MiNa
Microsystems and Nanotechnology Research Group
The University of British Columbia

Annual Report – 2007

Microsystems and Nanotechnology
Research Group

1 About the MiNa Group

We are:

- A leading-edge research group, engaged in many areas of microsystems and nanotechnology
- Distinguished by our level and range of expertise
- Driven by the potential impacts on society and the environment
- Actively looking to attract high quality students and engage industry partners in advancing research

We are engaged in many areas of microsystems and nanotechnology, with a particular focus on devices and systems, experimentation and fabrication. Applications of MiNa research span over many areas, including biomedical devices, nano-computing, nano-devices, communication, energy, sensors and actuators.

Areas of MiNa Application:

- **Bio-medical devices**: lab-on-a-chip, single-cell characterisation, micro-electrode arrays for neural implants, scaffolds for tissue engineering, implantable devices such as stents wireless cardiac monitoring using artery-implanted stents, MEMS devices for navigated surgery, hearing-aid prosthesis, MEMS ultrasound imaging, bio-photonics, DNA sequencing, targeted drug delivery.
- **Nano-devices and computing**: carbon nanotube devices, nano- and organic electronics, silicon nanowire gate-all-around transistors, nanowire memory devices, nanoscale electron emitters, nanocomputing using quantum cellular automata, Schroedinger-Poisson solvers for nanotransistors.
- **Energy**: super-capacitors based on nano-structured (polymer, nanotube) materials, nanowire and nano-composite solar cells, nanowire electrodes for batteries and energy storage.

- **Optical communications**: high frequency optical modulators, fiber communication, and semiconductor laser, vertical cavity lasers, photonics.
- **Sensors and actuators**: fiber optic high-voltage electric-field sensors, nanowire and nanocomposite sensors, plastic health monitoring devices, artificial muscles, adaptive MEMS sensors and actuators.
- **Development of Micro- and Nano-fabrication Technologies**: including controlled nanofabrication, inkjet micro-fabrication, 3D fabrication by micro-electro-discharge machining, catalytic chemical vapor deposition of carbon nanotubes, nanowire (silicon, germanium) growth, nanocomposite inks for inkjet printing, stamping and electrospinning, high resolution lithography and microscopy, microfluidic devices.

MiNa is a dedicated team of visionary and exploratory researchers from the departments of Electrical and Computer Engineering (ECE), Mechanical Engineering (ME), Chemical and Biological Engineering (CHBE) and Physics and Astronomy (Phys). A number of us are also members of ICICS – the Institute for Computing, Information and Cognitive Systems.

The MiNa group is currently well funded, with an annual NSERC Discovery Grant budget of **$516,320**, **$7,639,693** in current project grants (e.g. NSERC Strategic Grants), and **$3,349,685** in recent equipment grants.

Group Members:

Faculty Members	Department	Expertise, Research Interests
Karen Cheung	ECE	BioMEMS, microelectrodes, lab-on-a-chip
Mu Chiao	ME	MEMS, BioMEMS
Lukas Chrostowski	ECE	Semiconductor Lasers, VCSELs, Photonics
Edmond Cretu	ECE	MEMS, adaptive microsystems
Carl Hansen	Phys	Microsystems Technology for Biological Applications
Andre Ivanov	ECE	Nanoelectronics Design for Manufacturability, SoC
Nicolas Jaeger	ECE	Integrated Optics, Photonics
Eric Lagally	CHBE	Integrated microsystems for cells & molecule biology
John Madden	ECE	Molecular Mechatronics
Alireza Nojeh	ECE	Nanostructures and nanodevices, Carbon Nanotubes
David Pulfrey	ECE	Nanoelectronics, Carbon Nanotubes
Peyman Servati	ECE	Nanowires, Nanocomposites, Nanoelectronics
Boris Stoeber	ME, ECE	MEMS, Microfluidics
Kenichi Takahata	ECE	MEMS, Fabrication, Implantable microdevices
Shuo Tang	ECE	Biophotonics, OCT/MPM imaging
Konrad Walus	ECE	Nanoelectronics, Quantum-Dot devices, sensors

2 Equipment Available

Equipment	Investigators	Description
Micro- Nano- Fabrication Equipment		
XeF2 Silicon Etcher	M. Chiao	
Critical Point Dryer	L. Chrostowski	Release of NEMS/MEMS structures
Microdrop Inkjet System	K. Walus	
Parylene coater	K. Takahata	
Lapping machine	K. Takahata	
Dicing saw	N. Jaeger	
Chemical Vapour Deposition Furnaces	P. Servati	For growth of nanowires and nanostructures
Chemical Vapour Deposition (CVD) furnace	A. Nojeh	For growth of Carbon Nanotubes
Thermal and electron-beam evaporator	AN, KT, EC, PS	
CNC mill	E. Lagally	For drilling small holes (100 um dia.) in glass and silicon
Headway spinner	AN, KT, EC, PS	for resist deposition
Laurell spinner	K. Cheung, B. Stoeber	for resist deposition
Glove box	A. Nojeh	
Glove box	J. Madden	With a thermal metal evaporator
Mammalian cell culture: biosafety cabinet, incubator, centrifuge	K. Cheung, B. Stoeber	
Bacterial pathogen Biosafety level 2 lab	E. Lagally	Incubators, biosafety cabinets, and aerobic/anaerobic culture equipment
Characterization Equipment		
Atomic Force Microscope	J. Madden	
Atomic Force Microscope	A. Nojeh	Nanosurf Easy Scan 2
Philips 525 scanning electron microscope	AN, KT, EC, PS	
Laser Doppler Vibrometer	M. Chiao	
Optical Profiler, Wyko NT1100	B. Stoeber	
MEMS Probe Station	M. Chiao	
Cryogenic Vacuum Probestation	P. Servati	For electro-optical measurements on nanoscale devices (6 probe heads)
Inverted Fluorescence Microscope	M. Chiao	

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Equipment	Investigators	Description
Inverted Epifluorescence Microscope	K. Cheung	
Confocal microscope	K. Cheung, B. Stoeber	
High sensitivity color camera	K. Cheung	for single molecule detection
High speed camera (100,000 frames/s)	K. Cheung, B. Stoeber	
Fluigent pressure flow control system	K. Cheung, B. Stoeber	
Micro PIV system	B. Stoeber	Measurement of flow field in microfluidic devices
Ultra-high vacuum test chamber with electron source and detector	A. Nojeh	Multipurpose
Photonics		
Spectra-Physics Beamlok Gas	A. Nojeh	Ar Ion visible laser
Spectra-Physics WaveTrain	A. Nojeh	frequency doubler for UV generation
Coherent Verdi solid-state green laser	A. Nojeh	
Coherent Verdi-310	L. Chrostowski	Argon Ion visible laser
Optical Spectrum Analyzers	N. Jaeger	Ando AQ6317B, HP, Agilent 86146B, 2 wavelength meters
Monochromator	L. Chrostowski	Oriel Cornerstone 260 1/4m
Optical Amplifiers	L. Chrostowski, N. Jaeger	IPG Photonics 2W, Oprel, Avanex
Tunable Lasers	N. Jaeger	3 HP 8164A with 81682A tunable C-band plug-ins
Lightwave Signal Analyzer	N. Jaeger	HP 71401c (to 2.9 GHz), HP 71400c (to 20 GHz)
Electrical Test and Measurement Equipment		
Vector Network Analyzer	L. Chrostowski	Agilent E8361A, 67 GHz
Vector Network Analyzer	N. Jaeger	Agilent 8510C, 50 GHz
Anristu 12.5 Gb/s Bit Error Rate Test-set	N. Jaeger	
Keithley 4200 SCS/PIV semiconductor characterization	P. Servati	Low noise DC/pulsed electrical measurement
Semiconductor Parameter Analyzers	L. Chrostowski	5 Keithley 2602
Nortel OpTera OC-192 switches	N. Jaeger	
FPGA Development stations	E. Cretu (CMC)	with FPGA-MEMS interface module
Agilent 54845 Digital Storage Oscilloscope	E. Cretu, A. Nojeh, P. Servati	4 Channel, 1.5GHz

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Equipment	Investigators	Description
Agilent Arbitrary Waveform Generators	K. Walus, B.Stoeber	2X 80 MHz
Agilent Oscilloscopes	K. Walus, B.Stoeber	2X 300 MHz
Agilent Sampling Oscilloscope	N. Jaeger	40 GHz
RF Signal Generators	N. Jaeger	For signals up to 60 GHz: various synthesizers (20 GHz) with HP 8341B frequency multipliers, 20 and 65 GHz microwave amplifiers
Electrical Spectrum Analyzer	N. Jaeger	Tektronics 494p, up to 21 GHz with mixers to 40 GHz.
Impedance analyzer: Agilent 4294A	K. Cheung	
Lock-in amplifiers	K. Cheung	SR844
Lock-in amplifier	L. Chrostowski	SR810
Temperature Controllers	L. Chrostowski	Newport 3040, ILX 5910B

2.1 Computing Resources Available

Software	PI	Description
Dell Computer Cluster	K. Walus	160 Processor Cores
MEMS Pro	E. Cretu (CMC)	
Coventorware	E. Cretu (CMC)	
Ansys	E. Cretu (CMC)	
Comsol Multi-Physics	K. Walus, K.Cheung, B.Stoeber	Finite-element modeling
Matlab	ECE, UBC	
LabView	UBC	
Lumerical FDTD	L. Chrostowski	Optical simulations
Crosslight PICS3D	L. Chrostowski	Optoelectronics simulations
Synopsys Sentaurus Device	D. Pulfrey, L. Chrostowski (CMC)	Optoelectronics, Nanoelectronics simulations
CleWin	K.Cheung, B.Stoeber	Mask layout
Design Workshop dw-2000	L.Chrostowski (CMC)	Mask layout

2.2 AMPEL Nanofabrication Laboratory

This is a shared facility for the fabrication and characterization of advanced materials and devices. The laboratory is shared on a continual basis by 20 faculty and 60 students from UBC as well as about 6 faculty and a dozen students from SFU and UVic. Occasional users also come from other academic institutions and local small industry (eg. Angstrom Power, Ballard). The AMPEL Nanofabrication

Facility is a fee-based service laboratory open to UBC and outside users. The facility is subsidized by an NSERC MFA grant, and provides highly reduced fee access for academic users.

The cleanroom consists of a gowning room, a class 1000 lithography room (35 m^2), a class 10000 thin-film room (48 m^2), and a class 10000 thin-film / metrology room (50 m^2). The cleanrooms are equipped for most micro- and nano-fabrication needs.

The lithography room houses 2 wetbenches, with equipment to spin on photoresist and do wet chemistry, two mask aligners (3 inch masks front align only and 4 inch masks with backside alignment) and a Nomarski microscope equipped with a CCD camera and computer capture. It also houses a Scanning Electron Microscope (SEM) that has been programmed for electron-beam (e-beam) lithography. Also available in the yellow room is a dry clean bench, typically used for sample cleaving and preparation, and storage cabinets for the wet chemistry dishware.

The thin-film room houses a state of the art Electron Cyclotron Resonance (ECR) plasma etcher, with the following gases: Cl_2, BCl_3, O_2, Ar, He. It also houses equipment for sputter, e-beam and thermal evaporation of metals and dielectrics, a Plasma Enhanced Chemical Vapor Deposition (PECVD) system for deposition of SiO_2 and SiN films and also usable as a reactive ion etcher (RIE) using CF_4 and O_2 chemistry, two Rapid Thermal Annealling (RTA) ovens, a few conventional dry N_2 atmosphere ovens, a Reactive Ion Etching (RIE) chamber with CH_4, a XeF_2 etcher for Micro-Electro-Mechanical-Systems (MEMS) applications, a travelling probe alpha-step profilometer, and a wire bonder.

The class 10000 thin-film / metrology room is used for the following equipment: two thermal oxidation furnaces, and a Reactive Ion Etching (RIE) chamber with CF_4, O_2, N_2, Ar, He gases. There is room for expansion for new equipment in this room.

3 Grants

3.1 MiNa Member Grants: Basic funding

Granting Agency	Subject	Year	Investigator
NSERC Discovery Grant	BioMEMS: on-chip cell culture and characterization; implantable flexible neural arrays	2006–2009	K. Cheung
NSERC Discovery Grant	Anti-biofouling nanoporous membrane for implantable devices	2004–2009	M. Chiao
NSERC Discovery Grant	Optical Injection Locking of Vertical Cavity Surface Emitting Lasers	2005–2010	L. Chrostowski
NSERC Discovery Grant	Synergic Inertial Microsystems for Bio-Medical Applications	2006-2010	E. Cretu
NSERC Discovery Grant	Microfluidic Tools for Structural Biology	2005–2009	C. Hansen
NSERC Discovery Grant	Infrastructure Intellectual Property (IP) for Systems on Chip (SoCs)	2004–2009	A. Ivanov
NSERC Discovery Grant	Novel optical sensors and ultrahigh-speed optical modulators	2004–2008	N. Jaeger
NSERC Discovery Grant	Microfluidics: "Parallel Microsystems for Affinity Reagent Selection/Evolution"	2007–2009	E. Lagally
NSERC Discovery Grant	High Power Polymer Actuators and Capacitors	2003–2007	J. Madden
NSERC Discovery Grant	Controllable nanoscale electron emitters	2007–2011	A. Nojeh
NSERC Discovery Grant	Deep sub-micron integrity issues	2004–2007	D. Pulfrey
NSERC Discovery Grant	Morphologically Engineered Silicon Nanowire Devices	2007–2011	P. Servati
NSERC Discovery Grant	Thermally responsive polymer solutions - flow physics of complex microflows and microflow control	2006–2010	B. Stoeber
NSERC Discovery Grant	Implantable Wireless Microdevices for Pinpoint Diagnosis and Therapy	2006–2010	K. Takahata
NSERC Discovery Grant	Multi-Modality Optical Imaging in Tissues Using Ultrafast Lasers	2007–2011	S. Tang
NSERC Discovery Grant	Quantum-dot Cellular Automata Circuits	2006–2010	K. Walus
TOTAL	**$516,320**	in 2007	

3.2 MiNa Member Grants: Research Projects

Granting Agency	Subject	Year	Investigators
NSERC Strategic	Ultrasonic medical imaging system using capacitive micromachined transducer array	2008–2009	E. Cretu, S. Mirabbasi, R. Rohling, S. Salcudean
NSERC Strategic	MEMS based drug delivery devices	2007–2010	M. Chiao, S. Mirabbasi, R. Rohling, Burt
NSERC Strategic	High-speed transistor-VCSELs for Optical	2007–2010	L. Chrostowski, D. Plant, D. Pulfrey, N. Jaeger
UBC Martha Piper Fund	Optimization of photosynthetic proteins and attachment to electrodes for conversion of light to electrical current	2007	J. T. Beatty, J. Madden
NSERC SRO	Engineering of photosynthesis proteins & attachment to electrodes for conversion of solar light to electrical power	2007	J. T. Beatty, J. Madden
US Dept. of Defence	Microfluidic Prostate Cancer Biosensors	2008–2011	E. Lagally
NIH (USA)	Single Cell Chemical Genetics Platform	2007	C. Hansen
CIHR Team Grant	Microfluidic Technologies to Accellerate Stem Cell Research	2007–2011	C. Hansen, et. al.
MSFHR	Career Investigator Award	2007–	C. Hansen
MSFHR	Team for Monitoring and Control of Abnormal Brain Dynamics	2007–2010	M. McKeown, E. Cretu, et.al
Semiconductor Research Corp.	Combining Formal Analysis, Architectural Features, and Circuit Structures for Post-Silicon Debugging	2007–2010	A. Hu, A. Ivanov, S. Wilton, T. Aamodt
NSERC Strategic	Supercapacitors for Power Quality and Energy Storage	2006–2009	J. Madden, MacLachlan, M. Wolf, Michal

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Granting Agency	Subject	Year	Investigators
NSERC Strategic	Forward viewing Doppler optical coherence tomography with artificial muscle actuation	2006–2009	V. Yang, J. Madden, G. Wright
NSERC Strategic	Autonomous flow-following smart sensors for deployment of multiphase chemical reactors	2006–2009	C. Bennington, S. Mirabbasi, M. Chiao, J. Madden
CIHR NSERC CHRP	U-STAR: Universal Sequence-Tag Array Technology for Absolute Quantification of Per Cell Transcript Profiles in Eukaryotic Organisms	2006–2009	C. Haynes, M. Blades, R. Turner, L. Chrostowski
NSERC I2I	Low Voltage Organic Transistors	2006–2007	J. Madden
TOTAL	**$7,639,693**		

3.3 MiNa Member Grants: Equipment

Granting Agency	Subject	Year	Investigators
CFI/BCKDF - LOF	Enabling Advances in Healthcare and Biomedical Research: Microfluidics Concepts for Innovative Bioanalysis Methods	2007–2011	K. C. Cheung, B. Stoeber
CFI/BCKDF - LOF	Molecular Diagnostics	2007–2011	E. Lagally
CFI/BCKDF - LOF	Laboratory for carbon nanotube-based turnstile vacuum nanoelectronics	2007–2011	A. Nojeh
CFI/BCKDF - LOF	Nanowire and Nanostructured Device Characterization Laboratory	2007-2011	P. Servati
CFI/BCKDF - LOF	NanoSystems Laboratory for Optical Clocking of Quantum-Dot Cellular Automata Circuits	2006–2010	L. Chrostowski, K. Walus

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Granting Agency	Subject	Year	Investigators
CFI/BCKDF - LOF	Infrastructure for MEMS fabrication and characterization	2004-2008	M. Chiao
NSERC RTI	Surface treatment for biomedical devices and micromachining tools	2007	K. Takahata, J.Madden, M. Chiao, K. Cheung, J. N. Kizhakkedathu, B. Stoeber
NSERC RTI	Inkjet fabrication of novel microstructures and devices	2007	K. Walus, J.Madden, K. Cheung, B. Stoeber, E. Cretu, K. Takahata
NSERC RTI	Optical Profiler for Fabrication Process Development and Microdevice Characterization	2007	B. Stoeber, Cheung, Cretu, Walus, Madden, Takahata, Chiao, Lu
NSERC RTI	High-vacuum apparatus for electron emission experiments	2007	A. Nojeh
NSERC RTI	Femtosecond Laser for Developing Tissue Imaging System	2007	S. Tang, S. Lam, L. Chrostowski
CIHR Tools	Microfluidic Systems for High Throughput Proteomics Using MALDI Mass Spectrometry	2007	C. Hansen, et. al.
NSERC RTI	Autonomous flow-following smart sensors for deployment of multiphase chemical reactors	2006	C. Bennington, S. Mirabbasi, M. Chiao, J. Madden
NSERC RTI	Dielectric Characterization of cells within microfluidic networks	2006	K. Cheung
NSERC RTI	Flow physics of complex microflows	2006	B. Stoeber, K. Cheung, M. Chiao, S. Green, D. Grecov, U. Hafeli
NSERC RTI	Semiconductor, laser and nanostructure electro-optic characterization	2005	L. Chrostowski, N. Jaeger, J. Madden, S. Mirabbasi, M. Chiao
TOTAL	**$3,349,685**		

MiNa Publications, 2007

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[3] P. Beecher, P. Servati, A. Rozhin, A. Colli, V. Scardaci, S. Pisana, T. Hasan, A. Flewitt, J. Robertson, G. Hsieh, F. Li, A. Nathan, A. Ferrari, and W. Milne, "Ink-jet printing of carbon nanotube thin film transistors," *Journal of Applied Physics*, vol. 102, p. 043710, 2007.

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