Designs in Fabrication

Canada's National Design Network®

Prototyping Report:

April 2019 – March 2020

About CMC Microsystems and Canada's National Design Network®

Lowering barriers to technology adoption

CMC Microsystems (CMC) is a not-for-profit collaborative organization founded in 1984 to facilitate access to state-of-the-art design, manufacturing, and testing facilities for microsystems technologies. The organization manages CNDN, Canada's National Design Network® – a Canada wide collaboration between over 67 universities and colleges to connect 10,000 academic participants (4,000 researchers and 6,000 student users) with 1,000 companies.

CMC provides services essential for the research and training required to advance Canada's digital economy, for example, Industry 4.0, autonomous vehicles, big data, Internet of Things (IoT), cyber defence/security, 5G, quantum computing, artificial intelligence (AI) and more!

CMC Microsystems' fabrication reports describe Canada's National Design Network designs that have progressed to fabrication are published for distribution at www.cmc.ca

www.CMC.ca

CMC Microsystems Fabrication Report, 2019/20
Published: October 2020
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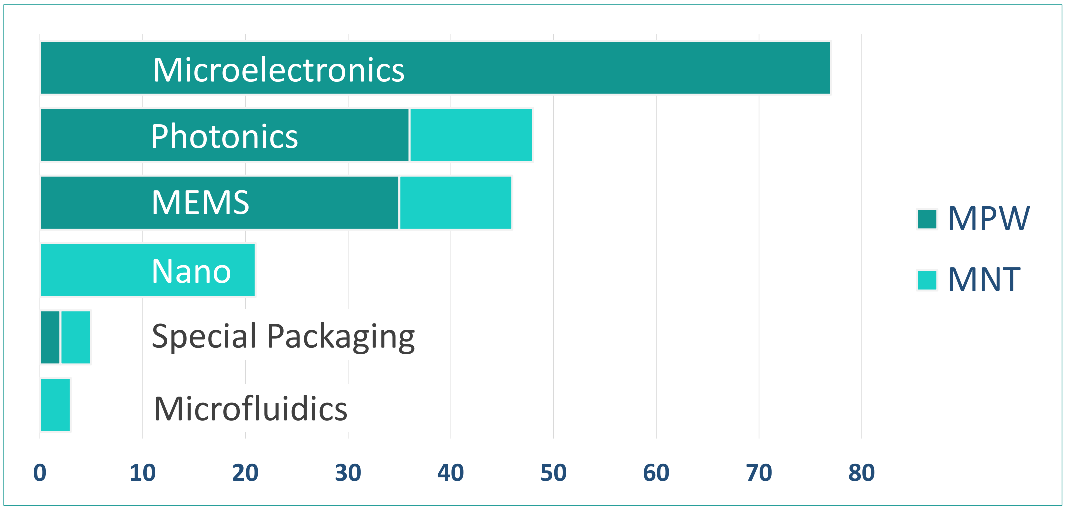
FAB HIGHLIGHTS 2019/20

CMC Microsystems (CMC) delivers key services including industrial-scale multi-project wafer (MPW) manufacturing services, value-added packaging and assembly services and in-house expertise for first-time-right prototypes. Support is available for industrial projects and academic R&D.

This report describes designs that have progressed to fabrication (FAB) for prototype purposes between April 2019 and March 2020. It provides a view into the activities of researchers in Canadian post-secondary institutions – often in the context of applications and solving problems.

In this period, **200 designs** were fabricated in **25 technology runs** through **9 foundries** worldwide (see Appendix B).

- **150** designs were fabricated through CMC's global network of industry-scale fabrication foundries.
- **50** designs were developed through Canada's MNT network of 40 university-based labs (see MNT FAB for examples).



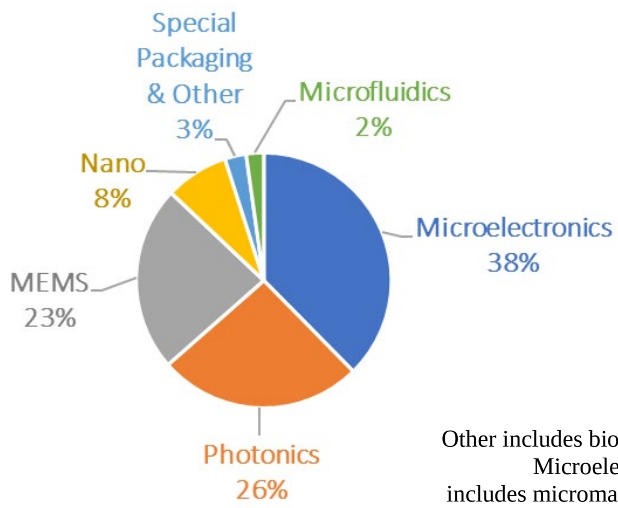
Multi-Project Wafer (MPW) & Micro-Nano Technology (MNT) Fabrication 2018/19

CNDN Technology Roadmap – new additions in to support novel R&D

- CMC partnered with GLOBALFOUNDRIES® (GF®), the world's leading specialty foundry, providing access to GF's advanced and specialized FinFET, RF SOI, FD SOI, SiGe, and Silicon Photonics platforms. CMC customers can access the GF GlobalShuttle Multi-Project Wafer (MPW) program as well as dedicated prototype and production runs in GF technologies.
- CMC partnered with Australian National Fabrication Facility (ANFF) of Singapore, with European support from Circuits Multi-Projets (CMP) of France, to facilitate silicon photonics wafer runs. This agreement increases opportunities for international collaboration and provides clients of both networks with easier access to world-leading nanotech expertise and equipment.

FAB – A five-year period

Designs for Fabrication
2015/16 – 2019/20
Designs: **1483**
Industrial designs: **77** (of 1483)



Other includes biosensors. Microelectronics includes micromachining.

Photonics, Optoelectronics, & Quantum

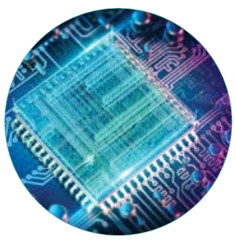
CMC's strategic investments have led Canada to be a global leader in photonics technology. By March 2020 over **850** photonics & optoelectronics designs progressed to fabrication for prototype purposes through CMC (2008/09 through 2019/20) – it includes over **600** silicon photonics designs (includes fabrication training program projects) and **120** III-V technology designs.

In June 2020, CMC became the first member of the **IBM Q Hub** – IBM's most advanced quantum computing platform – at the **Institut quantique** of Université de Sherbrooke. CMC will reduce the barriers to adoption of quantum computing technologies in Canada by providing leverage through cost sharing and facilitation.

CMC R&D Programs

- **SponsorChip** is an opportunity for companies to propose design challenges and to make contributions to the cost of designing, manufacturing, and testing of prototype microchips (chips) for research, education or new product development purposes. Companies can choose a R&D project, such as a chip fabrication technology, and CMC takes care of the rest!
  More: www.CMC.ca/SponsorChip
- **VIE** is a **Virtual Incubator Environment** offering CAD tool access, microelectronics, photonics, and electro-micro-mechanical systems (MEMS) state-of-the-art processes, as well as tools and technical expertise for the creation of hardware.
  More: www.CMC.ca/VIE

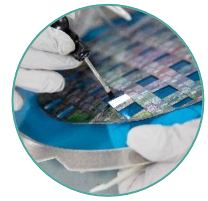
CONTENTS




www.cmc.ca/FAB

MICROELECTRONICS

CMC has access to a variety of technology nodes across various foundries worldwide, including AMS, GLOBALFOUNDRIES, STMicroelectronics, and TSMC. CNDN'S fabrication portfolio supports researchers across application areas spanning computing, communication, and biomedical applications, while staying aligned with industry trends.



Technology: 45-nanometer RF SOI

GF 45 RFSOI

Balanced RF Switch

Applications include: ICT

SPST/SPDT switch benchmarking circuit designed for on-chip probing. The end use is characterization for noise, bandwidth, insertion loss, and distortion as part of a research project investigating the use of on-chip magnetics in 45nmRFSOI for GF.

University of Waterloo
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GF 45 RFSOI

Energy-scavenging, Low-voltage Internet of Things (IoT) Transmitter

Applications include: ICT

Complete transmit PLL and antenna amplifier for a 0.5V energy-scavenging transmitter (2.4GHz ISM band)

University of Waterloo
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GF 45 RFSOI

Single-pole Double-throw mm-wave Switch

Applications include: ICT

A wideband, differential single-pole, double throw switch with high isolation.

University of Waterloo
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GF 45 RFSOI

Synthetic Transmission Line Phase Shifter

Applications include: ICT

A transmission line benchmarking circuit designed for on-chip probing. The end use is characterization for noise, bandwidth and insertion loss as part of a research project investigating the use of on-chip magnetics in 45nmRFSOI for GF.

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GF 45 RFSOI

Transceiver Front-end

Applications include: ICT

Bi-directional switches, low-noise amplifier and phase shifter for a wideband transceiver front-end.

University of Waterloo
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GF 45 RFSOI

Wideband Preamplifier

Applications include: ICT

A preamplifier benchmarking circuit designed for on-chip probing. The end use is characterization for noise, bandwidth and distortion as part of a research project investigating the use of on-chip magnetics in 45nmRFSOI for GF.

University of Waterloo
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Technology: 65-nanometer CMOS

TSMC 65nm CMOS

8-bit TDC with Ring Oscillator Time Amp and Double Edge Triggered SAR TDC.

Applications include: Automotive, Health/Biomedical, ICT

The design is an all digital two step pseudo pipelined TDC with the first step being a Flash TDC and the second step being a double edge triggered SAR TDC. The targeted sampling rate is 500MSps with a resolution of about 1ps. The ADC also uses a Ring Oscillator based time amplifier for high-speed linear time amplification. The Flash TDC in the first step is a generic flash TDC that uses high-speed strong-arm style comparators. The output of the Flash TDC is then used to generate the residue for the second step. The residue is generated using a MUX based residue generator instead of a cap-based residue generator. The residue is then amplified using a ring oscillator-based time amplifier which is highly linear and the amplifier feeds to a SAR TDC. The main drawback of the SAR TDC is that the input signal needs to be regenerated multiple times. However, with a ring oscillator TA, the amplified output can be regenerated as many times as desired.

The SAR TDC used in this design is a more power efficient double edge triggered SAR which does the comparison at both the rising edge and falling edges of the input. This allows the ring oscillator's design constraints to be much less than they would if it was a generic SAR TDC. The Flash TDC is generally fast and so is the Time Amplifier. The main bottleneck for the speed of the design is the SAR TDC. In order to remedy the issue with the speed, a preskewed delay line is used. Preskewing allows for sub unit gate delay which then speeds up the entire critical path. The preskewed delay line gives about the same resolution as a vernier delay line while being much faster. The finer resolution also allows the constraints on the TA to be relaxed. To meet the time constraints, the two steps of the TDC will be pipelined such that both TDCs are always functioning during the conversion. The design is all-digital, area and power efficient and high speed.

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TSMC 65nm CMOS

Analog Delay Sub-Ranging 10GS/s 7-Bit ADC

Applications include: Aerospace, ICT

In this run, we successfully demonstrated a single-channel 10GS/s 4-bit ADC with digital background calibration. Measurements show that at 10GS/s, the prototype ADC achieves an SNDR of 24.9 dB (3.84 ENOB), and 23.4 dB (3.59 ENOB), at low input frequency and Nyquist, respectively. The chip consumes 104 mW from a 1.3 V power supply. This project is to increase the resolution of the ADC to 7-bits by reusing the 4-bit ADC with a novel ADC topology circuit capable of operating at the base ADC rate of 10GS/s. The ADC will also incorporate a 10GS/s track and hold circuit previously verified in a previous design. The ADC will have 8 digital outputs made from the combination of 2 4-bit ADCs. This will enable the novel ADC topology to be verified and to be completely ready to apply the topology to applications such as Software Defined Radio (SDR) and RF direct-sampling receiver systems, in our case, the Square Kilometre Array (SKA).

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TSMC 65nm CMOS

Analog to Digital Converter for Silicon Photonics Control

Applications include: ICT

0.5 MS/sec, 10-bit resolution analog to digital converter for silicon photonics thermal control and stabilization.

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TSMC 65nm CMOS

Burst-Mode Receiver for Twelve-channel Parallel Optical link in Datacenters

Applications include: ICT

The tape-out consists of two parallel receivers for two channels out of the twelve channels typically deployed in datacenters. One receiver will remain in operation all the time while the other will turn ON and OFF with the burst of data. The project targets to demonstrate low turn on time of the second receiver by providing the phase information from the first channel CDR to the second CDR while the second receiver is in sleep mode.

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TSMC 65nm CMOS

Bio-impedance Analyzer Chip

Applications include: Health/Biomedical

In this project, a novel current pump design been proposed and is to be verified experimentally. The main advantage of the proposed design is its high wide-band output impedance. The high output impedance allows the design to be used in an on-chip bio-impedance analyzer, in which the pump is needed to inject the current into the tissue to measure its bio-impedance over a specific frequency range.

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TSMC 65nm CMOS

Fully Integrated Spectrophotometer in The Visible and Near-IR Range

Applications include: Health/Biomedical

This project aims to develop a wireless microsystem for performing diffuse multi-wavelength spectroscopy in real time monitoring of extracellular neurotransmitter concentration or protein interactions based on fluorescent sensing principles. As an example, fluorescence resonance energy transfer (FRET) is a technique, for observing the molecular scale interactions, that depends on the distance between a donor and acceptor. In this dual readout method, the source light excites the donor to emit light in a higher wavelength. The light of the donor excites the acceptor if it gets close to the donor. Therefore, the acceptor also emits light in a higher wavelength. Such assay, which sends one excitation wavelength and receives more than one emitting wavelength, has allowed the visualization of numerous protein interactions in many different cell types and organisms, and has contributed to applications like detection and quantification of DNA methylation.

The direct application of this method on clinical samples offers great promise for its translational use in early cancer diagnosis, prognostic assessment of tumor behavior, as well as monitoring response to therapeutic agents. chip includes photosensor elements and mixed-signal circuits integrated within a single chip. The photo-sensing elements consist of PIN photodiodes to convert the light into electrical current and a bank of metal patterns acting as nanoplasmonic filters. These nanoplasmonic filters aim to pass wavelength peaks at 480nm, 550nm, 605nm, 650nm, and 720nm with a 20nm passband filter as the Q factor. Based on our simulations, a rejection ratio of more than 20 dB between peak amplitude and the stop band is achieved which is enough for fluorescent-based applications. After the photo-sensing elements, the mixed-signal circuits will amplify and digitize the photocurrent using novel high-performance interface circuits.

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TSMC 65nm CMOS

Implementation of Memristor Emulator

Applications include: ICT (Artificial Intelligence, Deep Neural Networks)

This project aims to design and implement a memristor emulator array under CMOS technology intended for analog implementation of neural network.

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TSMC 65nm CMOS

Physical Unclonable Functions (PUFs) (Test chip)

Applications include: ICT (The circuits included in this chip contribute to enable longer battery life of mobile computing and the Internet of Things (IoT) devices.)

Strong PUFs, display driver circuits, sense amplifiers, and register design exploration.

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TSMC 65nm CMOS

Radio Frequency (RF) Energy Harvester

Applications include: Health/Biomedical

In this project, an efficient radio frequency (RF) energy harvester will be designed and fabricated. RF energy harvester can be used to charge battery based wireless IoT sensors. An efficient single-stage rectifier will be used to charge a 1V to 3V battery by PN junction diodes. Charging the battery of wireless sensors using RF energy harvesting can increase their lifetime and so make using a large scale of these sensors possible.

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Technology: 130-nanometer CMOS

TSMC 0.13µm CMOS

0.1-12GHz Frequency Synthesizer for Avionic SDR Applications

Applications include: Aerospace

The proposed design is a frequency synthesizer architecture for avionic software defined radio (SDR) applications. The synthesizer provides a carrier frequency range from 100 MHz to 12 GHz covering the avionic communication applications and existing wireless standards. The switched-capacitor (SC) voltage controlled oscillator (VCO) that the output frequencies are derived from is implemented covers a wide tuning range from 8 GHz to 12 GHz. The VCO ensures high phase noise performance with low power consumption. The transient phase locked loop (PLL) response shows a reduced settling time whereas the PLL loop bandwidth is of about 800 kHz. Furthermore, the synthesizer exhibits a phase noise, simulated at 12 GHz, of -104 dBc/Hz at a 1 MHz frequency offset with an overall power consumption of 30 mW.

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TSMC 0.13µm CMOS

A Novel MPPT Technique for Piezoelectric Vibration Energy Harvesters

Applications include: Environment, ICT, Natural Resource/Energy

Energy harvesting is a promising solution to develop self-powered wireless sensor nodes and Internet of Things (IoT) devices. In addition to environmental concerns with batteries, replacing the batteries in wireless devices may not be feasible in remote and inaccessible situations such as structural health monitoring and distributed smart monitoring devices in IoT applications. In this project we will design and fabricate power processing circuits including converters and low power maximum power point tracking (MPPT) controllers for piezoelectric vibration energy harvesters.

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TSMC 0.13µm CMOS

An Integrated Differential Power Processing Converter for Improving the Power Yield of Series Connected PV Cells

Applications include: Natural Resource/Energy

One of the most important challenges of photovoltaic systems is reduction of power yield due to the mismatch of series connected PV cells. The mismatch may exist due to the various causes, such as partial shading, manufacturing variability, thermal gradients, nonuniform aging, etc. In this project we will design and fabricate an on-chip buck-boost converter to improve the power yield of series connected PV cells through the differential power processing method. The proposed converter can improve the efficiency of maximum power point tracking (MPPT) by compensating the impact of submodule-level mismatch on captured power. Compared to other submodule MPPT equipment like DC optimizers, the approach of using integrated converters makes it possible to improve the MPPT efficiency and reduce the total cost of system due to the mass production advantages.

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TSMC 0.13µm CMOS

CMOS Interface for Closed-loop Recording and Optogenetic

Applications include: Health/Biomedical

In this project funded by NSERC, CIHR and the Weston Brain Foundation, we will develop a complete high-resolution multimodal CMOS brain implant on a chip. This system-on-chip (SOC) will provide both high-resolution multimodal electrophysiological recording and optogenetic photo-stimulation capability within a single chip for studying brain microcircuits of transgenic mice by enabling synchronized optogenetic stimulation and neural activity recording through a closed-loop system. The present design implements an innovative multichannel analog-to-digital interface prototype for this SOC. The prototype includes five main building blocks:

1) a 4-channel low-power and low-dropout LED driver to illuminate light-sensitized neurons through a brain-inserted multifunctional fiber-coupled micro-LED array developed by our partners at Université Laval,
2) a 10-channel low-noise and power efficient analog-front-end to collect the evoked bioelectrical activity in different selectable frequency band, each of which will be coupled to high resolutions,
3) 10 in-channel low-power third-order MASH Sigma-Delta modulators for analog-to-digital conversions,
4) a CIC4 decimation filter, and
5) a digital controller module to control all building blocks.

Each high-resolution digitally converted sample collected from the 10 recording channel system will be handled by the controller unit, and available to external units through the SPI bus. Similarly, photo-stimulation sequence will be reprogrammable in real-time through the controller module via the SPI bus as well. This proposed design represents the next step towards the realization of a complex mixed-signal brain implant on a chip including a microcontroller and all the necessary analog and digital modules to perform closed-loop optogenetics within a single chip. This SOC will be used to study the brain of freely behaving mice through an application paradigm related to the discovery of therapeutics against neurodegenerative diseases of aging.

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TSMC 0.13µm CMOS

Machine Learning (ML) DNA Sequencing Accelerator

Applications include: Health/Biomedical, ICT

The process of DNA measurement is becoming portable, with hand-held units currently available on the market. However, the data emerging from such devices requires intense processing by machine learning (ML) detectors in order to extract reasonable approximations of the measured molecule's structure. As a result, expensive computing resources must presently be reserved for such inferences thus compromising the portability of the entire scheme. This design addresses this by targeting a bioinformatics ML hardware acceleration ASIC tuned for a specific DNA sequencing problem and intended to achieve a 10X speed improvement with a 1000X power reduction over traditional desktop computing alternatives.

York University
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TSMC 0.13µm CMOS

Multi-Channel Implantable Neuronal Signal Processor

Applications include: Health/Biomedical

A multi-channel neuronal signal processor is designed for brain implants and neural prosthetic applications. It includes VLSI computational modules for data compression, data framing, and spike sorting.

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TSMC 0.13µm CMOS

Radio Frequency (RF) Energy Harvester

Applications include: Health/Biomedical

In this chip, we will try to increase the efficiency of the RF energy harvesters using Schottky diode along with other techniques that power loss of the transistors.

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TSMC 0.13µm CMOS

True Random Number Generator

Applications include: ICT (low power secure communication and cryptography)

Random Number Generators (RNGs) are required in many applications such as wireless networking, gaming, military communications, online payment, etc.… RNGs are used to generate keys, initialize vectors and other random numbers used in many security standards and applications. As an example, the Internet of Things (IoT) is a fast-growing market where data can easily be intercepted and devices can be hacked, especially if weak RNGs are selected. Our main objective is to design robust low-cost low RNGs for secure wireless communication applications. We are investigating several aspects in this area:

- Exploring different ways to generate RNG, i.e., chaos, non-linear maps, laser, quantum, ambient noise
- Analyzing different performance metrics of the designed generators
- Exploring the automatic and manual reseeding techniques
- Optimizing the designed random number generation to secure wireless communications
- Integrating designed RNGs on digital platform

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TSMC 0.13µm CMOS

Ultra-low Power All-digital Noise-shaping Time-to-Digital Converter Using a Differential Bi-directional Gated Delay Line Time Integrator

Applications include: ICT

Time-mode signal processing (TMSP) where analog information is represented by the time difference between the transitions of digital signals offers a viable and technology-friendly means to combat challenges encountered in processing analog signals. TDCs are the most important block of TMSP systems and low-power high-resolution TDCs are essential for a broad range of applications from car navigation to implanted devices. Delta-sigma operations are effective in suppressing in-band noise so as to achieve a high resolution. Realizing delta-sigma TDCs via TMSP requires an all-digital time integrator (ADTI). ADTIs can be realized using switched delay units and a pair of ring oscillators at the expense of power consumption. ADTIs can also be realized using a pair of time adder and a time register with the drawback of poor linearity and design difficulty arising from the permission of only positive time variables. The bi-directional gated delay line (BDGDL) ADTI developed by the applicant features low power consumption, fast integration, and good linearity. The design to be fabricated implements an ultra-low power all-digital 1st-order 1-bit noise-shaping TDC with a bi-directional gated delay line time integrator.

Ryerson University
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TSMC 0.18µm CMOS

0.18um CMOS Temperature Study (IQ9-2019)

Applications include: ICT (Research towards a modular platform for metrology of spin qubits hosted in silicon.)

Despite recent success in the field of quantum information, a clear path to a scalable quantum computing architecture has yet to be found. One promising approach is to leverage the expertise of the semiconductor manufacturing industry to fabricate quantum dot devices to form spin qubits. To achieve this goal, verification of sample properties at cryogenic temperatures must be performed. This project seeks take advantage of Institut Quantique (Université de Sherbrooke) expertise to design, test, and evaluate a platform which will both rapidly yield insight into device properties and present a path to efficient qubit readout. At this stage, the project will ascertain the viability and component properties of different design technologies available through CMC Microsystems (in this case, 0.18um CMOS from TSMC) down to temperatures below 100 millikelvin. Functionality of commercial semiconductor technologies at these ultra-low temperatures is not well understood, however it is crucial if classical hardware is to be co-integrated with spin qubit devices for rapid sample metrology.

Université de Sherbrooke
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A CMOS Lock-in-Amplifier with Semi-Digital Automatic Phase Tuning

Applications include: Health/Biomedical

In this design, we will develop a CMOS integrated photosensor for on-chip fiber photometry applications. Such a system will be key to collect Ca+ ionic transfers resulting from brain activity within freely moving photometry scheme. This SOC will provide high-sensitivity fluorescence optical recording along with optogenetic photo-stimulation for enabling optogenetically synchronized fiber photometry. The system is composed of an array of phototransistor as for highly sensitive photodetector in order to detect very small fluorescence light power under low illumination. An integrated analog front-end circuit and a novel automatic phase tuning lock-in amplifier (LIA) with a high dynamic reserve will extract the very low-input-power fluorescence calcium signals collected by the photodetector through a multimode fiber which will be inserted into the brain of a freely moving animal to study the intact brain. LIAs can retrieve signals of a known carrier from an extremely noisy environment. In an LIA circuit, the input signal is converted to a voltage using a photodetector and a trans-impedance amplifier (TIA). This voltage is then filtered using a band-pass filter (BPF) to increase further the signal-to-noise ratio (SNR). The resulting signal is down-converted to a lower frequency signal using a mixer and a local oscillator (LO) at the same frequency of modulated stimulation signal. The output of the mixer, which reflects the harmonic content of the LO, is filtered out by a low-pass filter (LPF) to extract the amplitude of the desired signal. LIAs are becoming increasingly adopted in various biomedical applications, such as fiber photometry and optical material spectroscopy. LIAs can retrieve a signal from negative input signal-to-noise ratio (SNR) where the desired input signal is buried in a considerable noise power many times higher than the desired input signal power. The designed LIA comprises analog and digital circuitry associated with the FSM in a new fashion.

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TSMC 0.18µm CMOS

A Wireless 32-channel Simultaneous Neural Recording and Stimulation System on a Chip (SoC)

Applications include: Health/Biomedical

This project is aimed to design, simulate and characterize a brain implant microsystem capable of simultaneous electrophysiological recording and electrical stimulation. The SoC is to be operated wirelessly and consists of 32 neural interfacing channels featuring ultra-low-power, low noise, high resolution and very high dynamic range recording front-end circuit. Having these specifications, this SoC can be used as a powerful research tool in studying the effect of electrical stimulation in treatment of various neurological disorders such as Alzheimer's and Parkinson's disease, seizure, and epilepsy. The SoC could be used along with a digital processor that receives the recorded neural information and triggers electrical stimulation upon detection of a specific event. The recorded neural signals could also be transmitted wirelessly to a computer-based station. As the system can record brain signals even during stimulation phase, it allows for continuous adjustment of stimulation pulse parameters towards achieving the highest efficacy in the targeted neuro-modulation task. To further compact the system, the downstream inductive link designed for wireless power transfer is reused for upstream wireless data communication through back-propagation, which will make the system needless of a bulky battery. The system's functionality will be verified using in-vitro and in-vivo experiments in collaboration with neurologists at York University.

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TSMC 0.18µm CMOS

Design of Neural Stimulation System for Closed-Loop Control of Blood Pressure

Applications include: Health/Biomedical

The main goal of this project is design and implementation of neural recording and stimulation system for closed-loop control of blood pressure (BP) for patients with hypertension. The proposed system-on-a-chip (SoC) will be used for vagal nerve recording and selective stimulation of aortic depressor nerve (ADN), which transmits blood pressure levels through vagal nerve fibers to the brainstem and triggers the baroreflex, balancing the BP. The neural recording is performed on the vagal nerve, using a tripolar front-end topology connected to a multi-channel cuff electrode array. The tripolar recording will maximize the rejection of non-ADN common-mode signals, yielding a nearly optimal localization of the ADN. The recorded signals are digitized on chip and communicated to an off-chip digital processor that performs the localization and triggers a subset of on-chip stimulation channels to provide a current-mode pulse train to artificially control the undesired BP change. After localizing the baro fibers, the balanced current mode stimulation will be applied through the specific electrodes to artificially trigger the baroreflex with minimum side effects. This project involves the design, simulation, and experimental characterization of an 8-channel tripolar neural recording and 24-channel neural stimulation. The SoC includes SAR ADCs for every recording channel and charge-balancing units for safe stimulation. The electrode-tissue interface impedance measurement together with an adaptive power supply control unit will also be integrated on chip to monitor the impedance alteration during chronic experiments and to adjust the supply voltage accordingly.

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TSMC 0.18µm CMOS

Designing a Stable and Reconfigurable DC-DC Converter

Applications include: Aerospace

The goal of the project is to design a step-down DC to DC converter, that is suitable for avionics application. The concept of the conversion works as follows: The output voltage, and reference voltage are each fed back to a voltage-controlled oscillator, which converts the voltage to frequency. The frequencies are then compared by the means of phase frequency detector, which will generate the up and down signals based on which frequency is higher. Then the output of phase frequency detector is fed to a charge pump and a low pass filter, which will generate an analog voltage which increase when we have an up signal and decrease in the case of a down signal. The analog voltage is then converted to pulse width modulated signal which is send to deadtime control and gate driver to feed the DC converter. The system will have the DC signal, bias voltage, reference voltage and clock signal as input and will generate a step-down DC voltage as output.

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TSMC 0.18µm CMOS

High-speed and High-sensitivity Imaging Sensor for Positron Emission Tomography Applications

Applications include: Health/Biomedical, ICT

According to the latest data from Statistics Canada, Cancer is our leading cause of death. In order to diagnose cancers at the early stage, medical imaging techniques including X-ray computed tomography (CT), magnetic resonance imaging (MRI), ultrasound imaging (UI), optical coherent tomography (OCT), and positron emission tomography (PET) have been employed. Among these imaging technologies, PET has become one of the most powerful tools to acquire functional images due to its high sensitivity to differences in the metabolic and biological activities at the molecular level. One of the key components of a PET imaging system is the photosensor in the PET detector. In this project, we plan to use the standard CMOS technology (TSMC 180 nm) to design and investigate one of the most sensitive silicon detectors – the digital Silicon Photomultiplier (dSiPM), which incorporates single photon avalanche diodes (SPADs) for low-level light detection and high-speed digital circuitry for accurate timing information. In this design, we focus on investigating 2 aspects of SPADs: photon detection efficiency (PDE) and the guard ring effect. Through the design, optimization, fabrication and measurement of the SPAD, we hope to achieve the following primary objectives.

- Optimize the design of SPADs in the standard CMOS technology for the PET applications.
- Study and design the front-end circuits like quench and reset circuits for SPADs.
- Investigate techniques and methods for the integration of the SPADs with signal conditioning and processing circuits.

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TSMC 0.18µm CMOS

Implantable Biosensor for the Continuous Detection of Anti-epileptic Drugs in Blood

Applications include: Health/Biomedical

A miniature chip for electrochemical detection and quantification of anti-epileptic drugs.

Polytechnique Montréal
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TSMC 0.18µm CMOS

Low-power FSK Transceiver Design for Biomedical Wearable Sensors

Applications include: Health/Biomedical

This design is aiming for a low-power transceiver for the application of biomedical wearable sensors. The transceiver takes the usage of FSK modulation/demodulation scheme to transmit more power from primary coil to secondary and improve the noise immunity for data communication.

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TSMC 0.18µm CMOS

Low-Power Multi-Channel Instrumentation Amplifier

Applications include: Health/Biomedical, ICT

This design is a multi-channel instrumentation amplifier. The focus of the work is on minimizing the power consumption of a multi-channel amplifier that is intended for biomedical applications (e.g., monitoring ECG, EEG, ...) without compromising the amplifier performance.

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TSMC 0.18µm CMOS

Photon-counting Hybrid Multispectral X-ray Imager

Applications include: Health/Biomedical

We aim to design a high-spatial-resolution single-photon-counting multispectral X-ray imager by combining a custom CMOS active-pixel-sensor (APS) readout integrated circuit (ROIC) with an amorphous-selenium (a-Se) photoconductor. Our imager will benefit from a new multispectral pixel design that will take advantage of the "small-pixel effect" (SPE) to achieve high photon count rates for such specialized bioimaging applications as dedicated-breast computed tomography (DBCT). Our design will also feature pixel dimensions below 75x75-um^2, which will enable higher spatial resolution compared to existing imagers used in mammography CT systems. Our proposed design is an extension of a previous design, which featured single X-ray-photon-energy discrimination only and did not directly take advantage of SPE. Our new design will feature two-energy-level discrimination (containing 20-keV and 40-keV X-ray-energy thresholds), which is suitable for mammography CT. We will also implement a novel "four-in-one" single-photon-counting pixel design that will provide the necessary conditions for SPE to occur.

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TSMC 0.18µm CMOS

Ultra-low Power Electrocardiogram (ECG) Processor

Applications include: Health/Biomedical

The project is to design an ultra-low power wireless smart ECG (electrocardiogram) sensor ASIC. The proposed ASIC contains an analog front-end (AFE), a power efficient level-crossing ADC (LC-ADC), a frequency tunable transceiver, and an artificial neural network (ANN) based classifier. The proposed ultra-low power AFE includes an innovative circuit topology to extend the dynamic range beyond supply voltage. The LC-ADC converts input signal into a continuous-in-time and discrete-in-amplitude (CTDA) data stream containing sparse sampling pulses, which leads to significant power saving. The proposed CTDA-based ANN classifier requires only simple network structure and reduced number of arithmetic operations. The effective wireless communication relies on the high-performance transceiver. Low power and small area are especially important for the battery restricted wireless wearable sensors. The project proposed a novel FSK modulator/demodulator by using programmable LLC resonant tank and N-path network to save power and area.

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TSMC 0.18µm CMOS

Voltage Controlled Oscillator (VCO)

Applications include: ICT

Voltage controlled oscillator test chip.

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AMS 0.35µm CMOS

A Compact Sensor with Monolithic 64 x 64 SPAD Image Sensor for Functional Near Infrared Spectroscopy

Applications include: Health/Biomedical

A novel integrated CMOS electronic and optical design was developed, incorporating gated detection and pulsed-laser illumination within a single chip, a feat that remained out of reach until now. Laser source and detector were combined in a single package demonstrating integration feasibility. Miniaturization is possible as the probes use detector and laser source places side-by-side, leading to a very small source-detector distance (SDD), which will allow interrogating deeper tissue volumes with late time gates. To achieve a higher photon harvesting efficiency, we also developed a time-gated 64 x 64 SPAD array-based system. The detector gating technique helps to reject the large signal from the surface of the tissue due to short time reflection, thus improving the sensitivity and ability to probe deeper inside the tissues. The proposed device also integrates a pair of two wavelength laser sources sensitive to oxygenated hemoglobin (HbO) and deoxygenated or reduced hemoglobin (HbR). The compact size, flexibility, and customization possibilities can be considered as the first step towards portable multi-channel and multi-wavelength TD-NIRS diagnostic tools for wearable healthcare applications.

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AMS 0.35µm CMOS

A New Design Methodology of Class-DE Amplifier for Driving Ultrasound Transducer Arrays

Applications include: Health/Biomedical

The MRI-compatible integrated Class-DE amplifiers to drive a ultrasound transducer array for high-intensity focused ultrasound (HIFU) therapy is designed based on a new developed design methodology, which optimizes the driving transistors to accommodate a range of impedance. Arbitrary choosing a wider driving transistor not only is less area efficient but also lowers the power efficiency as the power loss consists of conduction loss and gate loss. In this design, the size-optimized transistors for the full-bridge circuit topology account for both ON resistance and the gate capacitance to minimize the power loss while providing 1 W output power to the piezoelectric transducer array with 50 V power supply.

Lakehead University
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AMS 0.35µm CMOS (Base/OPTO)

Active Reset, Active Column Sensing

Applications include: Aerospace, Automotive, Defence (Safety, Security), Entertainment, Health/Biomedical, ICT

The Integrated Intelligent Sensing Laboratory at the University of Calgary is actively pursuing the development of low noise high sensitivity CMOS image sensors. For this design, we have included two separate sections to test and demonstrate the following new designs. The first and primary section is a design intended to combine and demonstrate the advantages of our previous work on Active Reset (AR) and Active Column Sensing (ACS). These techniques allow for two primary advantages, precise reset with reduced thermal noise, and the ability to sense the photodiode level without creating a threshold voltage drop. These can then be combined with a dynamic range extension algorithm while keeping the pixel structure compact and straightforward. With previous chips, we have demonstrated and proved the function of both AR and ACS function and now aim to combine them in an efficient, scalable manner. We have in previous work been able to obtain output swings of 2V and a sensitivity gain of 52dB both significantly better than state of the art. For our current design, we have incorporated both improvements on our AR and ACS functionalities, incorporating a single conditional reset along with active column sensing in order to achieve improvements in sensitivity and swing while keeping a highly packed pixel architecture. The second section of the chip is a small pixel array containing a new architecture of pixel readout and pixel layout for possible future readout optimization. It is based on neural networks and weighing different values to create a weighted value for further readout and processing.

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AMS 0.35µm CMOS

CMOS Neutrophile Detection

Applications include: Health/Biomedical (Periodontal)

This chip is designed to detect the living neutrophil cells using CMOS capacitive sensors. Our group has recently developed a CMOS chip using the same technology for the chemical sensing purposes. As the continuation of that work, we design and implement a new chip for highly precision detection of neutrophil cells for point-of-care diagnostic purposes.

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AMS 0.35µm CMOS

Fully Integrated Inductive Coupled Digital Isolator for Avionic Applications

Applications include: Aerospace

This work proposes the pulse polarity modulation scheme to design the inductive coupled digital isolator. The isolator consists of 4 unidirectional channels using two dies. For the first stage, starting by a specified carrier frequency (20MHz), the digital-to-analog modulation scheme will be chosen to design the transmitter's building blocks (i.e. positive/negative edge detection, cascaded inverters, current limiting inverters and driver transistors). Then, inductive coupling is used to transfer the modulated signal to the bondpads, which then transferred from the low voltage side to the high voltage side through bondwires. The next stage is to design the on-chip transformer-based isolator by designing a practical model for the proposed layout. Then, at the receiver side, the diode-based pulse detection scheme will be used to detect the high frequency signal component and eliminate the lower one. In addition, a differential amplifier and a hysteresis comparator are used for reconstructing the microcontroller's input digital signal and delivering it to the Insulated Gate Bipolar Transistor (IGBT) gate driver at the high voltage regime.

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AMS 0.35µm CMOS

High-Side and Low-Side Versatile Integrated Power Output Interface

Applications include: Aerospace

This project aims to build a high-side power output (PO) interface for driving current to different actuators in avionic applications. This interface is mainly a synchronous DC-DC converter -for stabilizing the variable input voltage supply coming from an airplane- composed of off-the-shelf passive and power components, in addition to an integrated dual-channel gate driver that is to be implemented in this fabrication run. The designed gate driver has a switching frequency in the MHz range, receives a control signal from an FPGA, regenerates the signal using Schmitt trigger, divides the signal into non-overlapping high-side and low-side signals by applying fixed dead-time. The high-side and low-side signals are driven to the half-bridge composing the DC-DC converter through buffer chains and level-shifter. Two auxiliary under-voltage-lock-out (UVLO) blocks are used in the high-side and low-side driver paths for ensuring correct operation and safety despite variations in power supply voltage. The primary objective is to validate new circuit techniques in the design of gate driver building blocks and evaluate the AMS HV-CMOS technology for integrating the rest of the interface.

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AMS 0.35µm CMOS

High Voltage Class D Power Amplifier for Versatile Aerospace Systems-on-Chip Integration

Applications include: Aerospace

The goal of this project is to implement a class D power amplifier circuit that provides a configurable output waveform. The proposed design receives a pulse width modulated signal from FPGA and produce the required output power level. This generated output is used to operate aircraft's actuators such as resolvers, force and pressure sensors, and electro-hydraulic servo valves (EHSV). The presented design consists of two phase non-overlapping clock that generates the deadtime required to prevent short circuit current in the output stage, two high voltage level up shifter to convert the low- voltage level to the required voltage levels, two buffer chains, two level down shifters for the feedback circuit, and two power MOSFETs in the output stage.

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TSMC 0.35µm CMOS

Improvements to Scalable SPM Tip Sharpening

Applications include: ICT (microscopy, microanalysis, metrology)

Designs on this chip include devices with the potential for improved lateral resolution of single-chip CMOS-MEMS scanning probes microscopes (SPMs), manufactured using a novel, high-throughput process. These designs represent improvements over previous designs for this purpose. The lateral resolution of SPMs is dictated by the sharpness (i.e., radius of curvature) as well as the shape (i.e., cone angle) of the probe tip. A new, scalable manufacturing process is being developed to control both the sharpness and shape of CMOS-MEMS SPMs probes for the first time. The designs on this chip represent potential improvements that would allow for enhanced quality and consistency using this new scalable process. Additional designs on this chip include new research devices that offer improved high-frequency scanning and devices that can be used for feasibility studies of integrating novel tip probes on CMOS-MEMS SPMs.

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AMS 0.35µm CMOS

Transducer Electronic Interface

Applications include: Health/Biomedical

Future personalized and preventative medical care is quite dependent on the development of wearable medical devices, and the latter relies on the miniaturization of the parts of electronic systems. Low-intensity pulsed ultrasound (LIPUS), as a non-invasive physical therapeutic application, has been proven to have functions such as the accelerated healing of fresh fractures and the treatment of established nonunions. All current available LIPUS products are built with several separating modules assembled on single printed circuits boards (PCBs). The advances of complementary metal-oxide-semiconductor technology makes it possible to further miniaturize the LIPUS products by integrating the whole transducer electronic interface into single chips. This approach can not only reduce the average manufacturing costs, but also provide low power consumption, low noise and light weight etc. A highly integrated LIPUS electronic interface is designed for portable application. The whole system consists of an oscillator, a digital control module, an ultrasound transducer driver and an DC-DC converter. The internal clock is generated by the oscillator, and then the digital control module modifies it into various frequencies and phases for the ultrasound transducer driver and the DC-DC converter. The DC-DC converter, also known as the charge pump, is used to transform the battery-powered voltage into the relatively high voltage required by the system. With such high voltage supply, the ultrasound transducer driver is able to produce the pulses with enough amplitude and appropriate power.

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AMS 0.35µm CMOS

Versatile Half-Bridge Based Transmitter for BD429 Data Bus Standard as sensor interface

Applications include: Aerospace

This design aims to implement a versatile half bridge for transmitting data in BD429 data bus standard as a sensor interface. The proposed design includes gate driver, level shifter, two power MOSFETs, and dead-time circuit. The rate and supply voltage are 1Mbps and 12V, respectively. The new proposed dead-time topology is included to control the power MOSFETs and eliminate the shoot-through effect, in which the two power devices are on. This will decrease the power consumption and enhance the system efficiency. Since the main concept of dead-time part is based on a reconfigurable delay circuit, this transmitter has the capability to be employed for different required delay circuit.

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AMS 0.35µm CMOS

Wide Dynamic Range Front-End Amplifier with Anti-Aliasing Filter

Applications include: Aerospace

This project aims to implement a front-end amplifier capable of operation in very high voltage range, up to 1kV, intended to avionics applications. This amplifier will be utilized for current sensing using shunt resistor as well as differential voltage sensing of 10V (provided from aircraft sensor) in presence of very high common mode signal. An amplifier at High Voltage (HV) side will drive a coil located on top of integrated hall plate. The hall plate will convert the magnetic field to a voltage signal. Current spinning technique together with one-layer spiral coil derived from Low Voltage (LV) side will eliminate DC offset of the plate. In addition, a gain programming technique as well as Anti-Aliasing Filter (AAF) have been employed to amplify and filter the signal based upon the specs of Analog to Digital Converter (ADC)following the front-end.

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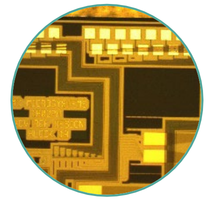
PHOTONICS & OPTOELECTRONICS

CNDN delivers a program that includes fabrication access to silicon photonics platforms for chip-level monolithic integration, methodologies for scalable integrated photonics design, and graduate-level training in the design, fabrication and testing of photonic integrated circuits. The addition of technologies from GLOBALFOUNDRIES to the CNDN portfolio allows for enhanced levels of electronic-photonic integration.



Technology: III-V Epitaxy

FBH

Asymmetric Laser Design for High Purity and Flux Quantum Light Source for Integrated Quantum Technologies
Applications include: Defence (Safety, Security), ICT

Optical quantum information processing, such as quantum computing and quantum key distribution, relies heavily on the generation, manipulation, and detection of non-classical radiation of light, such as entangled photon-pairs. To date, the generation of photon-pairs has been based on spontaneous parametric down-conversion (SPDC) using complex hybrid optical systems incorporating nonlinear crystals such as BBO and KTP which require components such as interferometers to achieve polarization entanglement. Such systems are complex, bulky, sensitive to vibrations and require frequent maintenance. Practical quantum information processing in future will require compact, robust and scalable sources of entangled photon pairs which have low power consumption and operate at room temperature. As such, GaAs/AlGaAs laser diodes are seen as promising components for polarization-entangled photon pairs generation due to the large non-linearity of the material system, the ready availability of mature growth and fabrication technologies, small form factor and proven reliability. Several techniques producing photon pairs via SPDC using AlGaAs waveguides have been developed; and to date, the Bragg reflection waveguide (BRW), originally developed by the Helmy group, is the only platform which has demonstrated electrically pumped generation of photon pairs at room temperature. However, the number of entangled photon-pairs generated has been below the level required for a practical or commercially viable system. The goal of this project is to alleviate the BRL platform from the previously encountered challenges that impact the pump laser performance. By addressing the challenges for achieving a high-performance pump laser with novel asymmetric design approaches, we aim to demonstrate a QLS with higher photon flux and higher state purity of entanglement, paving the way to practical quantum information processing systems and enable the development of commercial quantum information processing.

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FBH

Towards a High-Power Quantum Light Source for Quantum Information Processing

Applications include: Defence (Safety, Security), ICT

Quantum Light Sources (QLS) are enabling components for the development and practical implementation of quantum communications and information processing systems. The feasibility of such quantum information processing systems has been demonstrated by several groups [1]. However, the quantum light sources employed in these laboratory-scale demonstrators have been of a hybrid nature, comprising a number of finely tuned and sensitive components which require alignment to a high degree of tolerance and a stable environment. The Bragg Reflection Waveguide Laser (BRL), developed by the Helmy group, which integrates the key components of these hybrid QLS systems into a single low-power consumption device, is regarded as highly promising structure for the realisation of practical QLS. Further optimisation of the BRL structure is required to increase performance of this device and realise the full potential.

The goal of this project is to build on the modelling, simulation and experimental work carried out by the Helmy group to date to optimise the BRL structure and increase the performance to a level such that the devices may be employed in practical systems. Key to this is minimising the optical and electrical losses within the integrated structure to increase the power of the integrated pump laser and so maximise the non-linear conversion efficiency to greatly increase the quantum light output of the device and realise a truly high power QLS. In addition, it is necessary to reduce the optical loss to the internally generated quantum light component which due to the quantum nature of these photons is more sensitive to loss than those of the pump. As there are a number of key and inter-related, structural parameters which impact these losses we propose to take a matrix approach to this optimisation process and through careful variation of the key parameters.

1. Bennett, Charles H., and David P. DiVincenzo, Nature 404, no. 6775, (2000): 247.

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AMF SOI

Bragg-grating-based Silicon Photonic Modulator for Advanced Modulation Formats

Applications include: ICT

This project aims to design Bragg-grating-based silicon photonic (SiP) modulators for high-speed application. Advanced modulators, such as a dual polarization segmented-IQ (S-IQ) modulator, assisted by integrated Bragg grating resonators will be designed to achieve an ultra-compact footprint modulator that offers a stable operation, a high bandwidth, and a low power consumption. We will include several design variations with a different number of resonators and number of periods to examine the trade-off between modulation efficiency and stability. The dual polarization S-IQ modulators will have eight segments, which will allow generating the dual polarization 16 QAM modulation format without using a digital-to-analog converter.

In addition, we will investigate a design of MZM based on the waveguide crossing in order to compensate the efficiency difference between the two arms of MZM (shown in Fig. 5 in attachment). This issue is due to the asymmetry of the MZI structure, which should be observed for any MZM design due to fabrication imperfection including waveguide width difference and the misalignment because of the implantation layers. We will also explore another Bragg grating based SiP modulator for high-speed intensity modulation. We previously demonstrated that the use of an asymmetric Bragg grating modulator in a multimode waveguide allows operation in reflection without loss but achieving phase modulation in the larger waveguide is challenging. In this design (shown in Fig. 6 in attachment), we will introduce PNP junction to enhance phase modulation and examine a trade-off between efficiency and speed. Also, since the higher order modes are used, the phase shift response with respect to the applied voltage becomes more linear.

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AMF SOI

Deep Learning and High-Performance Computing with Silicon Photonics

Applications include: ICT

In artificial intelligent (AI) systems, machine learning is known as the capability of such systems to extract patterns from data, and then acquire their own knowledge. Intelligent machines are typically used to solve highly complex tasks which pose problems to other classical computational approaches. In this work, we use artificial neural networks (ANNs) as brain-inspired machines that allow us to tackle those complex problems. The main ANNs that can be found in the scientific literature are recurrent neural networks (RNNs), feedforward neural networks (FFNNs) that include multi-layer FFNNs for deep learning. These network models are the core architectures on which most AI applications are based. For instance, RNNs have been successfully utilized for speech recognition, channel equalization and prediction/forecasting. Also, deep learning employs convolutional neural networks (CNNs) as powerful and ubiquitous tools for extracting features from large datasets for applications such as computer vision and natural language processing. Therefore, the possibility of working with both architectures is fundamental for the development of AI. For deep learning applications, convolutions are computationally expensive operations in digital electronics and take more than 80% of the runtime. On the other hand, RNNs take as much runtime for processing long strings of data that allows them to achieve good performances. Neuromorphic photonics processors the potential to be much faster than state-of-the-art electronic processors while consuming less energy. The primary objective of this chip tapeout will be to demonstrate a modular-based structure that will allow us to implement FFNNs such as CNNs as well as RNNs with silicon photonics. In this way, we will introduce a multi-purpose processor model for general ANN-based machine learning applications.

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AMF SOI

Differential SPP Modulator

Applications include: ICT

In support of the exponential growth of bandwidth demand, we recently reported several silicon photonic (SiP) traveling wave Mach-Zehnder modulators (TWMZMs) enabling up to 200 Gb/s transmission using pulse amplitude modulation (PAM). In our systems work, we demonstrated several record breaking single and dual polarization PAM experiments using direct detection receivers. The objective of the proposed designs is to develop system level designs targeting coherent applications, 400G and 800G optical interconnects, high speed modulators, and isolators. Also, other devices will be studied as a part of the process design kit development (PDK). The circuits being proposed have not been built in a SiP platform and if successful would be extremely valuable to the SiP community. The probability of success is high because we employ known good (i) SiP device designs, and (ii) digital signal processing algorithms.

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AMF SOI

Ge-on-Si Photodetector with Optimized Efficiency and Bandwidth

Applications include: ICT (particularly short-link applications)

For Ge-on-Si photodetectors, there exists a trade-off between their efficiency and bandwidth. In our design, while maintaining small Ge size (2um*5um) to have large bandwidth we are trying to enhance the absorption in Ge layer by two approaches, integration of 2D photonic crystals in Si slab layer to confine light in Ge area and optimization of Ge lateral shape.

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AMF SOI

High-speed Coherent Transmitters

Applications include: ICT

The Optical Internetworking Forum recently launched an effort to standardize low-cost 400-Gb/s pluggable coherent modules for up to 120-km, requiring electronics-photonics integration for an ultra-small form factor and low power consumption. Thus, there is a strong interest in developing coherent solutions in silicon photonics for 400+ Gb/s. Silicon photonics provides an excellent platform for integrated coherent optical transceivers, offering compact, versatile passive waveguide components and the capacity of on-chip polarization multiplexing. In this project, we design and test novel silicon photonics modulators for high-capacity coherent optical transmissions.

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AMF SOI

Integrated 5G Optical Network Unit (ONU) Subsystems

Applications include: ICT

Analog transport rather than digital is favoured to bypass the constraints of current standards. Silicon photonics solution is a promising approach to commercially combine analog and digital PON signals for 5G femto-cells at ONUs at customer premises and OLTs at the central office. Based on cascaded ring resonators, we will develop ONU subsystems for enabling RoF signal transmission along the current digital PON traffic. Microring modulators will be also included in the subsystem to provide the uplink stream generation functionality. Other features include the polarization diversity and single feeder will also be achieved in the designs.

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AMF SOI

Integrated Frequency Microcomb

Applications include: Environment

Design of integrated frequency microcomb sensor.

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AMF SOI

Integrated Silicon Photonic Transceiver for Quantum Key Distribution

Applications include: ICT

We propose to design, implement, and characterize a fully integrated silicon photonic Quantum Key Distribution (QKD) transceiver for secure communication applications. This is important because it is the SiP platform that offers the promise of low-cost mass production and the co-integration of control electronics that will be required to optimize real system performance. The focus of this project is to first design and characterize the individual components of the QKD transceiver such as single photon detectors, single photon sources and WDM optical filters, and to consequently use the developed components to build a fully integrated QKD transceiver.

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AMF SOI

Label-free Silicon Photonic Biosensing Systems with Coupled LEDs and Stable Lasers

Applications include: Environment

We propose to demonstrate a lab-on-chip like biosensing system comprising of an all-silicon biosensor coupled to a gain chip. Our design will improve on the past-fabricated Fan-Out Wafer-Level-Packaging (FOWLP) based biosensors (including Mach–Zehnder interferometers, microring resonators, and Bragg gratings sensing configurations), and will not use Germanium photodetectors, external lasers, external SLED sources, external band-pass filters, or even an optical spectrum analyzer. Our design will integrate the aforementioned components on-chip and will thus enable us to demonstrate cost-effective biosensors that can be produced at high-volume and low-cost. In addition, we plan to package the biosensors through photonically wirebonding an SLED chip to the silicon photonic chip. This will be the first demonstration of packaging silicon photonic biosensors using photonic wirebonding.

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AMF SOI

Machine Learning and Neural Computing with Silicon Photonics

Applications include: Defence (Safety, Security), ICT

In artificial intelligence (AI), deep learning employs convolutional neural networks (CNNs) as powerful and ubiquitous tools for extracting features from large datasets for applications such as computer vision and natural language processing. Convolutions are computationally expensive operation in digital electronics and take more than 80% of the runtime. Neuromorphic photonics processors combine the high bandwidth and efficiency of photonic devices with the adaptive, parallelism and complexity similar to the brain. These processors have the potential to be much faster than state-of-the-art electronic processors while consuming less energy. The primary objective of this chip will be to demonstrate simple deep learning task by implementing CNNs with silicon photonics.

A secondary objective will be to continue our development of monolithically integrating electronic components into the AMF platform, including operational amplifiers and bipolar transistors. We also wish to make substantial improvements to our previous design by:

a) designing weight bank arrays of microring resonators connected to bond pad array for flip-chip bonding;
b) using these network-configurable components to implement linear operations, such as matrix multiplication, or even fixed operations such as fourier transforms;
c) implementing PN-doped bipolar transistors for operational and transimpedance amplification;
d) circuits for optical cancellation systems;
e) circuits for optical steganography and cryptographic key generation.

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AMF SOI

Moving Average Operation is Silicon Photonics and On-chip RF Antenna Integration with Photodector in Silicon Photonics Platform

Applications include: ICT

Project 1: Silicon photonics provides a unique platform for implementation of passive and active optical components by harnessing the well-developed CMOS fabrication technology. Furthermore, silicon photonics facilitates design and implementations of next generation high speed optical receiver front-ends by utilizing light on the photonic integrated circuit (PIC). One of the key bottlenecks, however, has been implementing the arithmetic operations such as integration on the PIC which is, indeed, vital for developing cost-effective high-speed optical receiver front-ends. In this project, which is inline with the objectives of I2I project, a moving average filter is proposed on the PIC. The proposed structure mitigates the charge sharing issue observed on the optical receiver front-ends. We successfully demonstrated the feasibility of implementing RC low pass filters on the silicon photonic chip. In this project, the optical sampling structure similar to one of our recent works performs the sampling of the light on the PIC. The optical signal will then be converted to the electric signal by utilizing integrated photodiodes. The performance of the initial structure was validated at 2.5 Gb/s. However, a power mismatch in the channels was observed. In the new design, the directional coupler will be replaced with a tunable coupler. Furthermore, shorter delay lines will be utilized to accommodate speeds up to 25 Gb/s.

Project 2: The possibility of having a RF antenna with Photodetector, radiating electromagnetic radiation in a controlled manner on Silicon photonic chip would greatly enhance the functionality of conventional Silicon photonics chips. Just as the RF antenna greatly amplified the scope and application of integrated electronics, its introduction to integrated photonics would open floodgates to countless applications.

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AMF SOI

Multi-mode Microring Modulators for Spatial Division Multiplexing Application

Applications include: ICT

Our design submission is a Polarization Sensitive Optical Modulator/Demodulator for high-speed spatial division multiplexing (SDM) network. The target modulation bandwidth is 20 GHz for each polarization, which will provide variable data transmission rates of greater than 100 Gbps for full-load work condition. The design not only offers a compact, cost-effective silicon photonic solution for high-speed optical transceivers but also provides the ability to configure the transceiver to adapt to variable transmission formats and bandwidths to maximize spectral efficiency. The main technical challenge of the design is to realize the multi-mode concentric microrings scheme in the modulator circuit which can be configured to pick different polarization at the same resonance from the bus silicon waveguide and then modulate/demodulate this specific signal. This technique will add another freedom beside the wavelength in the conventional Wavelength Division Multiplex (WDM), which potentially can further extend the communication bandwidth by 10 times or an order magnitude.

Our modulator consists of at least 2 concentric microring resonator with different radii. Each microring is made by a rib-slab waveguide with different rib width. To achieve high-speed modulation, we will use depletion-mode pn junctions embedded in the rib waveguide.

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AMF SOI

Programmable optical modulator/demodulator

Applications include: ICT

Our design submission is a Programmable Optical Modulator/Demodulator (POM/D) for high-speed optical communication networks. The circuit can be electrically programmed to perform N-level quadrature amplitude modulation (N-QAM) schemes with N selectable from 2, 4, 16, 64 up to 256. On the receiver side, the circuit can also be configured to perform coherent demodulation of signals in different N-QAM formats. The target modulation bandwidth is 20 GHz, which will provide variable data transmission rates of up to 320 Gbps. The design not only offers a compact, cost-effective silicon photonic solution for high-speed optical transceivers, but also provides the ability to configure the transceiver to adapt to variable transmission formats and bandwidths to maximize spectral efficiency. The main technical challenge of the design is to integrate the various N-QAM modulators and demodulators into one programmable circuit which can be configured to perform any chosen modulation scheme. In addition, for maximum operation flexibility, our high-order QAM modulator design will accept as input streams of binary-level electrical signals, instead of multi-level electrical signals since these are difficult to generate at high data rates.

Our modulator circuit consists of 4 parallel quadrature phase shift keying (QPSK) modulators connected through variable couplers. Each QPSK modulator consists of a pair of MZI modulators whose outputs are phase shifted before being combined. To achieve high-speed modulation, we will use depletion-mode pn junctions embedded in the MZI arms. The variable couplers are also implemented using pn-MZIs and used to set the appropriate splitting ratios of the outer MZIs depending on the N-QAM format chosen. On the receiver side, the demodulator consists of a 90-degree hybrid to perform quadrature addition and subtraction of the received signal and a local oscillator.

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AMF SOI

Raman Laser

Applications include: ICT

The most challenging part in silicon photonics research is to develop silicon-compatible materials for light sources, considering that the indirect band gap of silicon and germanium make them unsuitable materials for lasing. Stimulated Raman scattering (SRS) is a nonlinear effect that can be exploited to generate gain and obtain lasing in many materials including silicon. SRS provides wavelength conversion without having to resort to doping, heterogeneous bonding or epitaxial grows of III-V material on silicon photonic platform. In comparison with optical parametric amplifier, it is easier to exploit Raman gain to make a laser because it does not need dispersion engineering for wavelength conversion, it is an automatically phase matched nonlinear phenomenon. In this run, we want to submit a design for Raman laser working, for the first time, in mid-infrared part of the spectrum for sensing applications.

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AMF SOI

Rugged Silicon Photonic Transceiver

Applications include: ICT

Rugged transceivers, which can sustain harsh environments, are in high demand in the applications such as telecommunications, avionics, and space. Vertical-cavity surface-emitting laser (VCSEL)-based transceivers have been a cost-effective approach to address the demand. However, the exponential growth in the data volume, push the technology toward higher speeds at longer reaches. With the existing technology, the maximum allowable speed over a 100 m reach is 12.5 Gb/s. Silicon photonics (SiP) is an emerging technology that provides a unique opportunity for integration of photonic components by harnessing well-developed micro-electronic fabrication technology. Furthermore, SiP provides an excellent platform for developing high-speed optical interconnects. Moreover, advanced packaging techniques allow hybrid compact electronic-photonic system design for rugged applications. However, a few challenges are involved in developing new transceivers. Among them, coupling light from the laser into the photonic integrated circuit (PIC) and from the PIC waveguide into the single-mode (SM) fiber, and compatibility with the existing packaging technology are more of concern. In this project, SiP Mach-Zehnder (MZ) modulators at the speeds up to 25 Gb/s over a 1Km reach will be designed to be embedded in the next-generation of the rugged transceivers.

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AMF SOI

Scalable Neuromorphic Photonic Circuits

Applications include: ICT

We propose designing and implementing:

1) Ring-resonator modulators, and germanium detectors-based recurrent optical neuromorphic systems with 1-node, 2x2, 4x4, and 8x8 interconnected neurons to be controlled and derived in-house using electronics amplification.
2) Ring-resonator modulators, and germanium detectors-based recurrent optical neuromorphic systems with 1-node, 2x2, 4x4, and 8x8 interconnected neurons with edge-coupler opening to be controlled and derived in-house using semiconductor optical amplifier.
3) Ring-resonator modulators, and germanium detectors based-multi-layer feedforward optical neuromorphic system for integration with electronics amplification to solve for machine learning problem.

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AMF SOI

Scalable Neuromorphic Photonics

Applications include: ICT

We propose:

1) Integration of several units of ring-resonator modulators, and germanium detectors-based recurrent optical neuromorphic systems 4x4 interconnected neurons to solve for real time machine learning problem of higher size to be controlled and derived in house using transconductance amplifier, electronics amplification. Differential control of each ring-resonator is to be implemented with FPGA and CMOS.
2) Integration of several units of ring-resonator modulators, and germanium detectors-based recurrent optical neuromorphic systems 4x4 interconnected neurons to solve for real time machine learning problem of higher size to be controlled and derived in house using semiconductor optical amplifier, optical amplification. Differential control of each ring-resonator is to be implemented with FPGA and CMOS.
3) Integration of proposed multi-4x4 interconnected neurons with SiN-MRR frequency comb generator, and multi-wavelength sources.

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AMF SOI

Ultrafast, Ultralow Energy Consumption Optical Logic Gates on an Integrated Silicon Chip

Applications include: ICT

In analogy with their electronic counterparts, all-optical logic gates are “basic building blocks” required to create complex digital optical signal-processing (DOSP) circuits. However, so far, the demonstrated optical logic gates are “energy-hungry”. Recently, we demonstrated a proof-of-concept of zero switching-energy NOT gate which fundamentally neither consumes nor dissipate any energy in the switching process [1, 2]. The success of this proof-of-concept device shows great promise for realizing simultaneous ultrafast information processing with ultralow energy consumption. We also have investigated theoretically the potential of the new paradigm for realization of more complicated logic gates (specifically an XNOR) and circuits [2]. In this project, we plan to experimentally realize prototypes of theoretical designed gates we recently demonstrated in bulk optical devices on a silicon-chip through an active multi-project wafer (MPW) run. This research is a major attempt to complete a new green paradigm to ultimately build digital computing devices capable of performing formidable computations at much higher speed than of current machines with a fraction of their power consumption. We anticipate that this paradigm may allow photonics to compete with electronics not only in telecommunication systems, but also at through optical or optical-electrical hybrid computing at the personal and industrial device level. This research can be exploited by Canadian photonic component companies, for example, in the context of integrated optical switching modules or possibly open a new path for designing ultrafast processors in integrated chips.

References

1. R. Maram et al, “Passive linear-optics 640 Gbit/s logic NOT gate,” OFC 2015, Los Angeles, CA.
2. R. Maram et al “Ultrafast frequency domain passive logic”, to be submitted.

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Technology: Silicon Photonics – Passive Silicon on Insulator Training

Examples of projects using NSERC CREATE Si-EPIC (Silicon Electronic-Photonic Integrated Circuits Program), University of British Columbia, targeting the AMF Si Photonics technology, available through CMC.

AMF SOI

- AWG design Using Luceda Filter Toolbox and Rsoft AWG Utility
  CMC Microsystems | Designer: Neng Liu
- Bragg Grating Encoded Filters Using Superposition of up to Eight Grating Corrugation Widths
  University of British Columbia | Designer: Becky Lin | Professor: Lukas Chrostowski
- Cascaded Contra-directional Coupler Forming a High Extinction Ratio Reject Band Filter
  University of British Columbia | Designer: Sebastian Gitt | Professor: Jeff Young
- Design of Surface Grating couplers for Bloch mode output to SWG waveguides
  McGill University | Designer: Daniel Hutama | Professor: Lawrence R. Chen
- Fabricating Optical Filters Based on Cascading Multiple Ring Resonators
  University of British Columbia | Designer: Adan Azem | Professor: Lukas Chrostowski
- Fully Optical Artificial Neural Networks
  University of British Columbia | Designer: Jing Wang | Professor: Clarence de Silva
- High Extinction Ratio Square Frequency-domain Optical Filters
  University of British Columbia | Designer: Adam Darcie | Professor: Lukas Chrostowski
- Inverse Design of Arrayed Waveguide Gratings
  Université Laval | Designer: Daniel Robin | Professor: Wei Shi
- Imbalanced Mach-Zehnder Modulators
  Université Laval | Designer: Abdolkhalegh Mohammadi | Professor: Wei Shi
- Light Sources for Silicon Photonics
  McMaster University | Designer: Yanran Xie | Professor: Andrew Knights
- Optical Neural Network based on Micro Ring Resonator
  McGill University| Designer: Hao Sun | Professor: Lawrence R. Chen
- Silicon Photonic Mode Multiplexer for Highly Elliptical Core Fiber
  Université Laval | Designer: David Turgeon | Professor: Sophie Larochelle
- Silicon Photonic Optical Amplifiers and Lasers
  McMaster University | Designer: Renjie Wang | Professor: Jonathan Bradley
- SOA Integration Using Hotonic Wirebonds
  University of British Columbia | Designer: Connor Mosquera | Professor: Lukas Chrostowski

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MEMS

MEMS growth is fueled by sectors of the economy such as automotive, consumer goods, advanced manufacturing of medical technologies and diagnostics, machine health, smart buildings, and edge computing. The Canadian ecosystem includes two Teledyne MEMS foundries in Canada (Teledyne DALSA, Teledyne Micralyne), centres for pilot fabrication, packaging, and system development (INO, C2MI, and ACAMP).

Technology: PiezoMUMPs

MEMSCAP PiezoMUMPs

3D MEMS Electrostatic Actuators as Waveguide Positioners in Photonic Integrated Circuits for Active Components Alignment

Applications include: ICT (optical telecommunications)

The proposed waveguide positioner is based on utilizing 3D MEMS actuators to provide dynamic alignment to active components in photonic integrated circuits (PICs). The design consists of a platform supported by flexible beams, to host the positioned waveguide, in addition to actuators responsible of deflecting the platform in various directions to couple the light to the active components.

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MEMSCAP PiezoMUMPs

Aluminum Nitride Filters

Applications include: ICT (wireless communications)

Design includes a band pass Thin Film Piezoelectric on Substrate (TPOS) filter and resonators. Objective is to fabricate and measure a High-Q and narrow bandwidth filter.

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MEMSCAP PiezoMUMPs

Design and Manufacturing of Temperature Compensated MEMS Resonators for High Q-factor

Applications include: Automotive, Environment, ICT

the designated structures will be MEMS resonators mainly for the temperature compensation purpose. Different geometric and mechanical approaches will be applied on the MEMS resonators to compensate the frequency drift which is due to the temperature rise. Using thermal actuators will be the principal idea for this purpose. This will be applied for free beam, clamped beam and lame' mode resonators. In addition, other new designs for resonators will be purposed by modifying previous designs in the literature to obtain higher quality factors. Last, but not least, will be using movable anchors for the purpose of frequency tuning and more importantly, temperature compensation.

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MEMSCAP PiezoMUMPs

Design Automation of Piezoelectric MEMS Harvester (3 and 4)

Applications include: Natural Resource/Energy

During the last decade, energy harvesting from ambient has been recognized as a feasible method for powering the low-power electronic applications. In the literature, several attempts have been made to offer high efficient piezoelectric MEMS harvesters. However, most of the introduced methodologies are dependent on designers' decision. Therefore, in this study we propose the design automation technique for piezoelectric MEMS energy harvesters based on artificial intelligence. In this regard, deep learning technique is implemented to model a piezoelectric MEMS harvester, thus, the model can be utilized for optimization purpose. In order to verify ability of our proposed optimization methodology, the optimized harvester needs to be fabricated. As a result, the prototype measurement results will be used to show that this new optimization methodology can be considered as a feasible method for performance enhancing of the piezoelectric MEMS energy harvesters.

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MEMSCAP PiezoMUMPs

Development of Systems for Accelerated Bacteria Collection and Detection (ABCD) Using Electrokinetics

Applications include: Environment, Health/Biomedical

The design is microcantilever-based biosensors to detect E coli bacteria in water. The target is to detect them in very low concentration within a short time period to meet the demand from the real time monitoring. The cantilever will be driven by AC electric potential applied on the piezoelectric material. The cantilever resonant frequencies will change when bacteria are attached.

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MEMSCAP PiezoMUMPs

Electrostatic Arch Micro-Tweezers

Applications include: ICT

This project study the visibility of building a novel electrostatic micro-tweezers to manipulate particles. The tweezers consist of two grip-arms mounted to an electrostatically actuated initially curved micro-beam. It exploits then nonlinear phenomena of bistable structure, to close the separation distance between the two arms allowing them to grasp a large range of objects. This design is unique and smaller in size compare to the existing designs.

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MEMSCAP PiezoMUMPs

Electrode Configuration Impacts on Performance of MEMS Harvester

Applications include: Environment

The conventional micro-electromechanical system (MEMS) energy harvesters can only generate voltage disadvantageously in a narrow bandwidth at higher frequencies. In this paper we propose a piezoelectric MEMS harvester with the capability of vibrating in multi-degree-of-freedom, whose operational bandwidth is enhanced by taking advantage of both multimodal and nonlinear mechanisms. The proposed harvester has a symmetric structure with a doubly-clamped configuration enclosing three proof masses in distinct locations. Thanks to the uniform mass distribution, the energy harvesting efficiency can be considerably enhanced. To determine the optimum geometry for the preferred nonlinear behavior, we propose an automated design and optimization methodology based on the genetic algorithm (GA). By using the micromachining process, our optimized harvester with a total volume of 4.1 mm3 can be fabricated and measured.

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MEMSCAP PiezoMUMPs

High Power MEMS Switches for Avionic Application

Applications include: Aerospace

The main objective of this research work is to achieve a reliable and high power micro- electro-mechanical systems (MEMS) switches for a re-configurable system in avionic applications. In this approach, a DC contact MEMS switches based on chevron thermal actuation technique is design in-order to achieved high isolation and current respectively.

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MEMSCAP PiezoMUMPs

Lineal Displacement Sensor Adaptable to External Devices

Applications include: Aerospace, Automotive, Other (civil engineering)

The project consists in the development and improvement of a linear displacement sensor, which uses physical contact as a means of detection, as well as the analysis of the signal obtained by the deposited piezoelectric material. The primary sensor signal consists of the closing of the mechanical contacts formed by the same structure, which is flexed based on the applied load, generating a variation in the electrical resistance between the contacts, proportional to the displacement submitted. A secondary signal generated by the piezoelectric material will be measured. This signal will be generated caused by the external vibrations to the device, that will be quantified and will be used to compensate and reduce the noise in the output of the sensor signal.

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MEMSCAP PiezoMUMPs

MEMS Micromotor for Optical Filter

Applications include: Health/Biomedical

The design proposed are related to micro-opto-electro-mechanical systems and more specifically to develop piezo-MEMS micromotor for optical micromechanical systems based swept wavelength component. The piezo-micromotor is designed to move an integrated polygon mirror at very high speeds inside an optical coherence tomography (OCT) application. The basic design consists of stator poles that surround a circular rotor which rotates about a center bearing. The goal is to achieve optimal torque and wide angular sweep by using a novel design for the rotor. The current designs are upgraded version of MEMS micromotors with modification in rotor and stator designs for higher torque, large angular sweep, and smaller motor footprints. The design will also consist of polygon mirror fabricated using substrate trench. The suspended polygon mirror will be attached to the structural layer with the support of theathers.

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MEMSCAP PiezoMUMPs

Micro Linear Displacement Sensor

Applications include: Aerospace, Automotive, Other (civil engineering)

The goal is to optimize a novel type of MEMS displacement sensor that is based on resistive contacts. Gemotric amplification will be used to increase the displacement in different directions. This technique allows a better precision in measurement by reducing the minimal displacement of 2 um imposed by the technology. The Si-Si contact model was previously updated with the first generation of MEMS strain sensor. The MEMS device will be integrated with an embedded system to have complete strain sensor system. Different MEMS structures based on contact resistances will be investigated to find the most suitable for strain sensor applications. A post-processing might be done to coat the structures will metal to reduce the overall contact resistance is required. The design will allow to measure displacement from 2µm to 20µm.

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MEMSCAP PiezoMUMPs

MEMS Actuators as Waveguide Positioners in Photonic Integrated Circuits for Active Components Alignment

Applications include: ICT (optical telecommunications)

The proposed waveguide positioner is based on utilizing MEMS actuators to provide dynamic alignment to active components in photonic integrated circuits (PICs). The design consists of a platform supported by flexible beams, to host the positioned waveguide, in addition to actuators responsible of deflecting the platform in various directions to couple the light to the active components.

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MEMSCAP PiezoMUMPs

MEMS Actuators for Tunable Optical Components

Applications include: ICT

We are requesting CMC resources to test novel electrostatic microelectromechanical system (MEMS) actuators designed specifically for controlled tuning of optical component such as Mach-Zhender interferometer (MZI). Our MEMS designs consist of different actuator and spring iterations capable of analog and digital tuning of MZI. The movable platform designed with each actuator is designed to accommodate different lengths of silicon oxide-based perturbation waveguides. Bringing the platform closer to the fixed substrate (which accommodates MZI) will optically tune the MZI producing a pi phase shift in the propagating optical signal. While analog actuators based upon comb drive will provide precise control over the gap between the perturbation waveguide and the MZI, digital actuators based upon parallel plate actuation will provided discrete ON/OFF capability for optical tuning of the MZI. The resources requested now are to demonstrate and optimize different MEMS actuator designs that will be integrated with silicon nitride based optical components once their performance has been proven satisfactory. Electrostatic actuation is achieved through the comb drive and parallel plate designs in our MEMS devices. This actuation method is used for planar motion of the suspended platform. Serpentine spring structures of different spring stiffness are designed according the actuator capabilities for optimal tuning displacement under 200 V.

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New Architectures for PMUTS

Applications include: Automotive, Health/Biomedical

Working toward the design of new PMUTS (Piezoelectric Micromachined Ultrasonic Transducers) beyond the traditional circular shape. Designs has been prototyped using simulation and real-life measurements. These designs allow a higher displacement and a better control of the resonant frequency. The designs submitted in this area will allow real life measurements.

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MEMSCAP PiezoMUMPs

Out-of-plane Electrostatic Actuator

Applications include: ICT (telecommunications)

In this project we intend to testify a novel electrostatic MEMS actuator by using in-plane actuation force.

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MEMSCAP PiezoMUMPs

Piezoelectric Micromachined Ultrasonic Transducer (PMUT)

Applications include: Health/Biomedical

Development of Piezoelectric Micromachined Ultrasonic Transducer for operating frequency range of kHz to couple of MHz range for medical imaging and fault detection applications. Individual transducers and 1D arrays will be fabricated.

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MEMSCAP PiezoMUMPs

Piezoelectric Vibration Energy Harvester

Applications include: Environment, Health/Biomedical, Natural Resource/Energy

Working toward the improvement of energy harvesting technology. Non linear and multi modes designs are hard to simulate due to their nature. A design has been prototyped using simulation and real-life measurements. This design allows energy harvesting using multimodes and possesses a non linear frequency response. The design submitted in this area will allow real-life application due to its low resonant frequency.

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MEMSCAP PiezoMUMPs

Temperature Compensated MEMS Resonators with Tunable Frequency

Applications include: Automotive, Environment, ICT

This design aims to implement anchor design in a way to compensate the frequency drift due to the temperature rise while the resonator operates. The purpose of this design is to validate the theoretical model of the effect of input axial force on the frequency drift due to the temperature rise using the new anchor design.

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MEMSCAP PolyMUMPs

2D Replulsive Force Based Micromirror (I)

Applications include: ICT (head up display)

This application is to use PolyMUMPS to fabricate four pieces of 2D micromirror for head up display. Our group had successfully developed PolyMUMPS micromirror integrated with melting beams to solve the stiction problem. The present application is to develop a micromirror combining four pieces of small mirror in the same chip.

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MEMSCAP PolyMUMPs

2D Replulsive Force Based Micromirror (II)

Applications include: ICT (head up display)

This application is to use PolyMUMPS to fabricate four pieces of 2D micromirror for head up display. Our group had successfully developed PolyMUMPS micromirror integrated with melting beams to solve the stiction problem. The present application is to develop a micromirror combining four pieces of small mirror in the same chip. Less dimples will be used to increase the surface reflectivity.

Ryerson University
Designer: Hui Zuo | Email: hui.zuo@ryerson.ca
Professor: Siyuan He | Email: s2he@ryerson.ca

MEMSCAP PolyMUMPs

A MEMS based Optical Phase Array system with Pitch Tuning Capability

Applications include: Aerospace, Automotive

The proposed Optical Phase Array (OPA) system is formed by a one-dimensional array of MEMS micromirrors. The planar gap between the identical micromirrors is close to laser wavelength (1550 nm) used to achieve a considerable laser diffraction pattern through optical phase shifting. Each micromirror has a width that is close to the laser wavelength in order to achieve fine pitch size, while being much larger in length to achieve large aperture size (reflective surface area). A gold layer is used to realize high reflectivity of the micromirrors as well as to realize electrical contacts for bonding pads. Two design configurations are fabricated by using the standard PolyMUMPs process in order to perform optical beam steering for LiDAR applications. The former configuration is operated based on constant pitch approach and the latter one is operated based on variable pitch approach. In the first design configuration, the micromirrors can be individually moved out of plane (piston type motion) to diffract the incident laser beam. The top and bottom electrodes of each micromirror are used to realize an electrostatic parallel plate actuator for the out of plane linear translation. Each micromirror beam (top electrode) is suspended by a pair of actuating springs that are anchored to the substrate. All the top electrodes are electrically grounded while the fixed bottom electrodes are individually charged. At the center of the second design configuration, the identical and linearly spaced micromirrors are formed from a set of suspended beams which are connected and supported by holding springs at their both ends. Then the holding springs of the micromirrors are physically connected to the end-effectors of two lateral electrostatic comb drive actuators on both sides. The net force generated by the identical comb drive actuator pairs squeezes the holding springs towards the center of the symmetric structure. Thus, the planar gaps between the adjacent micromirrors can be adjusted.

University of Toronto
Designer: Tarek Mohammad | Email: tarekm@mie.utoronto.ca
Professor: Ridha Ben-Mrad | Email: rbenmrad@mie.utoronto.ca

MEMSCAP PolyMUMPs

cMUTs for Ultrasonic Non-destructive Testing

Applications include: Aerospace, Automotive, other (evaluating structure failures in industries)

A capacitive Micromachined Ultrasonic Transducers (CMUTs) array will be implemented with the goal of producing high resolution imaging for non-destructive testing. In a previous project also funded by CMC, CMUTs with a resonant frequency of 15 MHz were successfully fabricated and tested. In this project, an optimized architecture will be fabricated that needs less actuation voltage and have a resonant frequency that is less sensitive to process variations and can achieve longer range. This will allow a better frequency matching between elements of the array and therefore a higher sensitivity and better image quality.

Université du Québec à Montréal (UQAM)
Designer: Alexandre Robichaud | Email: robichaud.alexandre@courrier.uqam.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMSCAP PolyMUMPs

CO2 Gas Sensor

Applications include: Environment

The goal of this project is to investigate the feasibility of CO_2 measurement with a CMUT based sensor. Measurement principles and sensor design features will be investigated. The performance of a capacitive micromachined ultrasonic transducers (CMUT) implemented with the commercially available POLYMUMPs process is to be evaluated.

McGill University
Designer: Hani Tawfik | Email: hani.tawfik@mail.mcgill.ca
Professor: Mourad El-Gamal | Email: mourad.el-gamal@mcgill.ca

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MEMSCAP PolyMUMPs

Capacitive Micromachined Ultrasonic Transducer CMUT & M3CMUT

Applications include: Health/Biomedical

Development of Capacitive Micromachined Ultrasonic Transducer (CMUT) & Multiple Moving Membrane M3CMUT Transducer and Sensor

University of Windsor
Designer: Haleh Nazemi | Email: nazemih@uwindsor.ca
Professor: Arezoo Emadi | Email: arezoo.emadi@uwindsor.ca

MEMSCAP PolyMUMPs

GasChem Sensors G5 (I)

Applications include: Agriculture/Agri-Food, Defence (Safety, Security), Environment, Health/Biomedical

A novel gas and chemical sensors have been designed to detect toxic gases and chemicals in the air and water. A polymeric sensing material will be used to enhance the sensor sensitivity. New design features were modified and added to the existing design to improve the sensors capacity to carry the detecting polymer. PolyMUMPs fabrication process will be used to validate many experimental to proof the sensor functionality.

University of Waterloo
Designer: Mohamed Arabi | Email: msaaarab@uwaterloo.ca
Professor: Eihab Abdel-Rahman | Email: eihab@uwaterloo.ca

MEMSCAP PolyMUMPs

GasChem Sesors G5 (II)

Applications include: Agriculture/Agri-Food, Defence (Safety, Security), Environment, Health/Biomedical

A novel bifurcation gas and chemical sensors have been designed to detect toxic gases in the air and mercury in water. A polymeric sensing material will be used to enhance the sensor sensitivity. New design features were modified and added to the existing design to improve the sensors capacity to carry the detecting polymer. PolyMUMPs fabrication process will be used to validate many experimental to proof the sensor functionality.

University of Waterloo
Designer: Mohamed Arabi | Email: msaaarab@uwaterloo.ca
Professor: Eihab Abdel-Rahman | Email: eihab@uwaterloo.ca

MEMSCAP PolyMUMPs

High Power MEMS Switches for Avionic Application

Applications include: Aerospace

Reliable and high-power micro electro-mechanical systems (MEMS) switches for a re-configurable system in avionic applications.

École de technologie supérieure
Designer: Abdurrashid Hassan Shuaibu | Email: abdurrashid-hassan.shuaibu.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMSCAP PolyMUMPs

MEMS Gyroscopes

Applications include: Aerospace, Automotive, Entertainment

This design consists of square, rectangular and circular resonators being used for gyroscopic application. The objectives of these designs are to improve sensitivity and reduce drift.

University of Windsor
Designer: Nabeel Khan | Email: khan187@uwindsor.ca
Professor: Jalal Mohammed Ahamed | Email: jahamed@uwindsor.ca

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MEMSCAP PolyMUMPs

MEMS Micromotor for Optical Swept Filters (I, II, & III)

Applications include: Health/Biomedical

The designs proposed are related to microoptoelectromechanical systems and more specifically to develop MEMS micromotors for optical micromechanical systems based swept wavelength component. The micromotor is designed to rotate an integrated polygon mirror at very high speeds inside an optical filter for an optical coherence tomography (OCT) application. The basic design consists of stator poles that surround a circular rotor which rotates about a center bearing. The goal is to achieve optimal torque and angular velocity by fine-tuning the parameters of the design such as the number of poles on the rotor and the stator, as well as reducing friction by using a novel geometrical form for the rotor. The current designs are upgraded version of previous fabricated MEMS micromotors with modification in rotor and stator design for higher torque and smaller motor footprints

École de technologie supérieure
Designer: Amit Gour | Email: amit.gour.1@ens.etsmtl.ca
Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

MEMSCAP PolyMUMPs

MEMS Ultrasonic Transducers for Space Application (with Cornell and NASA) (I & II)
Applications include: Aerospace

Air Coupled moving membrane transducers for imaging on Mars in collaboration with Cornell University and the National Aeronautics and Space Administration (NASA).

University of Manitoba
Designer: Mayank Thacker | Email: thacker5@myumanitoba.ca
Professor: Douglas Buchanan | Email: douglas.buchanan@umanitoba.ca

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MEMSCAP PolyMUMPs

Reconfigurable amplifiers using MEMS technology
Applications include: ICT (wireless communication systems)

Various RF-MEMS switches with different dimensions are designed on top of transmission lines. Also, a MEMS tuner with 8-bit Switches are designed to test impedance coverage for amplifiers. This is a prototype of the final design.

École de technologie supérieure
Designer: Ehsan Fallahnia Email: ehsan.fallah-nia@lacime.etsmtl.ca
Professor: Ammar Kouki Email: ammar.kouki@etsmtl.ca

MEMSCAP PolyMUMPs

Vertical MEMS Actuator
Applications include: ICT (optical communications)

In this project we will test the capability of PolyMUMPs to generate vertical MEMS actuator.

École de technologie supérieure
Designer: Almur Rabih Email: almur-abdelkreem-saeed.rabih.1@ens.etsmtl.ca
Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

MNT (Micro-Nano Technology) FABRICATION

CMC's MNT Portal - www.cmc.ca/MNT
This network includes more than **40** university-based labs across Canada offering custom fabrication – mask generation, etching, materials deposition, lithography, and characterization. The following are examples of designs developed through the network that benefited from CMC's MNT Portal financial assistance.

MNT: Characterization

- Characterization of High Temperature Superconductor Coated Conductors
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Polytechnique Montréal
  Designer: Jean-Hughes Fournier Lupien | Email: j-h.fournier@polymtl.ca
  Professor: Frédéric Sirois | Email: f.sirois@polymtl.ca

- (Photo)conductivity Measurements of Chemically Controlled Eumelanin Biopigment Films for Sustainable Optoelectronics Applications
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Polytechnique Montréal
  Designer: Jordan De Angelis | Email: jordan.de-angelis@polymtl.ca
  Professor: Clara Santato | Email: clara.santato@polymtl.ca

MNT: MEMS

- A High-sensitive Circular Capacitive Micromachined Ultrasonic Transducer (CMUT) Transducer for Non-Destructive Testing Applications with a Nitride-to-Oxide-Based Wafer Bonding Process
  Lab: Giga to Nanoelectronics (G2n) Centre (University of Waterloo)
  University of Waterloo
  Designer: Tirad Owais | Email: taowais@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | Email: jyeow@uwaterloo.ca

- A High-transmit-sensitivity Circular Capacitive Micromachined Ultrasonic Transducer (CMUT) array for Non-Destructive Testing Applications
  Lab: Giga to Nanoelectronics (G2n) Centre (University of Waterloo)
  University of Waterloo
  Designer: Tirad Owais | Email: taowais@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | Email: jyeow@uwaterloo.ca

- Aqueous Electrolyte-Gated Metal Oxide Phototransistor for Portable Photocatalysis
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Polytechnique Montréal
  Designer: Gabriel Silva | Email: u096904@polymtl.ca
  Professor: Fabio Cicoira | Email: fabio.cicoira@polymtl.ca

- Capacitive Interrogated DC Electric Field Sensor
  Lab: Nano Systems Fabrication Laboratory (NSFL) (University of Manitoba)
  University of Manitoba
  Designer: Selva Priya Murugesan | Email: murugesp@myumanitoba.ca
  Professor: Cyrus Shafai | Email: cyrus.shafai@umanitoba.ca

- Development of an E-nose System Based on Capacitive Micromachined Ultrasonic Transducers (CMUTs)
  Lab: Giga to Nanoelectronics (G2n) Centre (University of Waterloo)
  University of Waterloo
  Designer: Zhou Zheng | Email: z57zheng@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | Email: jyeow@uwaterloo.ca

- MEMS Adaptive Optics Mirror System, using a Metal-polymer Mirror and Low Voltage Actuator Array
  Lab: Nano Systems Fabrication Laboratory (NSFL) (University of Manitoba)
  University of Manitoba
  Designer: Mohammad Mehdi Allameh | Email: allamemm@myumanitoba.ca
  Professor: Cyrus Shafai | Email: cyrus.shafai@umanitoba.ca

- MEMS Capacitive Sensor for Measuring Pressure in the Kidneys
  Lab: Advanced Materials and Process Engineering Laboratory (AMPEL) (University of British Columbia)
  University of British Columbia
  Designer: Nabil Shalabi | Email: nabils@ece.ubc.ca
  Professor: Kenichi Takahata | Email: takahata@ece.ubc.ca

MNT: Microfluidics

- 3D Innervated Tissue-on-chip for Studying Injuries of the Central Nervous System
  Lab: Microscopy and Imaging Facility (MIF) (University of Calgary)
  University of Calgary
  Designer: Sultan Khetani | Email: sultan.khetani@ucalgary.ca
  Professor: Amir Sanati Nezhad | Email: amir.sanatinezhad@ucalgary.ca

- Microfluidic Based Human Immunodeficiency Virus (HIV) Detection Device
  Lab: NanoFAB (University of Alberta)
  University of Calgary
  Designer: Maysam Pedram | Email: maysam.zamanipedram@ucalgary.ca
  Professor: Amir Sanati Nezhad | Email: amir.sanatinezhad@ucalgary.ca

- Microwave Integrated Microfluidic Platforms for In-Vitro Modeling of Anti-Cancer Drugs and Real-time Monitoring of Transport Efficiency
  Lab: Microsystems Hub (University of Calgary)
  University of Calgary
  Designer: Gurkan Yesiloz | Email: maysam.zamanipedram@ucalgary.ca
  Professor: Amir Sanati Nezhad | Email: amir.sanatinezhad@ucalgary.ca

MNT: Micromachining

- Fabrication of Patterned Electrodes with Different Photoresist Windows for the Characterization of Conductive Biomaterials
  Lab: McGill Nanotools Microfab (McGill University)
  McGill University
  Designer: Raed Gharbi | Email: raed.gharbi@mail.mcgill.ca
  Professor: Noémie-Manuelle Dorval Courchesne | Email: noemie.dorvalcourchesne@mcgill.ca

- Optimizing the design of patterned electrodes for characterization of bio-hybrid materials
  Lab: McGill Nanotools Microfab (McGill University)
  McGill University
  Designer: Saadia Wasim | Email: saadia.wasim@mail.mcgill.ca
  Professor: Noémie-Manuelle Dorval Courchesne | Email: noemie.dorvalcourchesne@mcgill.ca

- Silicon Nitride Windows for Differential Pressure Chamber Applications
  Lab: 4D LABS (Simon Fraser University)
  University of British Columbia
  Designer: Casimir Kuzyk | Email: ctkuzyk@ece.ubc.ca
  Professor: Alireza Nojeh | Email: alireza.nojeh@ubc.ca

MNT: Nanotechnology

- A Carbon Nanotube Field Emission Multi-pixel X-ray Source for Fluence Field Modulated Computational Tomography (I & II)
  Lab: Giga to Nanoelectronics (G2n) Centre (University of Waterloo)
  University of Waterloo
  Designer: Elahe Cheraghi | Email: echeraghi@uwaterloo.ca
  Designer: Jiayu Alexander Liu | Email: jiayu.alexander.liu@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | Email: jyeow@uwaterloo.ca

- Confinement of Exosomes in Nano-cavities
  Lab: McGill Nanotools Microfab (McGill University)
  McGill University
  Designer: Seyed Imman Isaac Hosseini | Email: seyed.isaachosseini@mail.mcgill.ca
  Professor: Sara Mahshid | Email: sara.mahshid@mcgill.ca

- Delivery of Therapeutic Drugs through Degradation of Polymer Nanospheres Encapsulating Magnetic Nanoparticles as Induced by Magnetothermal Technique
  Lab: 4D LABS (Simon Fraser University)
  Simon Fraser University
  Designer: Melissa Radford | Email: mradford@sfu.ca
  Professor: Byron Gates | Email: bgates@sfu.ca

- Design and Fabrication of Graphene Based Electrical Devices for Single-molecule Measurements
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Université de Montréal
  Designer: Amira Bencherif | Email: amira.bencherif@umontreal.ca
  Professor: Delphine Bouilly | Email: delphine.bouilly@umontreal.ca

- Electrochemical Aging of Nickel Electrodes for Oxygen Evolution Reaction (OER)
  Lab: 4D LABS (Simon Fraser University)
  Simon Fraser University
  Designer: Alexi Pauls | Email: alexi_pauls@sfu.ca
  Professor: Byron Gates | Email: bgates@sfu.ca

- Fabrication and Characterization of High-Frequency Field Effect Transistors based on 2D Black Phosphorus with Novel Metal Contact Architecture
  Lab: 4D LABS (Simon Fraser University)
  Simon Fraser University
  Designer: Abdelrahman Askar | Email: aaskar@sfu.ca
  Professor: Michael Adachi | Email: mmadachi@sfu.ca

- Fabrication of Capacitively-Shunted Flux Qubits Devices for Quantum Algorithms
  Lab: Quantum NanoFab (University of Waterloo)
  University of Waterloo
  Designer: Michal Kononenko | Email: mkononen@uwaterloo.ca
  Professor: Adrian Lupascu | Email: alupascu@uwaterloo.ca

- Fabrication of High-performance Flexible, Transparent, and Thin WS2-based LEDs
  Lab: 4D LABS (Simon Fraser University)
  Simon Fraser University
  Designer: Amin Abnavi | Email: amin_abnavi@sfu.ca
  Professor: Michael Adachi | Email: mmadachi@sfu.ca

- Fabrication of Optical Lithography Photomasks
  Lab: Quantum NanoFab (University of Waterloo)
  University of Waterloo
  Designer: Muhamet Ali Yurtalan | Email: mayurtal@uwaterloo.ca
  Professor: Adrian Lupascu | Email: alupascu@uwaterloo.ca

- Fabrication of Superconducting Aluminum Air Bridges for Superconducting Quantum Circuits Using a Novel Process
  Lab: Quantum NanoFab (University of Waterloo)
  University of Waterloo
  Designer: Muhamet Ali Yurtalan | Email: mayurtal@uwaterloo.ca
  Professor: Adrian Lupascu | Email: alupascu@uwaterloo.ca

- High-performance, flexible 2D FET based on TMDCs Heterostructure for Nanoelectronics and Nanophotonics with Tunable Electronic and Optical Properties
  Lab: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Junsen Gao | Email: junsen@ualberta.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

- Integrated Nano/Bio Platform for Sensitive and High Throughput Detection of Biological Analytes (PHASE 2)
  Lab: McGill Nanotools Microfab (McGill University)
  McGill University
  Designer: Mahsa Jalali | Email: mahsa.jalali@mail.mcgill.ca
  Professor: Sara Mahshid | Email: sara.mahshid@mcgill.ca

- MoS2-cavity Distributed Bragg Reflector for Exciton-Polariton Condensate
  Lab: Quantum NanoFab (University of Waterloo)
  University of Waterloo
  Designer: AJ Malcolm | Email: alan.malcolm@uwaterloo.cal
  Professor: Na Young Kim | Email: nayoung.kim@uwaterloo.ca

- Next Generation PtM catalysts for Proton Exchange Membrane Fuel Cells
  Lab: 4D LABS (Simon Fraser University)
  Simon Fraser University
  Designer: Sadaf Tahmasebi | Email: sadaft@sfu.ca
  Professor: Byron Gates | Email: bgates@sfu.ca

- Optimizing Sub-wavelength plasmonic graded gratings for highly sensitive molecular sensing
  Lab: Toronto Nanofabrication Centre (TNFC) (University of Toronto)
  University of Toronto
  Designer: Moein Shayegannia | Email: moein.shayegannia@mail.utoronto.ca
  Professor: Nazir Kherani | Email: kherani@ecf.utoronto.ca

- Superconducting Aluminum Bridges for Wiring Flux Qubits
  Lab: Quantum NanoFab (University of Waterloo)
  University of Waterloo
  Designer: Michal Kononenko | Email: mkononen@uwaterloo.ca
  Professor: Adrian Lupascu | Email: alupascu@uwaterloo.ca

MNT: Photonics

- A Novel Wide-band Miniature MOEMS Spectrometer with a Single Detector
  Lab: Laboratory of Micro and Nanofabrication (LMN) (Énergie Matériaux Télécommunications (Energy Materials Telecommunications) Research Centre, INRS)
  École de Technologie Supérieure
  Designer: Ranim Ahdab | Email: ranim.el-ahdab.1@ens.etsmtl.ca
  Professor: Frédéric Nabki | Email: frederic.nabki@etsmtl.ca

- Characterization and Optimization of SU-8 Whispering-gallery-mode Microresonators for Gas Sensing
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Polytechnique Montréal
  Designer: Cédric Lemieux-Leduc | Email: cedric.lemieux-leduc@polymtl.ca
  Professor: Yves-Alain Peter | Email: yves-alain.peter@polymtl.ca

- CMOS Compatible Bragg Reflection Waveguides for Second Harmonic Generation
  Lab: Quantum NanoFab (University of Waterloo)
  University of Toronto
  Designer: Trevor Stirling | Email: trevor.stirling@mail.utoronto.ca
  Professor: Amr Helmy | Email: a.helmy@utoronto.ca

- Enhancement of Light Emission and Light Absorption in CVD Grown Monolayer WS2 for using in Next Generation Optoelectronics and Solar Cells
  Lab: 4D LABS (Simon Fraser University)
  Simon Fraser University
  Designer: M Bakhtiar Azim | Email: aaskar@sfu.ca
  Professor: Michael Adachi | Email: mmadachi@sfu.ca

- Enhancing Polymer Light-emitting Electrochemical Cells by using Bipolar Electrodes
  Lab: NanoFabrication Kingston (Queen's University)
  Queen's University
  Designer: Shiyu Hu | Email: shiyu.hu@queensu.ca
  Professor: Jun Gao | Email: jungao@queensu.ca

- Fabrication of Fabry-Perot Gas Sensor
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Polytechnique Montréal
  Designer: Régis Guertin | Email: regis.guertin@polymtl.ca
  Professor: Yves-Alain Peter | Email: yves-alain.peter@polymtl.ca

- Integration of Ultraviolet LEDs onto Flex for Water Purification
  Lab: Quantum NanoFab (University of Waterloo)
  University of Waterloo
  Designer: Mohsen Asad | Email: mohsen.asad@uwaterloo.ca
  Professor: William Wong | Email: william.wong@uwaterloo.ca

- Nanophotonics using MoS2 for Biosensing Applications
  Lab: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Dipanjan Nandi | Email: dipanjan@ualberta.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

- Nonlinear Optomechanics in a Free-Standing Photonic Crystal Ring Resonator
  Lab: Western Nanofabrication Facility (Western University)
  Western University
  Designer: Brett Poulsen | Email: bpoulse@uwo.ca
  Designer: Michael Zylstra | Email: mzylstra@uwo.ca
  Professor: Jayshri Sabarinathan | Email: jsabarin@uwo.ca

- Ultrathin Metal-Dielectric Nanogratings for Multiwavelength Field Enhancement
  Lab: Toronto Nanofabrication Centre (TNFC) (University of Toronto)
  University of Toronto
  Designer: Katelyn Dixon | Email: katelyn.dixon@mail.utoronto.ca
  Professor: Nazir Kherani | Email: kherani@ecf.utoronto.ca

MNT: Other Technologies

- Biosensors: Fabrication and Characterization of Functionalized Organic Electrochemical Transistors (OECTs) for Wearable Biosensing Platform
  Lab: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Jiaxin Fan | Email: fan1@ualberta.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

- Biosensors: Organic Electrochemical Transistors (OECTs) based 9-Tetrahydrocannabinol (THC) Sensors
  Lab: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Darren Majak | Email: drmajak@ualberta.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

- Biosensors: Organic Thin-Film Transistors for Pressure Sensing Application
  Lab: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Michael Facchini-Rakovich | Email: mf4@ualberta.ca
  Professor: Manisha Gupta | Email: mgupta1@ualberta.ca

- Energy Storage Microdevices: Sustainable Flexible Materials and Devices Integrating Energy Conversion and Storage
  Lab: Thin Film Physics and Technology Research Center (GCM) (Polytechnique Montréal)
  Polytechnique Montréal
  Designer: Abdelaziz Gouda | Email: abdelaziz.gouda@polymtl.ca
  Professor: Clara Santato | Email: clara.santato@polymtl.ca

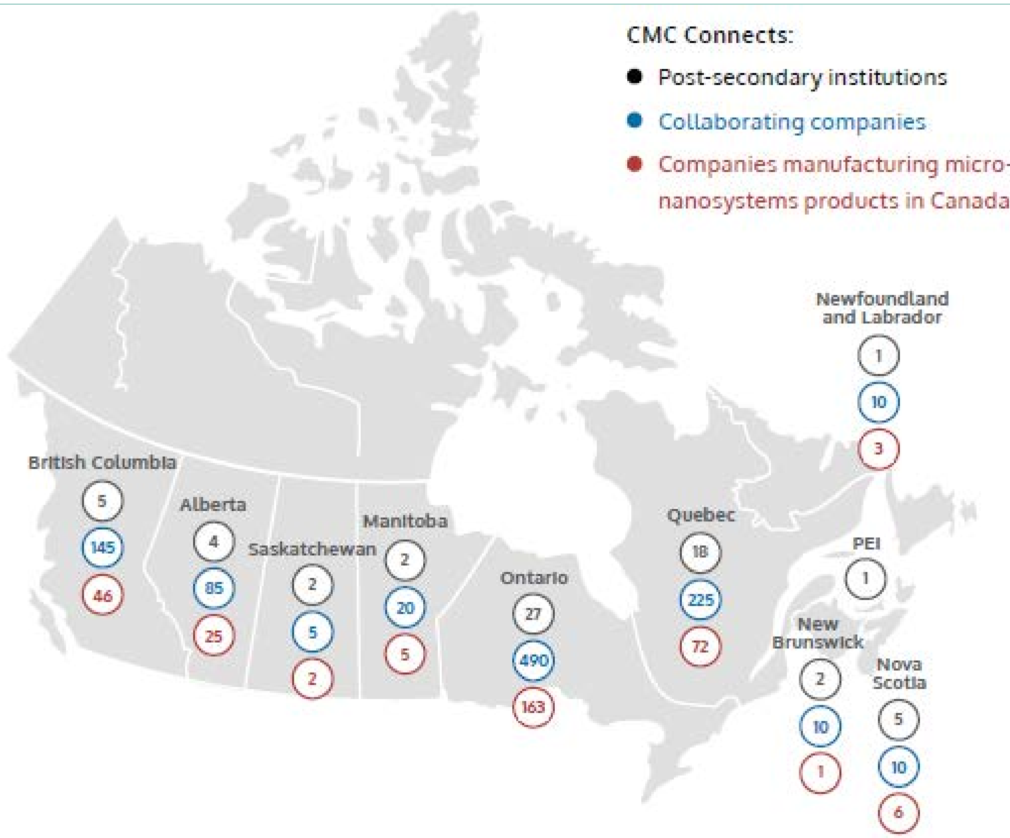
- Micro-assembly and Packaging: MRI-Compatible PET Detector Assembly in 2.5D
  Lab: 3IT.Micro (Université de Sherbrooke)
  Université de Sherbrooke
  Designer: Jonathan Bouchard | Email: jonathan.bouchard3@usherbrooke.ca
  Professor: Réjean Fontaine | Email: rejean.fontaine@usherbrooke.ca

- Microwave/Photonics: Transparent Metasurfaces
  Lab: Centre for Microfluidic Systems in Chemistry and Biology (CMS) (University of Toronto)
  University of Toronto
  Designer: Mahdi Safari | Email: mahdi.safari.iust@gmail.com
  Professor: Nazir Kherani | Email: kherani@ecf.utoronto.ca

Appendix A-1 – CNDN by the numbers

CMC Connects

CNDN is a national network of **10,000** academic participants and **1000** companies developing innovations in micro-nanotechnologies. CMC manages CNDN.



A Growing Community of Over 10,000 Users

1,275
Professors including 150 Research Chairs

3,720
Undergrads

3,405
Graduate Students

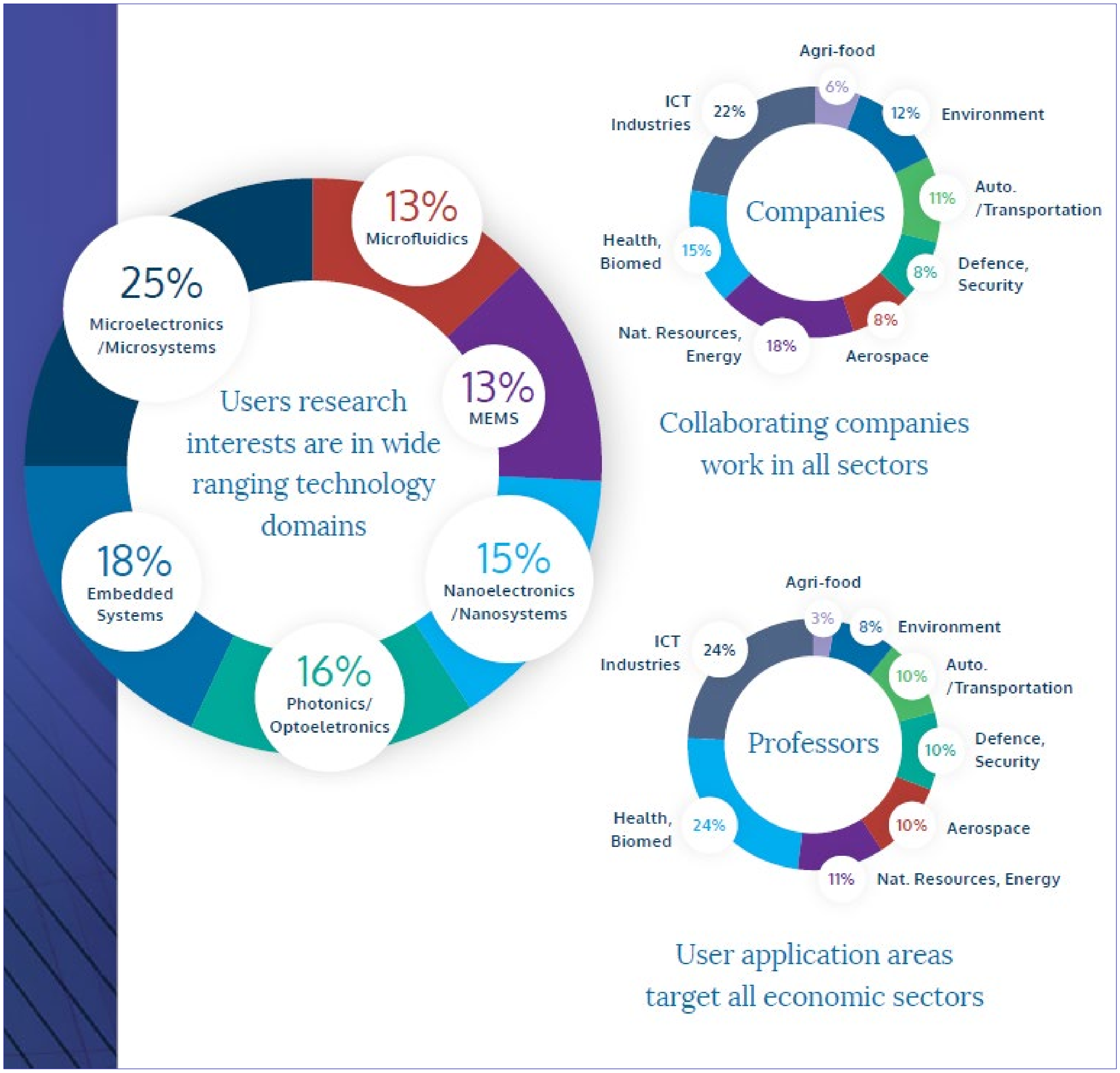
200
College Students

510
Post-Doctoral Fellows

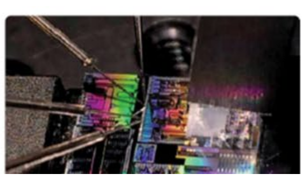
360
Research Staff

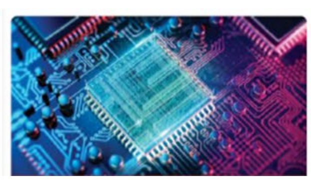
14 Companies and 3 Academics Outside Canada Directly Used Services

CNDN Research Interests

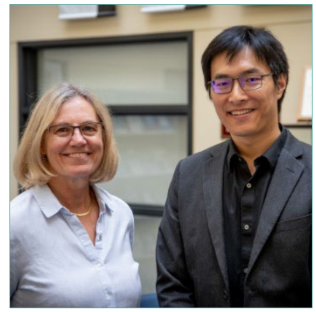


CNDN Technology Direction: The network facilitate access to state-of-the-art design, manufacturing, and testing facilities for foundational microsystems technologies - **microelectronics, photonics, embedded systems, and microelectromechanical systems (MEMS)** - technologies critical to enabling Canada's growing digital economy.

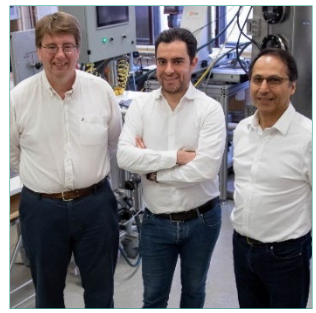


Appendix A-2 – Success Stories in 2019/20



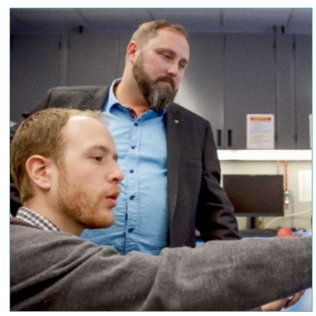
Commonplace material, extraordinary performance

Leslie Rusch and Wei Shi
Université Laval
An all-silicon modulator achieved the fastest-ever transmission on silicon photonics. Their low-cost, low-energy component, produced through standard foundry processes, solves a significant challenge in next-generation semiconductor design.
- Published February 2020



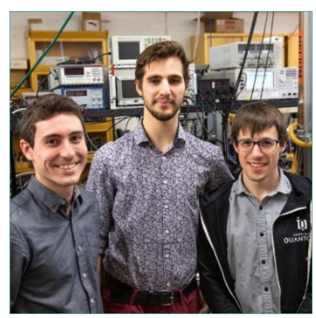
Sizing up a industrial solution

Pierre Sullivan, Amirreza Amighi, and Nasser Ashgriz
University of Toronto
Combining imaging, machine-learning, and statistical analytics to bring quality control to the tiny particles emitted by spray nozzles in a wide variety of industrial applications.
- Published November 2019



Adding a new dimension to light detection

Jean-François Pratte
Université de Sherbrooke
Ultra-sensitive detectors for capturing light signals are advancing the power and sophistication of a broad range of imaging technologies, from PET scanners to big-science endeavours such as neutrino detection.
- Published October 2019



A gem of a technology

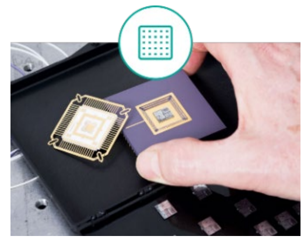
David Roy-Guay
Université de Sherbrooke
Using diamonds to find more diamonds - the novel diamond-based magnetometer prototype was chosen to be part of the Canadian Space Agency’s CubeSat Project. The quantum sensor technology shows promise in a wide variety of applications, including research in outer space.
- Published May 2019

Photo credit: Reinier deSmit

Read CMC Success Stories, including the examples listed above: www.cmc.ca/SuccessStories

Appendix B – Fabrication Services for Prototypes

Micro- Nanoelectronics



GF 8XP (130nm SiGe BiCMOS)
GF GF9HP (90nm SiGe BiCMOS)
GF 45 RFSOI
GF 22 FDSOI
GF 9WG
GF GlobalShuttle program:
- Options available on request

STMicroelectronics FD SOI 28nm CMOS
TSMC 65nm GP CMOS
TSMC 65nm LP CMOS
TSMC 0.13µm CMOS
TSMC 0.18µm CMOS
TSMC 0.35µm CMOS

AMS 0.35µm CMOS - options: Standard, Opto, High Voltage, Post Processing
Teledyne DALSA 0.8µm CMOS - options: Standard Voltage, High Voltage
National Research Council Canada (NRC) Gallium Nitride (GaN)

Photonics & Optoelectronics

AMF Silicon on Insulator, Passives and Actives
GF Silicon Photonics 9WG
Epitaxy - options:
- Canadian Photonics Fabrication Centre (NRC-CPFC) III-V Epitaxy on InP Substrates
- FBH-Berlin III-V Epitaxy on GaAs Substrates
- Landmark III-V Epitaxy on GaAs and InP Substrates

MEMS

MEMSCAP PiezoMUMPs
MEMSCAP PolyMUMPs
MEMSCAP - Post-processing for PolyMUMPS
Micralyne MicraGEM-Si™
Teledyne DALSA MIDIS™ Platform

Micro-Nano Technologies (MNT) Facilities Portal

40+ facilities located at universities across Canada

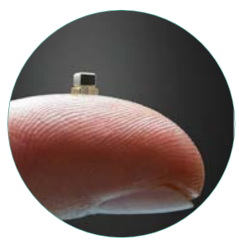
- Multi-project wafer services with affordable access to foundries worldwide
- Fabrication and travel assistance to prototype at a university-based lab
- Value-added packaging and assembly services
- In-house expertise for first-time-right prototypes

Don't hesitate to contact me about opportunities for industry and academic R&D.

Gayathri Singh
Sr. Engineer, Microelectronics
+1.613.530.4690
Singh@cmc.ca

This represents a sample of the prototyping products available to Canada's National Design Network. More information:

www.cmc.ca/FAB



www.cmc.ca/FAB

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CMC MICROSYSTEMS

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