Nanotools MicroFabrication Facility

Annual Report

June 2008 – May 2009

submitted 5 August 2009 by the Fab Operations Committee,

membership effective 5 June 2009:

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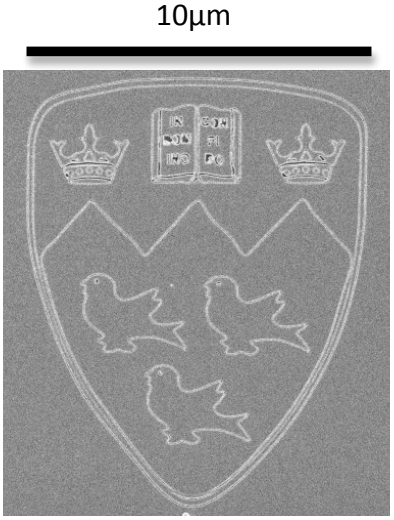

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Executive Summary

The 2008/2009 fiscal year has been a year of significant change for the McGill Institute for Advanced Materials NanoTools MicroFabrication Facility. The most important positive developments are:

- A total of 59 journal articles, conference proceedings, patents and book chapters reporting research made possible by the Facility have been published by McGill PIs since January 2008. These research publications are in the diverse areas of bio-sensing, bio-compatible materials, micro-fluidics, micro-/nano-electronics and micro-/nano-photonics.

- Research time spent on major equipment at the Facility increased by 61% over the last fiscal year, largely attributable to growing research programs of junior McGill PIs. The heaviest use of the Facility is by PIs affiliated with the Faculties of Engineering, Medicine and Science. Growth in facility usage is of strategic importance as the McGill Facility is much younger than comparable local facilities such as that at Université de Sherbrooke, as well as close by international renowned facilities, such as that at Cornell University.

- A total of 57 McGill HQP have been trained at the Facility, a 43% increase over the last fiscal year.

Other developments in the last fiscal year clearly point to critical actions that must be taken – and are already being taken – for the future success of the Facility and its users:

- Industrial usage of the Facility fell to 35 hours from 200 hours in the previous fiscal year, and there is presently minimal industrial use of the Facility. A strong industrial user base is a key component of many federal and provincial funding initiatives.

- The facility operated at a deficit of 327k CAD in the last fiscal year, as Facility usage fees were the primary source of revenue. The deficit was paid down with internal funding to the McGill Institute for Advanced Materials from the offices of the Vice Principle of Research and International Relations, the Dean of Engineering and the Dean of Science.

- Insufficient staffing (three highly trained professionals) has limited the Facility's responsiveness to the needs of academic researchers and the Facility's ability to undertake industrial outreach. Facility growth with the $3 million MDEIE investment of 2007 has exacerbated the situation.

Introduction

This document summarizes the activites of the McGill Institute for Advanced Materials NanoTools MicroFabrication Facility (hereafter referred to as the "Fab") for the last fiscal year, June 1st 2008 through May 31st 2009. As mandated by McGill Institute for Advanced Materials (MIAM) Director Andrew Kirk, this report has been prepared by the Operations Committee: Thomas Szkopek, Dept. of Electrical and Computer Engineering, Faculty of Engineering, committee chair; Matthieu Nannini, facility manager; Guillaume Gervais, Physics Dept, Faculty of Science; and David Juncker, Biomedical Engineering Dept., Faculty of Medicine. The Operations Committee was instituted on 5 June 2009 by the MIAM Director.

This report consists of a short description of the Fab facility, Fab impact on research & training, financial data on Fab operations for the past two years and a projection for the next, and finally a summary of operations plans for the Fab in the 2009/2010 fiscal year. The Operations Committee recommends this report be distributed to all Fab PIs.

Facility Description

The Nanotools MicroFabrication Facility is a shared use facility with infrastructure and technical staff to support microfabrication and nanofabrication research activities. The central infrastructure consists of a 980 square foot clean room facility (class 100 and class 1000) in the Rutherford Physics Building with a variety of semiconductor processing equipment including photolithographic patterning, etching, thin-film deposition, bonding, and a wide range of metrology capability (a complete equipment list is found in appendix I). Ancillary infrastructure includes semiconductor packaging equipment and an electron beam lithography system for nano-scale lithography in the Wong Building. This complete suite of process tooling enables the fabrication of electronic, photonic, and mechanical elements, stand-alone or in an integrated package. The Fab is presently staffed by one manager and two technical specialists. The Fab is accessible to both academic and industrial users with usage fees levied to cover operational costs (a complete fee schedule is found in appendix II).

Impact on Research & Training

The primary deliverables of the Fab are: a) enabling competitive research across multiple disciplines involving micro- and nano- technologies and b) training highly qualified personnel. While difficult to quantify, we provide below aggregate data that gives a picture of the Fab's service to the research community.

Enabling Research

Aggregate numbers of publications for January 2008 – June 2009 are summarized in Table 1, with a detailed list of journal articles and proceedings given in Appendix III. This publication count includes only those research reports that were made directly possible through the use of Fab facilities, and is a direct measure of the Fab's contribution to McGill's research output.

Journal Articles	Conference Proceedings	Patents	Book Chapters
17 + 5 under review	34	7	1

Table 1 – Publications in 2008 and 2009 (first 6 months) reporting research that involved usage of the Fab facilities.

Another metric of the Fab's service to the research community is the number of research hours spent by students, post-doctoral fellows and research staff on Fab equipment. facility usage for major equipment in the last two fiscal years is presented in Table 2, indicating an ***increase of 61% in research time spent on major equipment at the facility in the last fiscal year***. This increase is attributable largely to the increase in Fab related research being undertaken by recent academic hires whose research programs are ramping up. We note that research hours on numerous pieces of minor equipment, such as the dicing saw and wire bonder, are not monitored. Usage of work-horse equipment such as the photolithographic contact aligner is a good indicator that the Fab's service to the research community is growing. ***We note that in spite of the contact aligner being out of service for 15% of the year due to a difficult repair servicing, the contact aligner was still used for 44% of all available hours in the year.*** As a work-horse equipment, the aligner downtime proved to be a significant bottle neck to many users, but the Fab still witnessed an increase in overall usage. With the upswing in Fab usage, we anticipate that the volume of research publications enabled by the Fab will also increase in the coming fiscal year.

Tool	FY2007/08	FY2008/09
Resist Coater (Site)	15%	19%
Resist Coater (BidTec)	13%	29%
EVG Photolithographic Contact Aligner	23%	44%
EVG Wafer Bonder	4%	5%
SU-70 Electron Beam Lithography System	not installed	27%
Reactive Ion Etcher	8%	13%
XeF_2 Etcher	8%	8%
Sputter Deposition System (Denton)	12%	53%
Sputter Deposition System (MRC)	11%	12%
Solvent Hood	6%	9%
Acid Clean	5%	19%
Base Si Etch	18%	16%
Total Hours of Equipment Usage	**2708 hrs**	**4367 hrs**

Table 2 – Usage of key Fab facility equipment as a percentage of the total number of accessible time per fiscal year (52 weeks × 5 days × 9 hours = 2340 hours/year). Fab facility usage has increased 44% in the last fiscal year.

A breakdown of Fab usage (as measured by total number of hours reserved on major facility equipment) by association of principle investigators (PIs) is given in Fig. 2. It is clear that the Fab enables research across multiple disciplines. PIs affiliated with the Faculty of Engineering account for the greatest number of Fab hours. ***In the last fiscal year the Fab witnessed over 100% growth in Faculty of Engineering usage due largely to the ramping up of Fab related research activity by recently hired PIs in the Faculty of Engineering***. ***Facility usage by PIs affiliated with Medicine and Science also increased in the last fiscal year***, as measured by total hours spent in the facility. Several research projects in the Fab are collaborative projects involving investigators from different faculties, reflecting the fact that the Fab enables multidisciplinary research, for example:

- Engineering of the Central Nervous System, D. Colman (Medicine), P. Grutter (Science), B. Lennox (Science), D. Juncker (Biomedical Engineering), A. Kirk (Engineering), P. Wiseman (Science), Christopher Barrett (Science), A. Fournier, (Medicine), T. Kennedy (Medicine), E. Ruthazer (Medicine).
- Integrated Proteomics Platforms for High-Throughput Biomarker Discovery and Validation, M. Tabrizian (Medicine), D. Juncker (Medicine), A. Kirk (Engineering), funded by Genome Canada.
- Multi-Modal Multi-Site Recording Probe Array for Neural Prostheses, V. Chodavarapu (Engineering), S. Musallam (Engineering, associate member Medicine)

A strict faculty breakdown is therefore only a partial representation of the distribution of Fab usage. A complete listing of PIs is given in Appendix IV. It is noteworthy that the Fab has provided research services to external academic users from 6 major universities in the southern Québec region, including École Polytechnique and Université de Sherbrooke, both of which have well established microfabrication facilities.

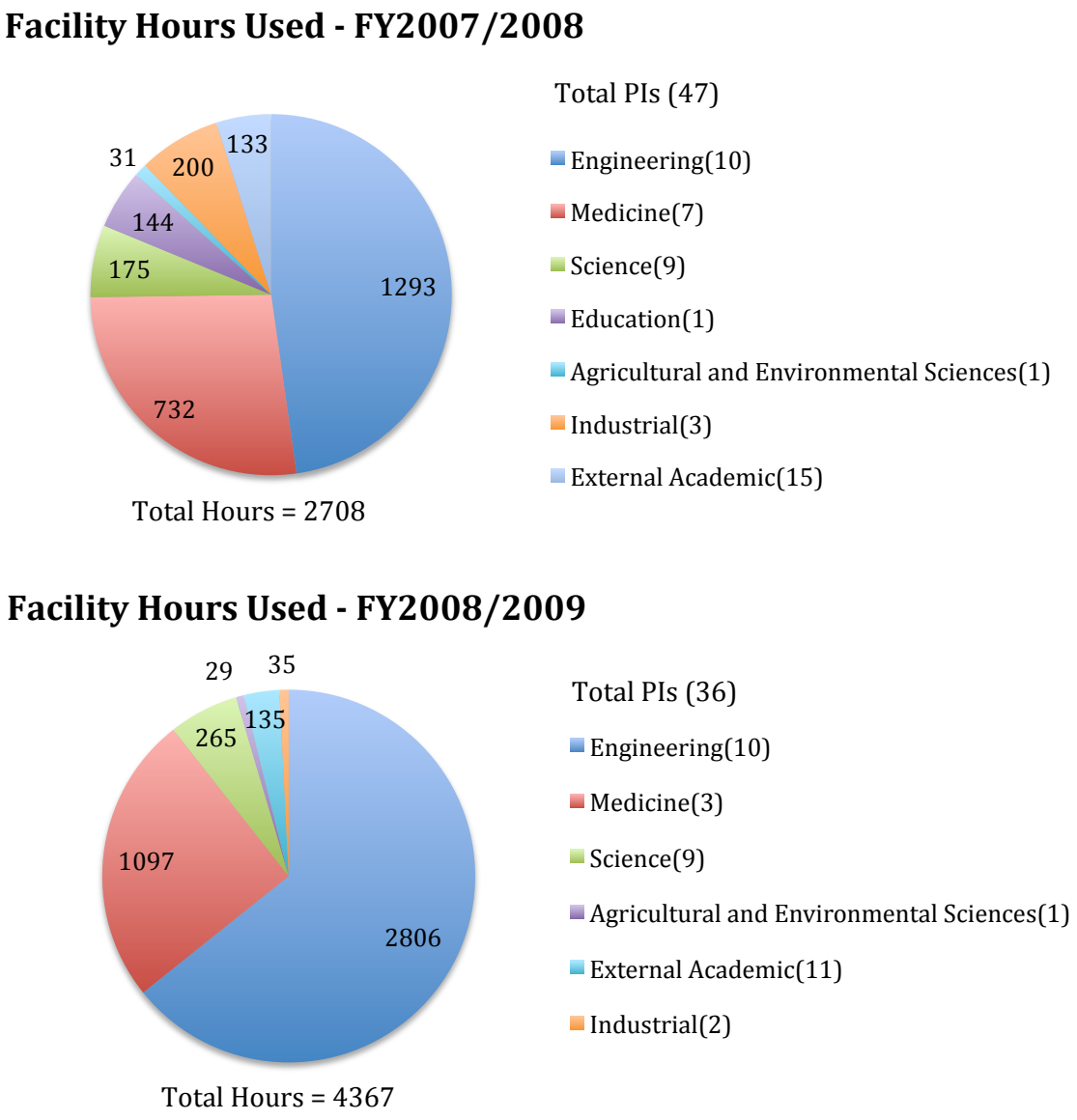

Figure 2: Breakdown of hours of Fab facility usage (derived from equipment reservation records) for fiscal years 2007/2008 and 2008/2009. The number of principal investigators (PIs) for each category is also given in brackets. Usage by PIs affiliated with the Faculties of Engineering, Medicine and Science is noteworthy, as is the collapse of industrial usage.

Training Highly Qualified Personnel

An important contribution of the Fab to the research community is the training of highly qualified personnel (HQP). A measure of HQP training is the total hours of Fab facility usage (reported above) as well as the number of researchers (students and post-doctoral fellows) that are directly involved in using the Fab. There has been ***a 43% increase in McGill HQP using the Fab in the last fiscal year.*** The greatest increase in HQP is associated with the Faculty of Engineering. However, the multidisciplinary nature of research in the Fab means that a breakdown by faculty association gives only a partial picture.

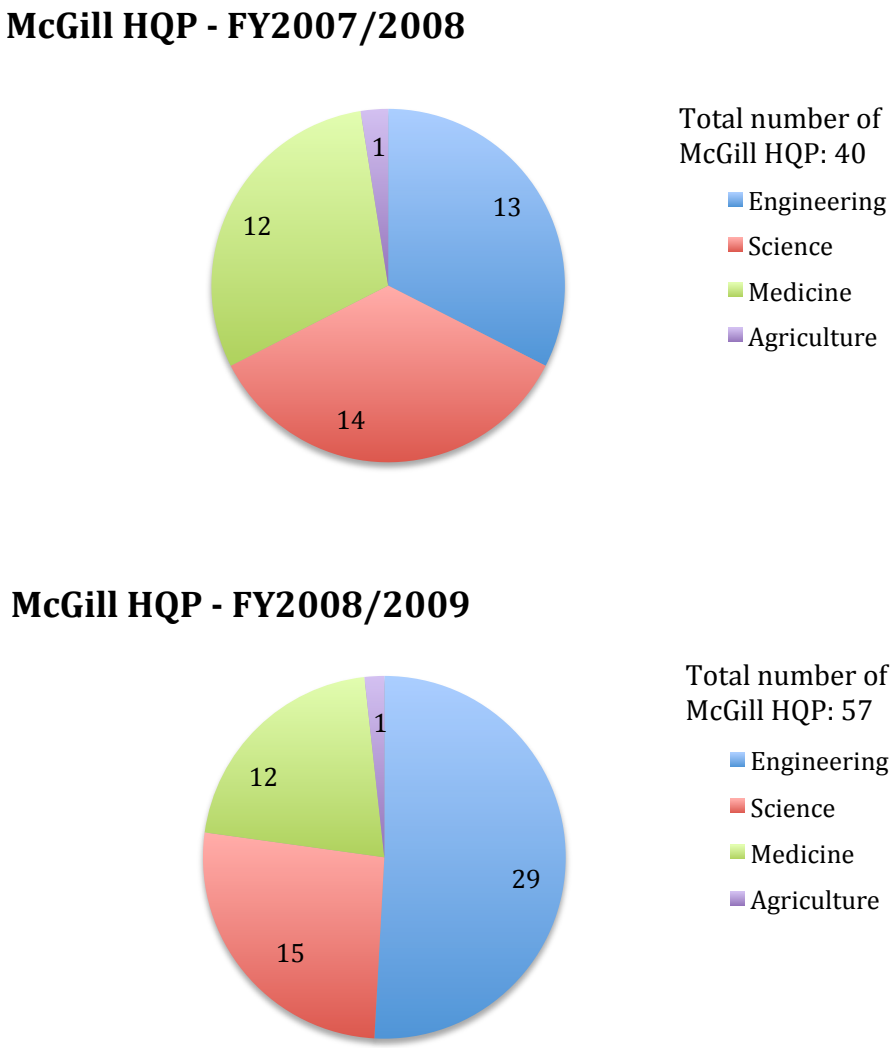

Figure 3: Number of McGill HQP using the Fab for fiscal years 2007/2008 and 2008/2009, broken down by Faculty affiliation. There has been a 43% increase in HQP using the Fab in the last fiscal year.

Industrial Usage

Industrial usage of the fab facility is an important indicator of the relevance of fab activities to local industry, and is strategically important for grant agency / government support. Unfortunately, as seen in Fig. 2, ***the last fiscal year has seen significant decrease of fab usage by industrials, with negligible active industrial use at the close of the 2008/2009 fiscal year.*** Insufficient staffing resources to pursue and maintain relationships with local industry is an important factor in the loss of industry interaction with the Fab. Past and present interaction with industrials is summarized below:

• **DALSA**, Bromont, digital imaging and semiconductor processing services, no Fab usage since 2006, ***negotiation of a $16k contract is underway***

• **Reflex Photonics**, Montréal, integrated photonic components, relied on the Fab for thin film deposition, the company has acquired its own on-site film deposition capability, no Fab usage since 2008

• **MicroBridge**, Montréal, electronically re-adjustable resistors, casual Fab usage for research and development purposes, total of 10hours of use in the last fiscal year

• **Semiconductor Insights**, Ottawa, integrated circuit reverse engineering, no Fab usage since 2006

• **Silk Displays**, Montréal, polymer displays, no Fab usage since 2006

• **Nanometrix,** Montréal, thin film deposition technologies, no Fab usage since 2005

• **Opsens,** Québec City, fiber optic sensing, no Fab usage since 2005

• **Quantiscript**, Sherbrooke, nano lithography, no longer in business

• **IatroQuest**, Verdun, biosensors, no longer in business

Securing industrial partnerships is a critical task to be addressed by concerted effort of the Executive and Operational Committees of the Fab in the current fiscal year. Local industry clients were maintained in the past in large part through continued contact by the previous Fab manager (Vito Loguidice). It is anticipated that rebuilding an industry user base will require significant outreach efforts to create and maintain industry relationships, and to cultivate the name recognition and positive reputation needed for growth of industry interaction.

Facility Finances

Consisting of approximately $12 million dollars of research infrastructure, the Fab is a complex facility that requires both highly skilled staff and significant material resources in order to function. The finances of the Fab are allocated from the McGill Institute for Advanced Materials. A summary of finances for the last two fiscal years, and a projection for the coming fiscal year are indicated in Table 4, and described in detail below.

	FY2007/2008 actual	FY2008/2009 actual	FY2009/2010 projected
Expenditure (non-salary)			
Maintenance and Repair	79,667.98	59,863.72	50,000.00
Consumables	35,000.00	46,832.96	47,000.00
Fab Process Development	2,183.68	309.17	2,000.00
Office	3,384.77	6,105.46	4,000.00
Misc.	3,794.22	2,020.98	1,000.00
New Equipment	8,831.73	0.00	0.00
total	132,862.38	115,132.29	104,000.00
Expenditure (salary)			
Fab Manager (M. Nannini)	X	X	X
Fab Associate (D. Berry)	X	X	X
Process Engineer (P. Huet)	X	X	X
Technician (to be hired)	not present	not present	33,000.00
total	289,000.00	289,000.00	322,000.00
Revenue			
User Fees	83,184.13	77,432.85	99,000.00
User Contribution (unsecured)	not present	not present	25,000.00
total	83,184.13	77,432.85	124,000.00
Surplus (Deficit)			
total	(338,678.25)	(326,699.44)	(302,000.00)

Table 4 – Summary of expenditures and revenue in CAD for fiscal years 2007/2008 and 2008/2009. Salary details are confidential and obtained directly from MIAM. Projections are explained in the following.

The Fab is a midsize facility, greater than a principle investigator laboratory but lesser than a national/international research facility. A mid-size facility can typically require total annual operating costs of about 10% of the capital investment in

infrastructure, according to a recent study* by the National Research Council, funded by the National Science Foundation and the Department of Energy in the USA. For the Fab, this would translate to approximately $1.2 million dollars per year. In the last year, the Fab operated at a cost of $404,000 per year, equivalent to only 3% of the capital investment in infrastructure and at the low end of operating budgets for midsize facilites.

Operating Costs (Non-Salary)

Fab infrastructure requires constant repair, with typical items ranging from replacement of custom electronic instrumentation to replacement/repair of specialized vacuum equipment. Fluctuations in repair costs are expected from year to year as equipment failure rates can not be predicted, presenting a challenge to management of all microfabrication facilities. Additionally, significant maintenance costs are involved in the operation of a microfabrication facility such as the Fab. These costs include regular cleaning of the facility and garment laundering to maintain the necessary cleanroom conditions, as well as regular servicing of ionized water facilities that are required for all wet processes. These services are provided by external contractors C.E.M. Technologies and Perotec Sciences. ***A 50% reduction in frequency of cleaning has been implemented as of July 2009 in order to save $10,000 in the next fiscal year.*** Clean room processes will be closely monitored in order to ensure that processing work is not negatively impacted.

In addition to maintenance costs, significant consumable resources are required to operate the Fab. The most significant consumable costs are chemicals (acids, bases, resists, solvents) and liquid nitrogen (as a source of pure nitrogen gas for both wet and dry processing). Minor items including metal targets and toxic gases also contribute to consumable costs. The installation of new equipment from the MDEIE investment is largely responsible for a higher volume of consumables in fiscal year 2008/2009 as compared to the previous fiscal year. Most important is the requirement for new resists and solvents for electron beam lithography (EBL), and the expected deep reactive ion etcher (DRIE). With the arrival of a DRIE system (the purchase order is presently with McGill's Legal Department), an increase in liquid nitrogen consumption is anticipated. Similarly, with the arrival of the MDEIE funded electron beam evaporator, metal target consumption is anticipated to increase. ***The operations committee will periodically recommend updates to user fee schedules to the MIAM director to ensure full cost recovery of consumables.***

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* *Midsize Facilities, The Infrastructure for Materials Research*, National Research Council of the National Academies, Washington D.C., 2006, pages 70-71.

Operating Costs (Salary)

In order to operate the Fab, highly trained and experienced staff are required. At present, there are three facility staff, whose duties include (but are not limited to):

Matthieu Nannini, Fab Manager: Oversees day-to-day operation of the Fab; responsible for coordinating equipment purchases, installations and repairs; orders consumables; trains new users; prepares invoices for users.

Don Berry, Fab Associate: Performs in-house trouble-shooting, maintenance, repair and installation of equipment and infrastructure; trains users.

Pierre Huet, Process Engineer: Provides technical assistance to users; develops Fab processes and procedures; prepares documentation for new equipment; trains users.

At present, the Fab is understaffed and cannot adequately provide the technical services required for operation of the expanding Fab facilities. The Fab regularly relies on the assistance of Robert Gagnon (Dept. of Physics technician) for training and trouble-shooting the wire bonder, as well as Thomas Szkopek (Dept. of Electrical and Computer Engineering) and his research group members for maintenance and trouble-shooting of the EBL. The present staff do not have adequate time to install and qualify the MDEIE funded equipment. More seriously, the Fab manager does not have the time to plan pro-active measures in Fab operation, nor to establish and maintain contact with academic and industrial users (as is the case at other comparable facilities).

A junior level technician will be hired in Fall 2009, funded by contributions from McGill principle investigators beyond fees levied for Fab usage. The junior technician will perform low level technical tasks to allow existing staff to attend to tasks such as: completion of installation and qualification of MDEIE funded equipment, increase contact with principle investigators and users to better meet the needs of users, and promote the Fab's capabilities with academics (primarily new hires) and industrials.

Revenue

The Fab's source of revenue is primarily in the form of fees levied for Fab facility usage. User fee revenue declined in fiscal year 2008/2009 as compared to fiscal year 2007/2008 as a result of a change in user fee structure. Prior to fiscal year 2007/2008, Fab usage was declining as several principle investigators ceased using the Fab, and recently hired principle investigators were ramping up research but were not using the Fab due to competitive pricing from nearby facilities at École Polytechnique and Université de Sherbrooke. ***In order to promote Fab usage by junior PIs, a monthly cap of $800 per PI per month was instituted during fiscal year 2007/2008, and contributed to the 61% increase in Fab usage in the last fiscal year***. Although the increased Fab usage did not bring about a concomitant increase in Fab revenue, the growth of a user base is strategically important. The McGill Fab is young, established in 2001, in comparison with similar local facilities, such as the Centre de Recherche en NanoFabrication et en Nanocaractérisation at Université de Sherbrooke, established in the 1980's, and the internationally reknowned Cornell NanoScale Science and Technology Facility, established in 1977.

The revenue figures for fiscal year 2008/2009 are given in Table 5, where it is seen that ***the cap system gave a net 42% discount on aggregated facility usage fees in the last fiscal year***.

Month	Fees Before Cap	Capped Fees (Invoiced)	Cap Discount
Jun-08	10,493.50	7,653.50	2,840.00
Jul-08	9,939.50	6,459.50	3,480.00
Aug-08	9,939.50	6,459.50	3,480.00
Sep-08	5,190.25	4,115.25	1,075.00
Oct-08	5,190.25	4,115.25	1,075.00
Nov-08	7,772.45	4,674.45	3,098.00
Dec-08	7,772.45	4,674.45	3,098.00
Jan-09	15,666.88	7,874.88	7,792.00
Feb-09	15,666.88	7,874.88	7,792.00
Mar-09	14,103.10	7,935.60	6,167.50
Apr-09	14,103.10	7,935.60	6,167.50
May-09	17,236.00	7,660.00	9,576.00
	133,073.85	**77,432.85**	**55,641.00**

Table 5 – Summary of total uncapped usage fees, capped fees that were invoiced and collected, and the cap discount in CAD for the months of fiscal year 2008/2009.

The user fee structure has been and will continue to be revised in order to increase revenue with minimum impact on research undertaken at the Fab. ***As of June 2009, the cap on Fab users fees was raised from $800 per PI per month to $1,000 per PI per month.*** With the number of principle investigators (~5) hitting the hard monthly cap on a regular basis***, we anticipate an increase in annual user fee***

revenue of $12,000. A further increase in the cap, or a soft-cap in which the marginal fee rate is decreased as user hours increase, will be considered as revenue and Fab usage are monitored in fiscal year 2009/2010. It is to be noted that excessive user fee increases may reduce Fab revenue due to competitive facilities located in the Montréal and Southern Québec region. We finally note that academic usage of the Fab is difficult to forecast due to the variability in principle investigator funding for Fab oriented research. ***The long-term solution to stabilizing user fee revenue is to increase the user base***. To this end, the operations committee is actively engaging new academic hires in micro-/nano- science and technology related fields.

Revenue to the Fab from industrial users was negligible in the last fiscal year. Negotiations are presently underway between the Fab and Dalsa Corporation for a 50 wafer processing contract of estimated $16,000 value. Following the 40% overhead levied by the Office of Technology Transfer, a revenue of $10,000 to the Fab is anticipated. With the successful conclusion of this contract, ***we anticipate that user fee revenue will cover non-salary operating expenditures, to within the certainty with which one can predict usage patterns.***

Operational Plans for 2009/2010

We summarize the key plans for Fab operations in the fiscal year 2009/2010:

1) ***Maximize the impact of the Fab on research and training.*** We believe that the research impact of the Fab can be increased. Minor infrastructure is being installed and new policies are being put in place to safely extend the Fab operating hours from 8am-5pm M-F to 8am-9pm M-F by Fall 2009. Further extensions will be considered. Increase in Fab access has been demanded by several recently hired PIs, and is indicative of the growing importance of the Fab to researchers at McGill. Preventative measures to minimize equipment downtime will also be taken.

2) ***Increase Fab user fee revenue***. The hard cap on Fab users fees was raised from $800 per month per principal investigator to $1,000 per month per principal investigator. Fab usage and revenue will be monitored, and as new equipment from the recent MDEIE investment is installed, policies will be put in place for full cost recovery on cost intensive items such as metal evaporator targets.

3) ***Decrease Fab operating expenditures.*** While Fab operating expenditures have been reduced in recent years, the operations committee has taken further efforts to reduce expenditures. Chief amongst these efforts are a reduction in cleaning frequency by external services to once every two weeks, for a reduction in cleaning costs by $10,000. Further decreases in operating expenditures are presently unlikely.

4) ***Complete installation of MDEIE equipment.*** Two major pieces of equipment funded by MDEIE will be installed in the coming fiscal year, the electron beam evaporator (anticipated delivery in Sept. 2009) and the deep reactive ion etcher (purchase order under review by McGill Legal Services). In consultation with the Fab executive committee, the balance in MDEIE funds will be used for minor equipment upgrades, potentially including a manual photolithographic contact aligner and table top scanning electron microscope.

5) ***Revitalize contacts with industry.*** In concert with the Fab executive committee, the Fab operations committee will work to raise awareness of the Fab's capabilities amongst local industry in the effort to revitalize industry contacts and win industry contracts. This is a critical task of strategic importance to secure grant money, and brings long-term benefits to academic PIs.

6) ***Hire a junior level technician.*** In order to achieve the several of the goals high lighted above, Fab staffing must be increased. A number of Fab PI's have committed funds *over and above* usage fees to fund this position. CV's for the junior level technician have been collected, and a hiring decision is anticipated in Sept. 2009.

Appendix I – Equipment List

An up to date list, with further detail, can be found at:

http://miam.physics.mcgill.ca/microfab/

Lithography

Electron Beam Lithography (30nm linewidth), Hitachi SU-70+ NPGS

UV Photolithography Contact Aligner, EVGroup 620

UV Photolithography Projection Alignment Stepper, Canon Mark III G-Line (offline)

Resist Coater & Developer, Site Service Automated System

Resist Coater, BidTec Manual Coater

Microwave Oxygen Plasma Asher, PVA TePla 200

Metrology

Film Thickness Mapper, Prometrix SM-150

Sheet Resistance Measurement System, Tencor M-Gauge 300

Surface Profilometer, Tencor P1

Film Stress Measurement System, Tencor Flexus 5200

Image Capture Microscope, Olympus MP40

Scanning Probe Microscope, Jeol 5200

Spectroscopic Ellipsometer, SOPRA GESE5

Stylus Profilometer, Ambios XP-200

Wet Processes

Resist processing wet bench

Acid clean wet bench

Base Silicon etch wet bench

Solvent Fumehood

Metal Etch wet bench

Rinser/Dryer, Verteq

Dry Etching

XeF_2 Isotropic Silicon Etcher, Xactix Xetch e1

4 chamber Reactive Ion Etcher (SiO_2, pyrex, Si, GaAs, Si_3N_4), Applied Material P5000

Thermal Processes

Thermal Diffusion Furnace, Tylan Tytan, Tube 2

Wet/Dry Thermal Oxidation Furnace, Tylan Tytan Tube 1

LPCVD Silicon Nitride, Tylan Tytan, Tube 3

LPCVD Polysilicon Tylan Tytan, Tube 4

Thin Film Deposition

3-target RF/DC Sputter System (Au, Ti, Cr, ITO, Al, AlN, TiN, Mg, Zr, Cu), Denton Vacuum Explorer 14

3-target Sputter System, MRC 603

Other Processes

Wafer Bonder, EVGroup 501

Critical Point Dryer, Tousimis 915B

Laminator, GBC Catena 35

Packaging

Wire Bonder, WestBond

Dicing Saw, ESEC 8003

Substrate Polisher, Allied

Appendix II – Fee Schedule

The fee schedule for accessing the Fab facility is detailed below. Updated policy is posted on: http://miam.physics.mcgill.ca/microfab/

Fees: The fees listed are applicable to McGill internal researchers as well as to academic researchers outside McGill University.

Monthly cap: Academic researchers both internal and external to McGill benefit from an equipment access fee cap of $1000 per month per PI, regardless of the number of active projects under the PI's responsibility.

Daily access fee: A cleanroom access fee of $10 per day will be applied for all academic users of the facility. This fee will be charged over and above the listed equipment access rates and is necessary to cover a small portion of the cost of cleanroom supplies (gloves, masks, etc.), cleanroom maintenance and consumables (nitrogen, DI water, etc.).

Non-academic fees: McGill welcomes non-academic users from both industry and government. Fees for non-academic access will be negotiated on a case-by-case basis.

Group 1 Photo (Self-User: $23/hr):
EVG 620 aligner
EVG 501 bonder
Canon Stepper
Site coater

Group 2 Dry Etch (Self-User: $58/hr)
Applied P5000 RIE
Xactix Si etch
DRIE
Electron Beam lithography

Group 3 Wet Processes (Self-User: $17/hr)
Solvent hood
Acid Clean
Acid: HF
Base: Si etch
Metal etch
Critical point dryer

Group 4 Deposition (Self-User: $17/hr)
MRC 603 sputter
DentonE14 sputter
Wet oxidation
Diffusion
LPCVD - Si
LPCVD – Nitride

Group 5 Assembly-I (Self-User: $8/hr)
Allied polisher
Oven
Bidtec coater
PVA O2 plasma

Group 6 Assembly-II (Self-User: $17/hr)
Wire bonder
Dicing saw
Jeol 5200 AFM

Notes:
* Technical support for operations listed above can be obtained at an additional premium of $32/hr.
* Engineer support for process development can be obtained at an additional premium of $60/hr.
* Initial equipment training will be provided at the Self User rates shown above.
* An additional premium may be charged for the deposition of precious metals such as gold.
* There is no charge for access to the following metrology equipment:

CCD microscope
Nanospec 2100 optical film thickness measurement
Flexus 5200 film stress measurement
M-Gage sheet resistance meter
Prometrix SM150 optical film thickness mapper
Tencor P1 surface profiler

Appendix III – Publication List

A listing of scholarly works published in 2008 and 2009, and work presently under review, is given in the following according to category.

Journal Papers

M. Hajj-Hassan, V. Chodavarapu, S. Musallam, "Reinforced Silicon Neural Microelectrode Array Fabricated in Commercial MEMS process", Accepted for Publication in SPIE Journal of Micro/Nanolithography, MEMS, and MOEMS, 2009.

L. Yao, R. Khan, V. Chodavarapu, V. Tripathi, F. Bright, "Sensitivity Enhanced CMOS Phase Luminometry System using Xerogel-based Sensors, In press, IEEE Transactions on Biomedical Circuits & Systems, 2009.

E. Ghafar-Zadeh, M. Sawan, D. Therriault, S. Rajagopalan, V. P. Chodavarapu, "A direct-write microfluidic fabrication process for CMOS-based Lab-on-Chip applications", In press, Microelectronic Engineering, 2009.

M. Hajj-Hassan, V. Chodavarapu, S. Musallam, "Microfabrication of Ultra-long Reinforced Silicon Neural Electrodes", Micro & Nano Letters, vol. 4, pp. 53-58, 2009. (Featured Letter of the Issue)

M. Hajj-Hassan, T. Gonzalez, E. Ghafer-Zadeh, H. Djeghelian, V. Chodavarapu, M. Andrews, D. Therriault, "Direct-Dispense Polymeric Waveguide Platform for Optical Chemical Sensors", Sensors, vol. 8, pp. 7636-7648, 2008.

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Appendix IV– Principle Investigator List

A listing of principle investigators that have used the Fab, their Faculty and Department affiliation, and Faculty aggregate Fab usage hours, are given below.

Fiscal Year 2007/2008

Engineering	
Mourad El-Gamal	Electrical Eng
Andrew Kirk	Electrical Eng
Vamsy Chodavarapu	Electrical Eng
Srikar Vengallatore	Mechanical Eng
Thomas Szkopek	Electrical Eng
Jorge Angeles	Mechanical Eng
Pascal Hubert	Mechanical Eng
Reghan Hill	Chemical Eng
Francois Barthelat	Mechanical Eng
Total Hours:	**1,293.00**
Medicine	
David Juncker	Biomedical Eng
Mladen Glavinovic	Physiology
Alvin Shrier	Physiology
David Colman	MNI
Janet Henderson	Exp. Medicine
Michael Petrides	Neurology
Maryam Tabrizian	Biomedical Eng
Total Hours:	**732.00**
Science	
Peter Grutter	Physics
Guillaume Gervais	Physics
Roland Bennewitz	Physics
Zaven Altounian	Physics
Maria Kilfoil	Physics
Mark Andrews	Chemistry
Bradley Siwick	Physics
Bruce Lennox	Chemistry
Theo van de Ven	Chemistry
Total Hours:	**175.25**
Education	
Dilson Rassier	Kinesiology
Total Hours:	**144.00**

Agricultural and Environmental Sciences

Ashraf Ismail	Food Science	
Total Hours:	**30.75**	

External Academic

Luc Frechette	Mechanical Eng	Universite de Sherbrooke
Michel Meunier	Electrical Eng	Ecole Polytechnique
Venkat Chandrasekhar	Physics	Northwestern University
Ali Dolatabadi	Mechanical Eng	Concordia University
Niall Tait	Electrical Eng	Carleton University
Ammar Kouki	Electrical Eng	Ecole de technologie superieure
Francois Martin	Electrical	INRS
Francois Normandin	Engineering	INRS
Olivier Guenat	Engineering Physics	Ecole Polytechnique
Richard Martel	Chemistry	Universite de Montreal
Mohamad Sawan	Biomedical Eng	Ecole Polytechnique
M. Packirisamy	Mechanical Eng	Concordia University
Raman Kashyap	Electrical Eng	Ecole Polytechnique
Mohamed Chaker	Electrical Eng	INRS
Olivier Grenier	Physics	Ecole Polytechnique
Total Hours:	**133.00**	

Industrial

Microbridge Inc.	
Semiconductor Insights	
Reflex Photonics Inc.	
Total Hours:	**199.75**

Grand Total:	**2,707.75**

Fiscal Year 2008/2009

Engineering

Vamsy Chodavarapu	Electrical Eng
Mourad El-Gamal	Electrical Eng
Zetian Mi	Electrical Eng
Srikar Vengallatore	Mechanical Eng
Andrew Kirk	Electrical Eng
Thomas Szkopek	Electrical Eng
Reghan Hill	Chemical Eng
Pascal Hubert	Mechanical Eng
Total Hours:	**2,805.50**

Medicine

David Juncker	Biomedical Eng
Alvin Shrier	Physiology
John Hanrahan	Physiology
Total Hours:	**1,096.50**

Science

Peter Grutter	Physics
Bradley Siwick	Chemistry
Michael Hilke	Physics
Maria Kilfoil	Physics
Mark Andrews	Chemistry
Guillaume Gervais	Physics
Dominic Ryan	Physics
Bruce Lennox	Chemistry
Total Hours:	**264.50**

Agricultural and Environmental Sciences

Ashraf Ismail	Food Science
Total Hours:	**29.00**

External Academic

Alexandre Champagne	Physics	Concordia University
Ali Dolatabadi	Mechanical Eng	Concordia University
Luc Frechette	Mechanical Eng	Universite de Sherbrooke
Richard Martel	Chemistry	Ecole Poly
M. Packirisamy	Mechanical Eng	Concordia University
Olivier Guenat	Engineering Physics	Ecole Polytechnique
Luc Frechette	Mechanical Eng	Universite de Sherbrooke
Vincent Aimez	Electrical Eng	Universite de Sherbrooke
Mohamed Chaker	Electrical Eng	INRS
Mohamed Siaj	Chemical Eng	UQAM
Raman Kashyap	Electrical Eng	Ecole Polytechnique
Total Hours:	**134.50**	

Industrial

0409231	Reflex Photonics Inc.
0511281	Microbridge Inc.
Total Hours:	**35.00**

Grand Total:	**4,365.00**