet find a smoking gun for the "Majorana physics", they believe they have made an advance in creating the (or one of the) first superconductor-semiconductor-superconductor (SNS) device in the ballistic regime, i.e. a device so clean that electron moves straight and do not collide. This could prove an important step towards their ultimate goal to engineer a new "quantum state" in solid-state from a materials' designer point-of-view.

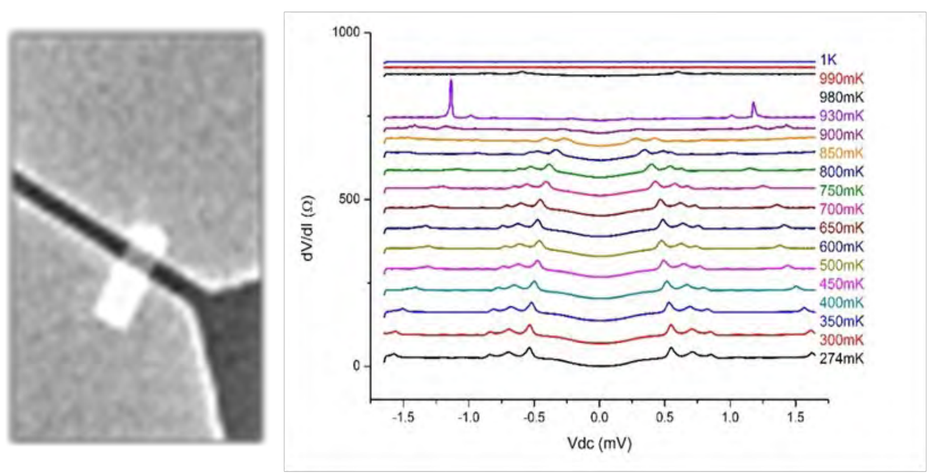
Methods and Results:

InN single nanowire devices are fabricated at the McGill Nanotools facilities. The vertical-standing epitaxial intrinsic InN single nanowire, grown by molecular beam epitaxial (MBE), are made lying on new substrates transferred by ultra-sonic IPA bath. E-beam lithography (EBL) is then employed to make the electrodes for a single nanowire. Because of the small size of the nanowire (~100 nm in diameter, ~1um in length), it requires extremely sharp exposure edge and precise stage movement during the EBL process. Hence, Gervais et al. have divided the electrodes fabrication process into two exposure steps.

The first exposure is achieved with extremely precise position control, giving two small electrode pads lying exactly on the nanowire with a sharp and small gap.

The second step is used to fabricate the larger electrode pads, for wire bonding, with larger position precise tolerance. InN single nanowire contact was successfully achieved after e-beam evaporation of electrode metal and lift-off processes following the above EBL process. Electrical transport measurements for the single nanowire device were done at 77K (nitrogen) and 4K (helium) temperature by means of a quasi-DC lock-in technique in the Gervais lab.

Ackowledgement We thank NSERC, FQRNT, RQMP, CIFAR, the Faculty of Science and the Faculty of Engineering for financial support.



SNS device fabricated at Nanotools by Szkopek, Gervais, and Mi. The left picture shows an SEM picture of the device, and the right transport measurement performed at low temperatures in the Gervais lab.

Contributions by: Andrew Kirk, Guillaume Gervais, Marc McKee, Peter Grutter
and Rowena Franklin.

THE MCGILL INSTITUTE FOR ADVANCED MATERIALS

Rm. 6C, Frank Dawson Adams Bldg,
3450 University Street
Montreal, Quebec, Canada H3A 2A7

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 communications, information technology, transportation, clinical diagnosis and care, and energy generation, for example.

www.mcgill.ca/miam

Contact: Rowena Franklin

Administrator,
McGill Institute for Advanced Materials
Tel: (514) 398-8718
administrator-miam.engineering@mcgill.ca

Director, Prof. Andrew Kirk

Rm 382, Dean's Office
Macdonald Engineering Bldg
817 Sherbrooke St West, Montreal, QC
Canada H3A 2K6,
andrew.kirk@mcgill.ca

miam