THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
FALL/AUTOMNE 2023

# BULLETIN


SPECIAL ISSUE ON

## Complex Fluids and Microfluidics

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# CONTENT

FALL/AUTOMNE 2023



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# Editor's Letter

It is with great pleasure that we bring you the Fall 2023 issue of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*. This issue is dedicated to highlight advancements in **Complex Fluids and Microfluidics**. It is co-edited with the CSME Technical Committees (TC) in Microtechnology and Nanotechnology and Fluid Mechanics Engineering, represented by former TC chair Dr. **Mohsen Akbari** and current TC chair Dr. **Dana Grecov**, respectively. We hope you enjoy the issue.

The CSME 2023 Congress was held in May, 2023 in Sherbrooke, Québec and our colleagues at Université de Sherbrooke have provided us with a few highlights of the event. We look forward to the next CSME Congress which will be hosted by the University of Toronto. Please make sure to submit an abstract before the January 29, 2024 deadline.

The issue's *feature articles* highlight the use of microfluidics and complex fluids in the areas of healthcare, energy, and sustainability. Dr. **Bonnie Gray** shows us how flexible wearable microfluidic architectures can be used for rapid disease detection. Dr. **Ravi Selvaganapathy** and his colleagues at McMaster University highlight their new advancements on the development of superhydrophobic surfaces, a topic of critical interest for de-icing surfaces, such as wind-turbine blades. Finally, Dr. **Dana Grecov** shows us how green nano-lubricants can reduce friction losses, thereby increasing energy systems' efficiency.

A new generation of faculty members in Canada are also focusing on microfluidics and understanding complex flows and fluid dynamics. We highlight four of them: Dr. **Huiyan Li** (University of Guelph), Dr. **Houman Savoji** (University of Montreal), Dr. **Kevin Golovin** (University of Toronto), and Dr. **Giuseppe Di Labbio** (ÉTS Montréal). Dr. Li investigates the use of highly sensitive multiplexed biochips for more effective disease management and food safety. Dr. Savoji aims at developing 3D in-vitro models for predictive drug discovery and functional tissue-engineered implants. Dr. Golvin is addressing the need to phase-out environmentally hazardous "forever chemicals" by developing replacement technologies from sustainable and biologically inert materials. Finally, Dr. Di Labbio investigates the fluid dynamics of pulsed jet arrangements for aquatic propulsion, batch mixing and aerodynamic flow control.

Young researchers in Canada can be found not only in academia but also in industry. In our *Q&A* section, we asked Dr. **Amir Seyfoori**, Founder and CEO of Apricell Biotechnology Inc., about his experience transitioning from academia to entrepreneurship.

To complement the articles above, the *ME News* section highlights recent developments in microfabrication. In the CSME *history* section, Dr. Altintas provides the second installment of the history of mechatronic programs in Canada, this time reviewing Western University's program.

This issue is the last with Dr. **Pouya Rezai** as associate editor. Dr. Rezai has been both editor (2017-22) and associate (2016-17 and 2022-23) editor of the CSME *Bulletin* and has been responsible for many changes that have substantially improved the quality of the *Bulletin*, such as suggesting that each issue focused on a technical topic, helping develop the *Bulletin* editorial policy, creating an open call process for contributions, and helping new editors to get started. The CSME *Bulletin* Editorial Board will miss him, but also look forward to working with our new associate editor, Dr. **Ryan Willing** (Western University). Ryan has been the technical editor for the journal (2019-2023) and brings with him the experience and dedication required to continue to improve the CSME *Bulletin*.

The next CSME *Bulletin* issue will highlight recent advancements on Sustainable Energy Systems and will be co-led by Drs. **Xili Duan** and **Sunny Li**, chairs of the Advanced Energy Systems and Heat Transfer CSME Technical Committees. Please let the CSME editors know your suggestions for future issues.

We hope you enjoy this issue of the CSME *Bulletin*.

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*Professor, Department of Mechanical Engineering*
*University of Victoria*

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# President's Message

## Message du Président

Dear CSME members,

It brings me immense pleasure to update you on the noteworthy progress and initiatives that the Canadian Society for Mechanical Engineering (CSME) has diligently undertaken.

A highlight that exemplifies the CSME's commitment to excellence was the resounding success of the 2023 International CSME Congress, hosted in the picturesque city of Sherbrooke, Quebec. This flagship event brought together the brightest minds in the field, featuring over 400 papers and associated meetings that spanned a vast spectrum of topics vital to the mechanical engineering discipline. The Congress served as an invaluable platform for the exchange of knowledge and the cultivation of meaningful networking opportunities. Building on this triumph, we eagerly anticipate the forthcoming 2024 CSME Congress, which will be organized by our esteemed colleagues from the University of Toronto and is scheduled to take place from May 26th to May 29th, 2024. I eagerly look forward to reuniting with many of you at this prestigious event.

In alignment with our resolve to promote equity, diversity, and inclusion (EDI) within the CSME and the broader mechanical engineering profession, we have taken significant strides. To this end, we have established a dedicated EDI committee mandated with crafting comprehensive strategies, fostering awareness of anti-racism, and creating innovative initiatives and opportunities that will drive positive change throughout our profession. We look forward to implementing their eventual recommendations starting in 2024.

Furthermore, it is with great pride that we announce the recipients of the CSME's 2023 technical and regular awards, honoring exceptional individuals who have made significant contributions to the field of mechanical engineering. You will find their names and citations listed in this issue. These honorees exemplify the pinnacle of excellence in mechanical engineering, and their contributions are truly inspiring. We extend our heartfelt congratulations to each of them.

As we move forward into the next year, we remain dedicated to the continued growth and prosperity of the CSME. I am happy to report that a total of 78 new professional members have joined the society this year. Your continued support, engagement and dedication are indispensable to our shared success. Together, we will shape the future of mechanical engineering in Canada and beyond.

Thank you for your unwavering commitment to the CSME. I look forward to the opportunities and challenges that lie ahead and to the continued collaboration with all of you.

Warmest regards,

Dr. **ALEKSANDER CZEKANSKI**, PhD, MBA, P.Eng., FCSME, FEIC, FCEEA
CSME *President*
*Associate Professor, Mechanical Engineering*
*Lassonde School of Engineering, York University*

Chers membres de la SCGM,

C'est avec une immense joie que je vous informe des progrès notables et des initiatives que la Société canadienne de génie mécanique (SCGM) a entrepris avec diligence.

Un point culminant qui illustre l'engagement de la SCGM envers l'excellence a été le succès retentissant du Congrès international de la SCGM 2023, qui s'est tenu dans la pittoresque ville de Sherbrooke, au Québec. Cet événement phare a réuni les esprits les plus brillants de la discipline, avec plus de 400 présentations et des réunions associées couvrant un large éventail de sujets essentiels pour le génie mécanique. Le Congrès a servi de plateforme inestimable pour l'échange de connaissances et la création de précieuses opportunités de réseautage. Forts de ce succès, nous attendons avec impatience le prochain Congrès de la SCGM en 2024, qui sera organisé par nos estimés collègues de l'Université de Toronto et est prévu du 26 au 29 mai 2024. J'ai hâte de vous retrouver nombreux à cet événement prestigieux.

Conformément à notre engagement résolu à promouvoir l'équité, la diversité et l'inclusion (EDI) au sein de la SCGM et de la profession du génie mécanique en général, nous avons fait des progrès significatifs. À cette fin, nous avons créé un comité EDI l'avons chargé d'élaborer des stratégies globales, de sensibiliser à l'antiracisme et de créer des initiatives et des opportunités innovantes qui favoriseront un changement positif dans notre profession. Nous sommes impatients de mettre en œuvre leurs recommandations à partir de 2024.

De plus, c'est avec une grande fierté que nous annonçons les lauréats des prix techniques et réguliers de la SCGM pour 2023, honorant des individus exceptionnels qui ont apporté une contribution significative au domaine du génie mécanique. Vous trouverez leurs noms et leurs citations répertoriés dans ce numéro. Ces lauréats incarnent le summum de l'excellence en génie mécanique, et leurs contributions sont vraiment inspirantes. Nous leur adressons nos plus sincères félicitations.

Alors que nous avançons dans la prochaine année, nous demeurons dévoués à la croissance continue et à la prospérité de la SCGM. Je suis heureux de vous informer que 78 nouveaux membres professionnels ont rejoint la société cette année. Votre soutien, votre engagement et votre dévouement continus sont indispensables à notre succès commun. Ensemble, nous façonnerons l'avenir du génie mécanique au Canada et au-delà.

Merci pour votre engagement indéfectible envers la SCGM. J'attends avec impatience les opportunités et les défis à venir, ainsi que la poursuite de la collaboration avec chacun d'entre vous.

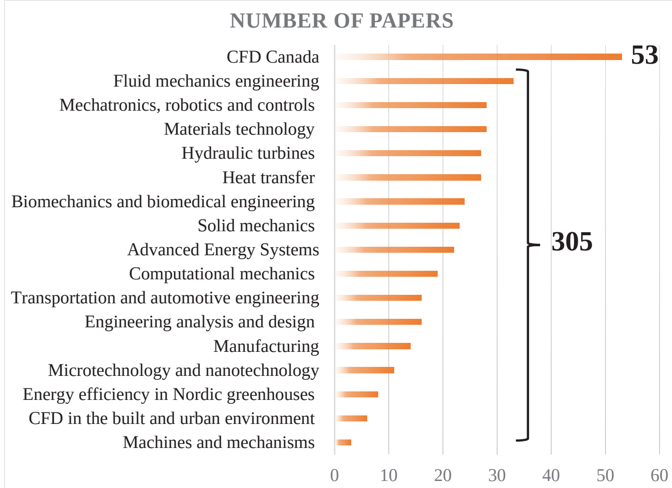
Bien cordialement,

Cordialement,

Dr. Aleksander Czekanski, PhD, MBA, PEng, FCSME, FEIC, FCEEA
Président de la SCGM
Professeur agrégé, Génie mécanique
Université York

PHOTO: LASSONDE SCHOOL OF ENGINEERING

# International Congress 2023




The Canadian Society of Mechanical Engineering (CSME) and the Computational Fluid Dynamics (CFDCanada) societies organized their annual joint international congress from May 28th to May 31st, 2023, at the Faculty of Education, Université de Sherbrooke, Canada. The primary objective was to provide an attractive platform for students, engineers, and researchers to present and discuss novel ideas and share their areas of interest in all fields related to mechanical engineering with delegates from not only across Canada but also from around the world. More than 450 attendees from 8 countries presented approximately 360 accepted contributions (after peer-review) in 10 parallel sessions (See Figure). These presentations were distributed across 18 symposia. The congress included five plenary lectures, two keynote lectures, one workshop, and 358 podium presentations spread across 18 symposia. Additionally, two companies, Siemens and Creaform, presented their R&D activities. Two social events were also organized, along with tours of two research facilities — the Centre de recherche acoustique-signal-humain de l'Université de Sherbrooke (CRASH-UdS) and the Interdisciplinary Institute for Technological Innovation (3IT).

The attendance breakdown at the event provided a fascinating insight into the diverse composition of participants. A total of 10.7% of attendees encompassed both private or semi-private companies and foreign universities including institutions from France, the USA, Spain, China, and the UAE, illustrating the engagement of the industrial sector and the international dimension of the event. A significant majority of attendees came from Canadian universities (of 89.3%), with the highest representation from Quebec at 49.1%, followed by Ontario at 33.5%, Alberta at 8.2%, and 9.2% from other provinces. Further analyzing the university participation, the top 10 institutions with the most attendees emerged were as follows: Université de Sherbrooke took the lead with 51 attendees, closely followed by École de technologie supérieure with 39 participants. Université Laval and the University of Alberta both had 30 attendees, while Concordia boasted 29, York University 28, Polytechnique Montréal 26, Toronto Metropolitan University 23, Western Ontario 16, and the University of Toronto with 15 attendees.


**CSME INTERNATIONAL CONGRESS WELCOME RECEPTION.**

The publication of the proceedings in "Progress in Canadian Mechanical Engineering Volume 6" is currently being worked on. These proceedings will be published by the University of Sherbrooke library, and a unique DOI number will be assigned to each paper/abstract.

We would like to express our gratitude to our sponsors and supporters, the CSME and CFDCanada communities, especially the two Boards of Directors, for providing us with the opportunity to host this congress. We also extend our thanks to the CSME Congress Committee for their support, drawing from their advice and experience from previous CSME congresses, as well as to all symposium Chairs/co-Chairs, reviewers, and attendees. Destination Sherbrooke, owned by the City of Sherbrooke, generously supported the CSME/CFD Canada 2023 Congress by providing attendees with free public transport passes and lanyards and badges. We highly appreciate their assistance.

We wish the Organizing Committee of the CSME/CFD Canada 2024 Congress at the University of Toronto all the best and look forward to seeing the community there from May 26 to May 29, 2024.

Professors **LEYLA AMIRI**, **STÉPHANE MOREAU**, and **SÉBASTIEN PONCET**
*CSME/CFD Canada 2023 Organizing Committee*

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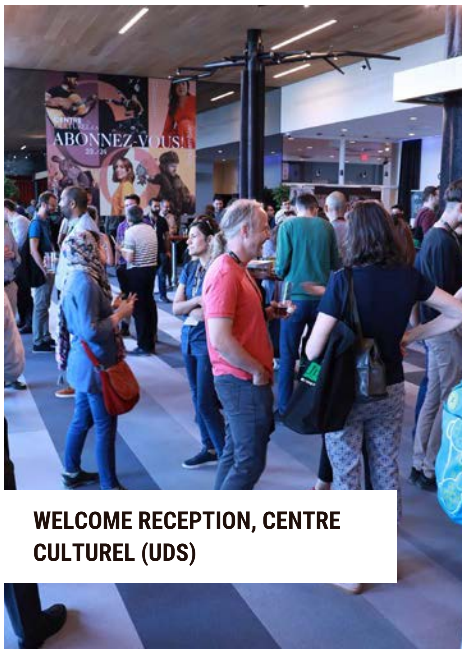
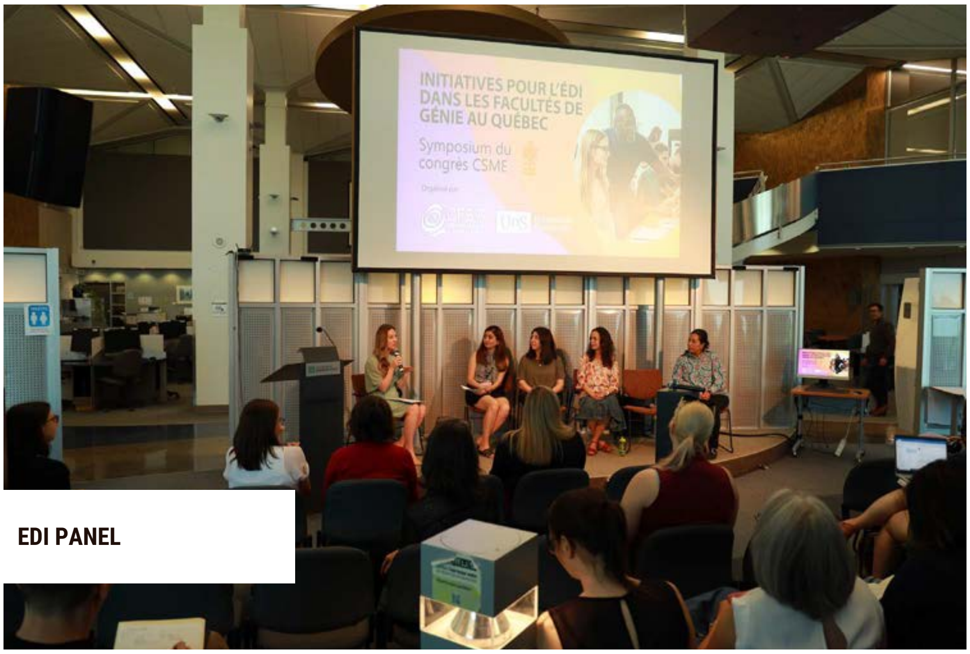
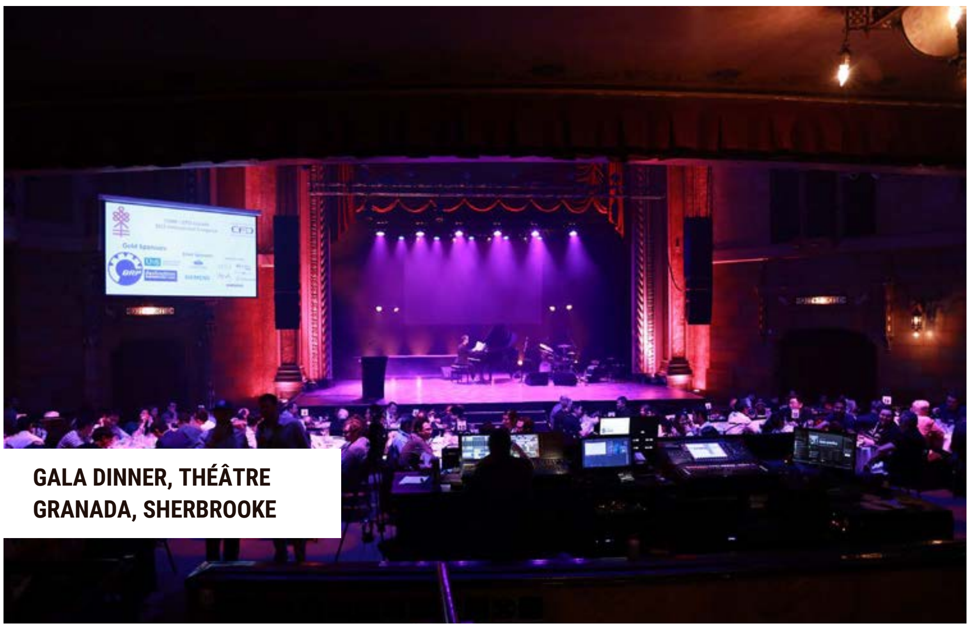



**WELCOME RECEPTION, CENTRE CULTUREL (UDS)**




**EDI PANEL**



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# News from the Transactions of the Canadian Society for Mechanical Engineering (TCSME)

### *New CSME–TCSME Agreement: Page charge waivers for CSME professional members*

Growing quality Canadian-based research in *TCSME* and strengthening relations with our affiliated society are top of mind for our journal community. Along with the new Canadian Research Knowledge Network (CRKN) open access deal signed earlier this year (http://bit.ly/3tYMO69), CSME members are now eligible to publish in *TCSME* free of charge.

*TCSME* is pleased to share that a new agreement with the Canadian Society for Mechanical Engineering will provide support to waive journal page charges for CSME professional members choosing to publish in *TCSME*. Support for approximately a dozen articles will be available on a first-come, first-served basis to manuscripts submitted beginning January 1st of each calendar year that contain at least one author who holds professional membership with the CSME and is affiliated with one of the society's Sustaining departments.

We are hopeful that these agreements will bring new opportunities for growth, increase the visibility and accessibility of research published in *TCSME,* and benefit our authors and research community in fulfilling future open access mandates set in place by tri-council funding in Canada.

### *Call for Papers: Advanced Manufacturing in Healthcare Special Issue*

TCSME is excited to share an open call for papers for its latest thematic Special Issue: Advanced Manufacturing in Healthcare. See https://bit.ly/40qBlsj for more information.

The Food and Drug Administration (FDA) of the United States defines the phrase "advanced manufacturing" as a collective term for novel medical product manufacturing technologies that have the potential to improve drug quality, alleviate shortages of medicines, and speed up time-to-market. This Special Issue aims to publish high-quality research articles, review papers, and short communications related to, but not limited to, rapid prototyping, 3D printing, 3D metrology, and advanced biomaterials with exotic properties (i.e., metamaterials) in healthcare, as well as bioprinting, microfluidics, bio-MEMS, and medical devices.

Researchers are encouraged to submit manuscripts that focus on either fundamental or applied research. CSME members who submit to this Special Issue will qualify for the above-mentioned deals.

This Special Issue will be guest edited by Drs. **Mohsen Akbari**, University of Victoria; **Hamid Akbarzadeh**, McGill University; **Ali Ahmadi**, École de Technologie Supérieure; and **Farbod Khameneifar**, Polytechnique Montréal.

Submission deadline for manuscripts: **March 31, 2024**.

Please visit the following links for more information on:

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For general inquiries, or questions regarding the new CSME page charge waiver agreement, contact the journal's development specialist Brandi Shabaga at Brandi.Shabaga@cdnsciencepub.com.

Dr. **MARIUS PARASCHIVOIU**, PhD, FCSME, FEIC
*Editor-in-Chief, TCSME*
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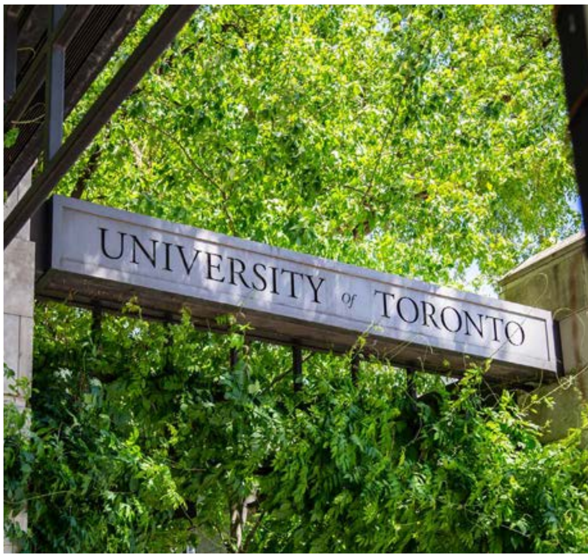
*Concordia University*




# CSME/CFD 2024

Canadian Society for Mechanical Engineering International Congress

31st Annual Conference of the CFD Society of Canada

May 26-29, 2024 - University of Toronto

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**Call for papers**

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Deadline to submit: **January 29, 2024**

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# Microfluidics for flexible and wearable devices and systems

MICROFLUIDICS IS THE SCIENCE AND TECHNOLOGY of manipulating very small (e.g., nanolitre to picolitre) volumes of fluid in channels whose geometries are most easily measured in tens to hundreds of micrometres. Microfluidics emerged over the last three decades and has been applied to a wide range of applications in biology and medicine through development of sample-to-answer systems, point of care diagnostics, and labs-on-a-chip that are inexpensive and use only small amounts of sample and reagent. Microfluidics often finds a place behind the scenes enabling important developments such as drug discovery, disease detection and personalized medicine, pathogen detection, and DNA analysis. Arguably the most prominent microfluidics devices are paper based lateral flow assays for, e.g., detection of the SARS CoV-2 virus.

Historically, microfluidics has been heavily influenced by the materials and techniques available for microfabrication. Traditionally, microfluidic devices were fabricated in rigid substrates such as silicon or glass, or flexible materials such as polydimethylsiloxane (PDMS) that are bonded to rigid substrates. Over the past two decades, however, microfluidics has seen a paradigm shift to polymer-based systems, including not only relatively rigid thermoplastic polymers microfabricated using, e.g., injection molding and hot embossing[1], but flexible polymer devices and systems. Mechanically flexible polymers such PDMS, polyimide, polyurethane, paper, polyethylene terephthalate (PET), off-stoichiometry thiol-ene-epoxy (OSTE+), gels, and textiles have been investigated for microfluidics[2], for development of high-stroke actuators for pumps and valve arrays[3,4], as well as for flexible and wearable microfluidic-based devices and systems[5,6,7]. Flexible microfluidics are particularly attractive when combined with flexible electronics to realize combined sensor and actuator systems that are highly portable, mechanically flexible, and can be worn[8,9]. However, there are many challenges that must be overcome for flexible and wearable microfluidics to succeed. These challenges fall into three main categories: biological metric, technological, and sustainability challenges. We examine each of these challenges, and recent advancements to overcome them. Such advancements include modular and integrated approaches on both flexible and stretchable polymer substrates, as well as textiles and skin-attachment based devices. We present example applications highlighting these challenges, as well as potential benefits of flexible and wearable microfluidics.

DR. BONNIE GRAY, PhD, P.Eng.

*Dr. Gray is a Professor of Engineering Science at Simon Fraser University (SFU) in Canada. She received the PhD from the University of California, Davis in 2001. Dr. Gray has published primarily on novel materials and fabrication methods; flexible and wearable microfluidics and biosensors; point-of-care instruments; and chip-based cell trapping methods. She has given over 25 invited/keynote/plenary presentations at international conferences, and has chaired the SPIE Conference on Microfluidics, BioMEMS, & Medical Microsystems from 2014-2024. Dr. Gray was Chapter Chair for the Vancouver IEEE Electron Devices Society (EDS) from 2007-2017, and is on the Editorial Board of the* IOP Journal of Micromechanics *and* Microengineering. *She is active in IEEE awards committees and EDI initiatives, including the IEEE Women in EDS Committee and Women of Wearables.*



***Biological metric challenges***

While devices such as wearable glucose sensors may take measurements using interstitial fluid or blood, most wearable microfluidic devices are concerned with analytes found in perspiration, or other biofluids such as tears, saliva, or breath. While researchers borrow heavily from more traditional rigid-material microfluidics to determine what can be measured in saliva, blood, breath, or urine, other less commonly sampled fluids such as interstitial fluid, tears, and sweat are not as well studied. For example, what biomarkers found in such fluids may be useful to determine overall health or monitor specific conditions?

Significant research has been performed to answer these questions. For example, tear glucose levels appear to at least somewhat follow those found in blood, although with high variability from person to person[10]; however, it is unknown if tear glucose levels are adequate for long-term monitoring of diabetes. Even so, glucose levels in tears have been measured with flexible biosensors for contact lenses[11,12] providing an alternative to more invasive blood collection. Perspiration, or sweat, is also an attractive sample in both availability and content[13], and can be collected passively or via electrochemical stimulation[14]. Potassium and other electrolytes, skin pH, glucose, lactate, and urea are all found in sweat. Some of these analytes reflect certain health conditions, such as potassium levels for cystic fibrosis[15] and skin pH for dehydration levels[16]. However, some important biomarkers, such as lactate, while known to play a role in assessing tissue oxidation, physical exertion, and wound healing[17], still need further study. Cytokines which are important indicators of inflammation, are another biomarkers in sweat for which scientific studies are still in progress[18]. In any case, scientists and engineers are presented with a "chicken and egg problem": which comes first, the wearable technology to non-invasively measure important biomarkers over time, or the studies to determine what the concentration of various biomarkers mean from a health perspective?

***Technological challenges***

As engineers, it is often technological challenges that we are most concerned with, of which there are many for development of flexible and wearable microfluidics. Such microfluidic devices and systems must satisfy a large number of requirements, including: performance (e.g., sensitivity and selectivity for sensors; cooling levels for body cooling systems; or drug delivery rates); be lightweight, water resistant, rugged, flexible/stretchable, inexpensive, and biocom-

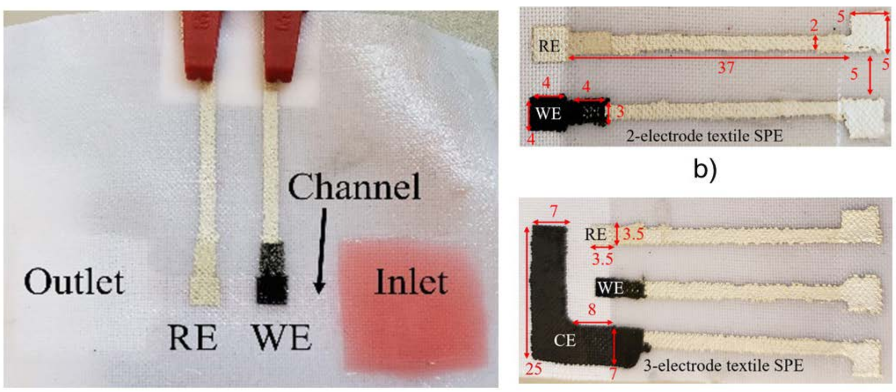


FIG. 1: A) PH SENSOR FULLY SCREEN-PRINTED ON TEXTILE SUBSTRATE WITH INTEGRATED SCREEN-PRINTED MICROFLUIDIC CHANNEL; B) CLOSE-UP OF 2-ELECTRODE SENSOR DESIGN SHOWING LATERAL DIMENSIONS IN MILLIMETERS; C) 3-ELECTRODE DESIGN. (ADAPTED[17,21] WITH PERMISSION)

patible; and not impeded motion. For many of these requirements, polymer-based systems are very attractive.

One main challenge is that while flexible materials can easily produce passive microfluidic structures such as channels and reaction chambers that conform to body or other contours, they are often difficult to integrate with active devices such as electronic sensors and electromechanical actuators. To meet this challenge, many techniques have been developed. For example, we develop and employ conductive polymers[7,8,9] and geometries such as Peano curves for easy flexing and stretching of electronic traces[19]. Other developments include devices that are adhered to the skin in a similar fashion to temporary tattoos[13], and 3D printed integration[20] of passive microfluidics and active devices. In any case, microfluidic systems may be built of modular layers, with electronics/sensors and microfluidics in separate stackable layers[5].

Another main challenge for microfluidic sensor-based systems is getting samples to the sensor. While tattoo type sensors sit directly on sweating skin, other technologies must provide a means of transport. Paper and textile-based devices may rely on capillary action to passively transport sample[21]. For example, *Figure 1* shows a fully screen-printed pH sensor on a textile substrate with integrated screen-printed microfluidic channel. We developed this sensor using only inexpensive screen-printing methods to define electrodes and sample delivery to the sensor surface, which is accomplished by using capillary action along a channel defined in the textile by printed hydrophobic barriers to confine the fluid flow. We also employ other flexible actuation techniques for pumping, such as high-stroke flexible magnetic polymer actuators[3,4].

Finally, flexing a device should not change device operation; while a flexible microfluidic system might sit close or be attached to the body, the geometries of these structures should not significantly change around body contours or as the body moves, as this can significantly alter device performance[2]. *Figure 2* shows a mixing structure that we developed as a demonstration of a screen-printed microfluidic device, showing operation of the mixer both while flat and while wrapped around a tube used to simulate a body contour such as the arm. The exception, of course, is situations in which the device in question is used as a sensor to measure body contour or motion.

***Sustainability challenges***

Clothing and consumer electronics industries face many sustainability and recyclability challenges already even without the addition of new materials and devices that may be difficult to extract and/or be intended to be disposable. Some microfluidic devices based on bio-degradable materials exist, such as microneedles[22] and microfluidic channels fabricated from polylactic acid, polyglycolic acid, and/or their copolymers (PLGA)[23]; and biodegradable biosensors[24]. Finally, power considerations are still an impediment to successful wearable microfluidics development. Batteries are not optimal from a sustainability standpoint, and many alternative methods have been developed to meet wearables' power supply challenges, including supercapacitors[25], fuel cells[26], and physical energy harvesting. We are currently working to combine wearable biochemical sensors with microbial fuel cells, as the technology used to develop these different devices can be quite similar.

***Summary***

As the fields of flexible electronics and microfluidic-based labs-on-a-chip continue to advance, developments at the intersection of these fields are particularly exciting. We have presented a short review of recent approaches for flexible and wearable microfluidics, including major challenges and recent advancements to provide solutions to these challenges. As this field continues to grow, scientists and engineers must work together to produce flexible and wearable microfluidics that have high performance, while also being cost-effective and comfortable.

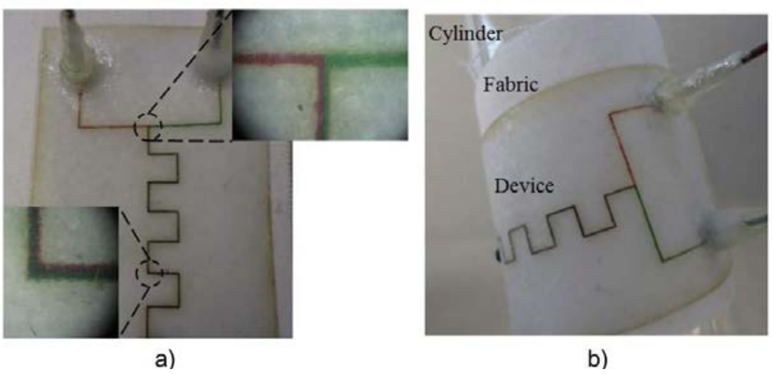


FIG 2: TESTING OF THE FLEXIBLE FLUIDIC MIXER ON TEXTILE SUBSTRATE: A) FLAT SURFACE SHOWING MIXING AND CLOSE-UPS OF DIFFERENT SECTIONS OF THE CHANNEL; B) MIXER OPERATION ON CURVED CYLINDER SHOWING UNALTERED MIXING OPERATION. (REPRODUCED[7] WITH PERMISSION)

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# SUPERHYDROPHOBIC SURFACES

## From laser treatment of polymeric surfaces and behaviour of Newtonian and non-newtonian fluids with them on impact

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SINCE THE REVELATION OF THE LOTUS EFFECT, which demonstrated the remarkable ability of lotus leaves to repel water and effortlessly cleanse themselves in the process[1], there has been a burgeoning interest in the development of hydrophobic surfaces and a deep dive into the underlying principles. Two key factors counted when considering the self-cleaning property observed in lotus leaves: the contact angle and the sliding angle[2]. These concepts have given rise to the study and application of hydrophobic and superhydrophobic surfaces across a wide array of fields, ranging from de-icing and defogging to self-cleaning functionalities, antimicrobial coatings, and efficient water/oil separation techniques[3,4].

Surfaces boasting contact angles greater than 150° are labeled as superhydrophobic. To provide a theoretical understanding of droplet behavior on hydrophobic surfaces, two fundamental models have been established: the Wenzel[5] and the Cassie-Baxter[6] model as shown in *Figure 1a*. In the Wenzel model, fluids completely wet and penetrate the rough surface structures. In contrast, the Cassie-Baxter model proposes that wetting occurs primarily at the tips of the solid rough features on the surface, leading to the entrapment of air bubbles in the asperities[6]. Wenzel's theory correlates surface roughness with the ratio of actual surface area to the projected surface area, thereby contributing to heightened surface hydrophilicity. Conversely, the Cassie-Baxter equation computes the overall surface contact angle based on factors like the solid-air surface fraction and surface roughness. Generally, the Wenzel state is applied to sticky surfaces with substantial contact angle values, while the Cassie-Baxter state finds suitability for non-wetting surfaces.

There are diverse strategies employed in the creation of superhydrophobic surfaces, each tailored to the specific needs of the application. One prevalent method involves the meticulous engineering of micro and nanostructures on the surface, achieved through techniques such as laser treatments[7]. These processes significantly increase the surface roughness, preventing the contact of liquids and making the surface superhydrophobic. Alternatively, chemical coating plays a pivotal role in altering surface properties. Through advanced electrochemical processes and salinization, surfaces can be rendered highly water-repellent[8]. This chemical modification not only transforms the surface energetics but also ensures long-lasting superhydrophobicity. Another intriguing approach involves the application of external stimuli. By subjecting the surface to controlled heating, the wetting properties can be dynamically manipulated[9].

Our research team is currently focused on investigating the dynamic behavior of fluids on superhydrophobic surfaces. We are particularly interested in assessing how these surfaces interact with both Newtonian and non-Newtonian liquids, including shear-thinning and shear-thickening fluids. Our material of choice for achieving exceptional superhydrophobicity is graphene, more specifically, laser-induced graphene (LIG). We have successfully created LIG by employing direct $CO_2$ laser writing on polycarbonate sheets, a widely used plastic material in daily life, as shown in *Figure 1b*. The resultant LIG exhibits remarkable non-wetting properties, showcasing water contact angles that can reach up to 170.6°.

Graphene, owing to its outstanding electrical and thermal conductivity, chemical stability, and antimicrobial attributes, has found its application in a diverse range of fields[10,11]. These

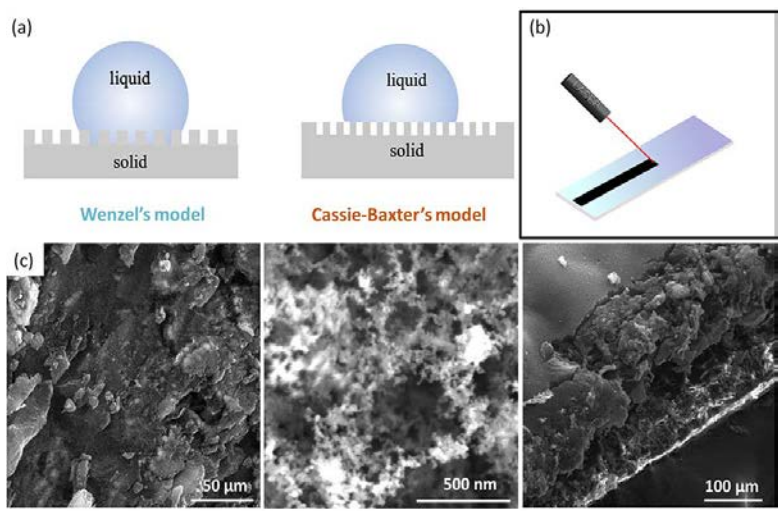


FIG. 1: FIGURE 1. (A) SCHEMATIC OF WENZEL'S MODEL AND CASSIE-BAXTER'S MODEL (B) SCHEMATIC OF LIG FABRICATION. (C) SEM FIGURES OF TOP- AND CROSS-SECTIONAL VIEW OF LIG SURFACES WITH HIERARCHICAL STRUCTURES.

applications span from energy storage solutions to biomedical devices and biosensors, among others. What sets our research apart is the endeavor to fabricate LIG with superhydrophobic property, which opens exciting possibilities and applications.

To delve into the reasons underpinning LIG's wettability characteristics, we have conducted an in-depth analysis of its surface morphology. Using scanning electron microscopy (SEM), we have gained the capability to scrutinize micro/nanostructures present on the surface. The SEM images in *Figure 1c* reveal a sponge-like structure in LIG, characterized by hierarchical features. Micrometer-scale flakes are discernible, distributed across the surface with a layered arrangement. Importantly, nanometer-scale spherical structures are visible on these flakes, and it is this intricate hierarchy that contributes to the high surface area and roughness, which, in turn, underpins the non-wetting properties exhibited by LIG.

Our research journey also involves the evaluation of the dynamic interactions between LIG and a diverse range of liquids. These interactions have been meticulously captured using a high-speed camera, allowing us to gain deeper insights into the behavior of fluids on superhydrophobic surfaces. Our exploration began by subjecting the prepared surface to an initial examination with water, aimed at unveiling its inherent surface properties. As illustrated in *Figure 2*, the small water droplet was observed to bounce off the surface, and this phenomenon continued several times until the droplet's departure. This extraordinary 'bouncing back' and the absence of residual water traces affirmed the remarkable non-wetting characteristics of the surface. Such surfaces hold immense promise for applications requiring non-wetting and self-cleaning attributes. The same test was conducted on untreated Polycarbonate surface as control set where the water droplet stayed still after coming in contact. Furthermore, owing to its remarkable conductivity, the surface can serve as an efficient heater, and its superhydrophobicity can be harnessed for anti-icing and thermal management purposes. Our investigations extended to the exploration of non-Newtonian fluids, where we introduced a simple shear-thickening fluid, such as a corn starch solution, to this remarkable surface. The results unveiled a distinct behavior of the shear-thickening fluid on the surface. As depicted in *Figure 3a*, while the prepared surface retained its hydrophobic nature, there was no longer the pronounced bouncing-off effect which was due to the increased viscosity due to shear thicknening effect introduced as the droplet comes in contact with the surface. However, upon tilting the surface, the droplet rolled along the surface due to non wettability of the surface. As demonstrated in *Figure 3b*, this rolling action of the shear-thickening fluid exhibited the ability to cleanse the surface, effectively removing loose layers of graphene from its topmost layer. This

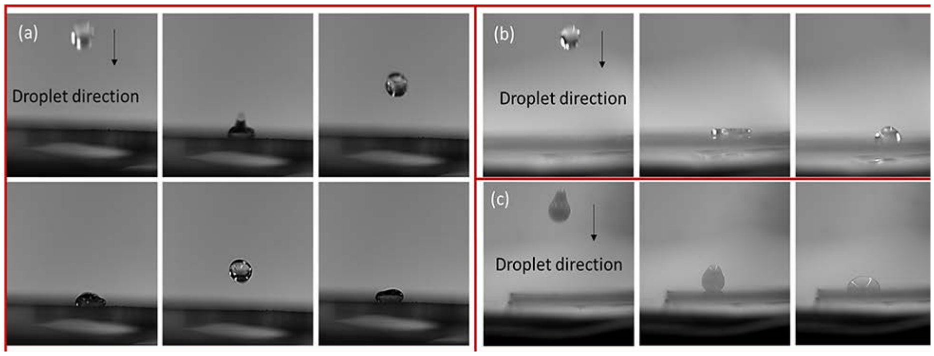


FIG. 2: THE INTERACTION OF WATER DROPLET WITH (A) LIG SURFACE, (B) PC SURFACE.

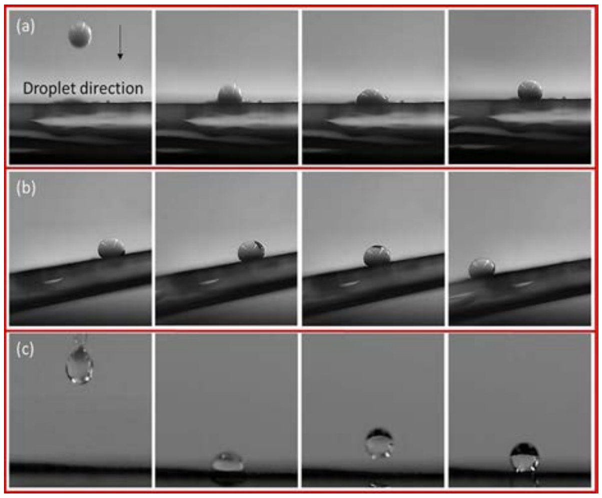


FIG. 3: THE INTERACTION OF SHEAR THICKENING FLUID WITH LIG SURFACE: A) FLAT LIG SURFACE AND B) TILTED LIG SURFACE.

novel interaction holds the promise of diverse applications, showcasing the versatility of superhydrophobic surfaces in our quest for innovative materials and engineering solutions. Our examination of a shear-thinning solution yielded results more similar to a water droplet as shown in *Figure 3c* . Utilizing a commonplace fluid like a gellan gum solution in water, a droplet was dropped onto the prepared surface. Upon the impact of the droplet on the surface, the bouncing-back behavior was observed. However, the droplet exhibited a shorter rebound compared to Newtonian fluids. The key to understanding this unique behavior lies in the inherent properties of the shear-thinning solution. As the droplet impacted the surface, the solution's viscosity, influenced by its shear-thinning nature, decreased under the applied stress. Consequently, the droplet's kinetic energy dissipated rapidly due to the reduced internal friction within the fluid. This efficient energy dissipation mechanism curtailed the bouncing motion, resulting in the observed abbreviated rebound duration.

In conclusion, our findings emphasize the need for tailored approaches when designing superhydrophobic surfaces for specific applications, taking into account the rheological properties of the liquids involved. As we continue our journey, these discoveries serve as a stepping stone toward innovative solutions, guiding the development of advanced materials capable of revolutionizing diverse fields, from healthcare to manufacturing, and beyond.

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# GREEN NANO-LUBRICANTS FOR SUSTAINABLE ENGINEERING


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INDUSTRIAL LUBRICANTS ARE WIDELY USED in mechanical systems to reduce wear and energy losses. With the increasing demand for sustainability, developing environmentally friendly lubricants has become crucial. The newly developed lubricants should meet the lubrication standards needed to compete with and replace the current lubricants in the market. Nanomaterials are the most recent additives proposed for formulating lubricants. The nano-lubricants are colloidal suspensions composed of a base fluid and suspended nanoparticles that act as friction modifier (FM), antiwear (AW), and extreme pressure (EP) additives. The lubricants can be considered as "green lubricants" when all components of the formulation are biodegradable. Some examples of green lubricants include vegetable oil[1], waste cooking oil, or water-based lubricants with biodegradable nanomaterial additives, including cellulose nanocrystals (CNC)[2,3], carbon nanotubes[4], graphene nanoparticles[5], and aluminum oxide nanoparticles[6].

In this article, we review the current findings on the lubrication performance assessment of green nano-lubricants. The characterization techniques used for understanding their lubrication performance, the proposed mechanisms for explaining their improved lubrication performance, and the optimization of the lubrication performance by adjusting different parameters are presented. Lastly, some of the challenges regarding the development of green nano-lubricants are discussed.

### *Characterization Techniques*

There is a wide range of characterization techniques contributing to the understanding of the lubrication performance of green nano-lubricants. A tribometer is the most common tool for assessing the friction reduction of a lubricant. This device simulates the evolution of the friction coefficient at the interface between tribo-pairs (the two sliding surfaces), lubricated by a specific lubricant. Some of the most common tribo-pairs are four-ball, pin-on-disk, and pin-on-flat (*Figure 1*). The research has shown that the geometry and orientation of the tribo-pairs would significantly affect the magnitude of the friction coefficient. As such, the friction reduction of nano-lubricants is system-dependent, and under different testing conditions, they may respond differently[7,8]. To evaluate the load-carrying capacity and EP condition, nano-lubricants are usually tested using four-ball geometry. Whereas to simulate FM and AW conditions, tribometry under pin-on-disk or pin-on-flat configurations is preferred[9,10]. Profilometry is an optical technique that evaluates the macroscopic features of the wear track, such as wear depth and height. To measure wear dimensions precisely, the tribo-pairs need to be cleaned by a proper solvent prior to profilometry, to remove all wear residues. Using nanoparticles, the amount of wear may be reduced significantly compared to classical lubricants[7,11]. Scanning electron microscopy (SEM) provides information about microscopic and nano-scale features of the tribo-pairs. Using SEM, wear residues (size and number), tribofilm formation, and lubrication mechanism (to be discussed later) may be assessed[8,9]. Rheometers provide information about the viscosity and viscoelastic characteristics of the nano-lubricants. Some of the rheological properties such as consistency factor, measured under high shear forces, could be correlated to the tribological behavior of nano-lubricants[3,12]. Also, linear viscoelastic properties, measured under low shear forces, and yield stress, could be correlated to the microstructural integrity of the nano-lubricants at rest[13,14].

### *Lubrication Mechanisms*

Defining the proper lubrication mechanism for different nano-lubrication systems is an ongoing debate in the literature. Some of the most

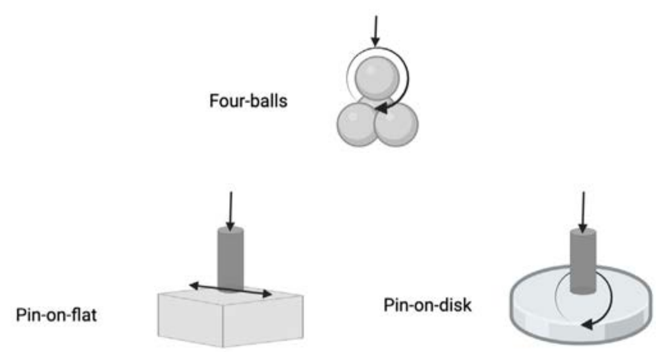


FIG. 1. TRIBO-PAIR CONFIGURATIONS USED FOR THE TRIBOLOGICAL STUDY OF NANO-LUBRICANTS.

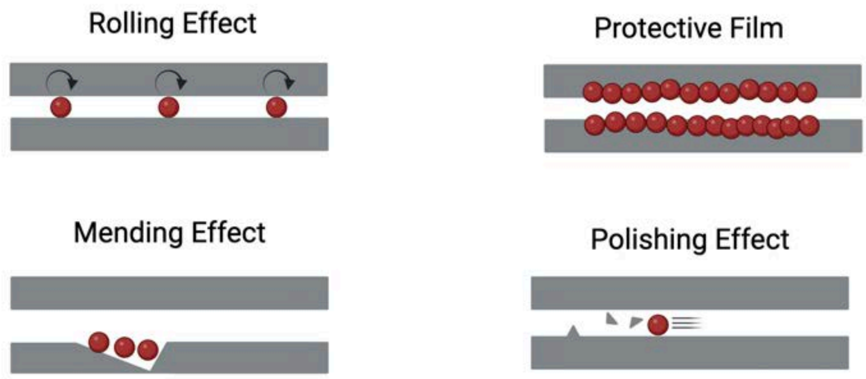


FIG. 2: LUBRICATION MECHANISMS OF THE NANO-LUBRICANTS

well-known friction reduction mechanisms are the rolling effect, protective film, mending effect, and polishing effect[7,12] (*Figure 2*). The rolling effect is a mechanism proposed for the lubrication performance of spherical and quasi-spherical nanoparticles. Such particles act as nano-scale ball-bearings that roll under the contact area. It should be noted that this mechanism is mostly valid under low loads where the integrity of the nanoparticles is protected[9]. The protective film mechanism relates the friction reduction performance to near surface tribo-chemistry reactions. During the tribological characterization, a reaction between the nanoparticles and the tribo-pairs occurs where a film known as tribo-film is formed. This film not only helps in protecting the surface of tribo-pairs by reducing the friction, but it also inhibits the propagation of the potential cracks on the surface[12]. Through mending effect (or self-repairing effect), nanoparticles fill the scars and grooves of the wear track and compensate for the loss of mass. This mechanism has been proposed for the nanoparticles that possess rod or spindle-like geometries[11]. The polishing effect attributes the friction reduction phenomena to the abrasive effect of nanoparticles. The abrasion would decrease the surface roughness and smooth out the wear track[9,15]. There are different surface characterization methods, such as energy dispersive spectrometer (EDS), and X-ray photoelectron spectroscopy (XPS), proposed to investigate the lubrication mechanism of different nano-lubricants. It is worth noting that in some cases, a combination of different mechanisms has been observed for a particular nano-lubrication system[12].

***Formulation Parameters***

There are different parameters that need to be considered while formulating a green nano-lubricant *(Figure 3*). Different studies have investigated the effect of some of these parameters, such as nano-particle size, concentration, stirring time, and ultrasonic treatment, on lubrication performance. The most studied parameter is the concentration[9,12,15]. The progressive addition of nanoparticles to the matrix of the green base fluids would decrease the friction coefficient and wear down to a certain minimum point. Above a critical concentration, the amount of wear and friction increases due to the nanoparticles' agglomeration. In some cases, agglomerates possess a large size, inhibiting their entrance to the contact area[2,3,15]. Another key parameter is the stirring time. A proper mixing time would significantly help in dispersing the individual nanoparticles and reducing the number of agglomerates. There are some studies showing that by increasing the mixing time, the resultant nano-lubricant would significantly reduce the friction coefficient, compared to a lubricant that was not stirred properly[9,16]. It should be noted that in some instances, the severe aggregation of nanoparticles can be overcome only by using more severe mixing methods such as ultrasonic treatment. A proper range of sonication energy would decrease the number of aggregates and improve the dispersion of particles[11,17]. However, over-sonication would damage the integrity of the nanoparticles and their corresponding mechanical properties[18]. The nanoparticles' size is another parameter affecting the lubrication performance. If the nanoparticles' size is larger than the gap between surface asperities, they may not be able to deposit on the wear track. Smaller particle size would significantly reduce nanoparticles' sedimentation and improve their dispersion stability[12]. Lastly, the hardness of the nanoparticles is directly proportional to their size. Larger particles could potentially possess a high level of hardness, greater than the hardness of tribo-pairs. This could cause an abrasive behavior on the wear track[9,19].

***Challenges***

Using nanomaterials as additives in the matrix of bio-lubricants is crucial for energy savings and the protection of our environment. However, some challenges need to be addressed to develop such lubricants. For example, there are difficulties in improving the dispersion stability of the nanoparticles. The current characterizations, such as microscopy and ultraviolet (UV) spectroscopy, reveal information about dispersion stability prior to tribometry. The physical modification of nanoparticles' surface cannot always prevent reaggregation. The aggregation of nanoparticles during tribometry has not been investigated yet. On the other hand, chemical degradation can occur during severe tribo-chemistry conditions. Lastly, with the current advancements in the design of industrial machinery, developing lubricants that maintain their integrity under extreme temperature, force, and speed is crucial. Many of the currently proposed nanoparticles decompose around 150°C, a temperature much lower than the working temperature of a wide range of machinery applications.

*References page 22*

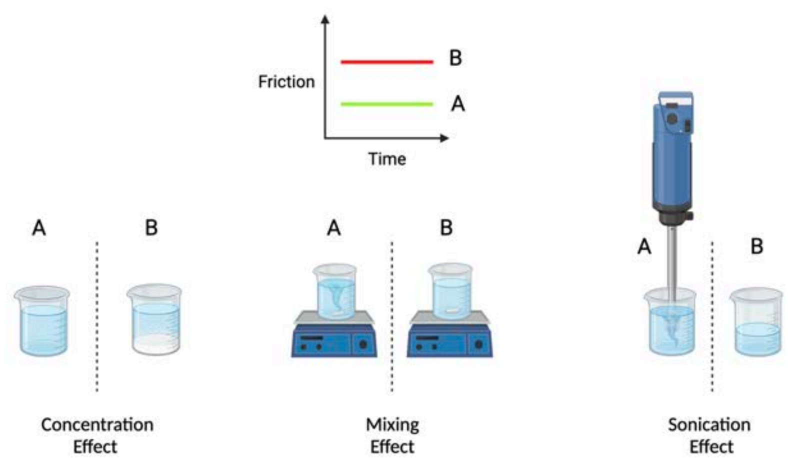


FIG. 3: EFFECT OF FORMULATION PARAMETERS ON THE NANO-LUBRICATION PERFORMANCE.

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Office of the President

November 2023

The Canadian Society for Mechanical Engineering (CSME), founded in 1970, is pleased to announce the winning recipients of its 2024 technical awards. These awards may be bestowed biannually to members of the society for their outstanding contributions to specific areas of mechanical engineering in Canada.

The following three exceptional professionals will be presented with their medals on 28 May at the 2023 CSME International Congress to be hosted on 26-29 May by the MIE Department at the University of Toronto, ON. Each winner will be presenting a plenary lecture at the Congress.

Please consider attending the 2024 CSME International Congress to congratulate these exceptional winners and attend their lectures: www.csmecongress.org.

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**CSME Fluid Mechanics Medal**

*For "exceptional research and innovation contributions to the field of fluid mechanics in Canada"*

**Ian Frigaard**, PhD, FCSME
Professor, Mechanical Engineering, University of British Columbia
Vancouver, BC

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**CSME Manufacturing Medal**

*For "exceptional research and innovation contributions to the field of manufacturing in Canada"*

**Mohammad Jahazi**, PhD, MCSME
Professor, Département de génie mécanique, École de Technologie Supérieure
Montréal, QC

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**CSME Solid Mechanics Medal**

*For "exceptional research and innovation contributions to the field of solid mechanics in Canada"*

**Zheng Hong (George) Zhu**, PhD, FCSME
Professor, Department of Mechanical Engineering, Lassonde School of Engineering, York University
Toronto, ON

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## Call for Nominations – 2024 CSME Annual Awards

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*CSME Fluid Mechanics Medal*

## Dr. Ian Frigaard

Dr. Ian Frigaard, of the Department of Mechanical Engineering at the University of British Columbia, is a world-renowned expert on non-Newtonian fluid mechanics and the foremost expert on the fluid mechanics of oil well cementing. He has made seminal contributions to the understanding of viscoplastic fluids, which behave uniquely under stress, and his work has helped to reduce greenhouse gas emissions from the oil and gas sector by improving cementing processes that are essential for secure and sustainable operations. Dr. Frigaard has also trained nearly 100 postdoctoral fellows and graduate students, initiated two successful workshop series on complex fluids, and served as President of two national professional societies (CAIMS and CSR), in addition to holding many other offices. With a prolific publication record, his highly-cited work has advanced both fundamental understanding and practical applications, advancing the field of fluid mechanics and contributing to safer industrial practices.

*CSME Manufacturing Medal*

## Dr. Mohammad Jahazi

Dr. Mohammad Jahazi, a distinguished Professor and Industrial Chair at École de technologie supérieure (ÉTS) in Montreal, is a leading figure in the field of advanced manufacturing. Renowned for his research in high-temperature deformation of high strength alloys used in transportation and energy industries, Dr. Jahazi has long standing experience in the practical application of innovative manufacturing technologies, including Friction Stir Welding and Linear Friction Welding. His collaborative efforts with industry giants such as PWC, SAFRAN Landing Systems, as well as a large number of SMEs including Finkl Steel, DKSpec, Verbom, and DBMReflex, have resulted in the development of robust, high-performance materials and methods elevating safety and efficiency standards within the energy and transportation industries.

Dr. Jahazi's unwavering dedication to bridging theory with practice has positioned him as a vanguard in advancing the frontiers of manufacturing, making him a deserving candidate for the CSME Manufacturing Medal.

*CSME Solid Mechanics Medal*

## Dr. Zheng Hong (George) Zhu

Dr. Zhu is a Professor of Mechanical Engineering at York University. He is a visionary researcher in solid mechanics, combining fundamental engineering principles with impactful applications and education. His innovative work has gained international recognition, such as the transformative nodal position finite element method and high-fidelity multi-physics modeling in computational mechanics. Dr. Zhu's expertise extends to micromechanics and carbon-nanotube multifunctional carbon fibre composites. Beyond this, Dr. Zhu has led two notable satellite missions. He is a prolific author, with over 200 peer-reviewed journal articles, 163 conference papers, and five book chapters to his name.

Dr. Zhu is recognized as an Academician of International Academy of Astronautics and College Member of Royal Society of Canada. He holds fellowships with Canadian Academy of Engineering (CAE), Engineering Institute of Canada (EIC), Canadian Society for Mechanical Engineering (CSME), American Society of Mechanical Engineers (ASME), and American Institute of Aeronautics and Astronautics (AIAA).

# HIGHLIGHTS

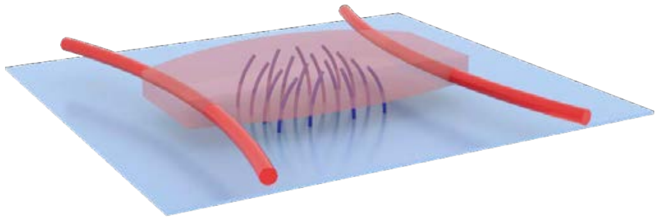

FIG. 1: SCHEMATIC OF THE HEART-ON-A-CHIP DEVICE, WITH PEDOT:PSS MICROPILLARS DEPICTED AS BLUE HAIRS AND THE THERMOPLASTIC ELASTOMER + QUANTUM DOT NANOCOMPOSITE MICROWIRES SHOWN IN RED.

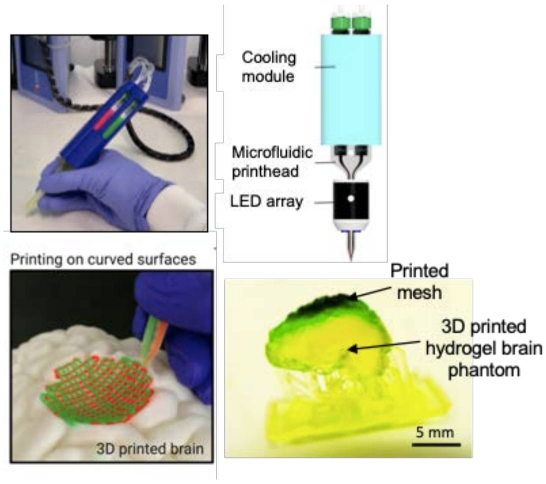


FIG. 2: PHOTOGRAPH AND DIAGRAM OF THE HANDHELD BIOPRINTER (TOP), AND EXAMPLE MESHES PRINTED ON CURVED STRUCTURES REPRESENTING BRAINS (BOTTOM).

## New 3D printed heart-on-a-chip device

The organ-on-a-chip field employs microfabricated devices that can replicate and measure critical physiological properties. Applications for heart-on-a-chip microfluidic devices include drug development, disease modelling, personalized medicine, toxicology testing, high-throughput screening, and more. For cardiac tissues, consideration of contractive forces and electrophysiology of the tissue is important for understanding functional development and how diseases manifest. However, simultaneous measurements of contractive forces and electrophysiological measures in 3D tissue cultures has proven difficult. A solution to this was recently described by a team lead by Dr. **Milica Radisic** at University of Toronto and Dr. **Jadranka Travaš-Sejdić** from The University of Auckland in a manuscript published in *Biofabrication* this year[1]. Their design integrates highly flexible, vertical 3D micropillar electrodes for electrophysiological recording and elastic microwires to assess the tissue's contractile force. The soft conductive polymer micropillar arrays were 3D printed from an "ink" containing poly (3,4-ethylenedioxythiphene) doped with polystyrene sulfonate (PEDOT:PSS) via extrusion from a micropipette. The elastic microwires were made of a thermoplastic elastomer and quantum dot nanocomposite microwire deposited using a 3D bioprinter with a 60 um micronozzle and were used as optical force sensors. After describing the development and calibration of their device, they demonstrate its capabilities by recording extracellular field potentials in cardiac tissues with the PEDOT:PSS micropillars while simultaneously measuring tissue contractile properties, both with and without epinephrine (a drug that increases contraction rate of cardiac tissues). Importantly, the 3D printing approach they used facilitates customization to achieve tissue-like mechanical properties and suitable sensor dimensions, improving data acquisition compatibility and relevance of the system for biological studies. — *Technical Editor, Prof. Ryan Willing,* MCSME


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## Futuristic handheld bioprinter

A recurring scene in futuristic sci-fi movies features a doctor hovering a tool over a character's wound, which magically deposits new tissue overtop of the wound. This future might not be as far away as we think, as researchers have already developed systems for printing bioinks that can assemble tissues. While this was initially limited to printing onto dishes, recent work has included the development of handheld 3D bioprinters that are capable of depositing bioinks onto injured areas. Previously developed devices, however, have been limited in terms of the number of different bioinks they could simultaneously print, simple bioink combinations, high cost, bulky size and heavy weight, all of which have restricted their range of applications. In another recent paper published in *Biofabrication*, Dr. **Mohsen Akbari** (University of Victoria) and his team developed a new handheld modular bioprinter capable of depositing multiple materials with precise control over their spatiotemporal physicochemical properties[2]. They employed a bioink cooling module to overcome issues caused by heat from the user's hand being transmitted into the bioink, and 3D printed printheads that can be varied to produce different methods of mixing the bioinks (e.g. parallel versus coaxial extrusion). They demonstrated the systems efficacy for printing multi-component fibers with different cross-sectional shapes and material compositions, incorporation of drug-loaded microcarriers, biosensors and wearable electronics, as well as single-component and multi-component cell-laden fibers. Although it is not yet that sci-fi tool that repairs damaged tissue in seconds, this new technology is an attractive option for clinical settings for efficient delivery of cells and therapeutic agents. — *Technical Editor, Prof. Ryan Willing,* MCSME


Reference:

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# Université de Montréal
# Dr. Houman Savoji

## *Advanced Biofabrication of Functional Biomaterials for Tissue Engineering, Regenerative Medicine, and Organ-On-Chip Applications*

Advanced biofabrication of functional biomaterials for tissue engineering, regenerative medicine, and organ-on-chip applications is a fast-growing field with great promise to develop functional substitutes for the injured tissues or create 3D in vitro models for the mechanistic understanding of healthy and diseased tissue function and to test the safety and efficacy of potential therapeutics. Dr. Savoji's group's overarching goal is to develop advanced biofabrication techniques integrated with insights from developmental biology to build engineered 3D in vitro models for predictive drug discovery and to create functional tissue-engineered implants for regeneration.

To this aim, Savoji's Laboratory has recently formulated composite inks from poly(vinyl alcohol), carrageenan, and gelatin and characterized their physicochemical, morphological, mechanical, rheological, biocompatibility, and hemocompatibility properties for tissue engineering of heart valves. The results showed that the formulated inks could be used for high-fidelity in-air 3D printing of tissue-engineered heart valves. The valves demonstrated hemodynamic performance and functionality under aortic conditions[1] (*Figure 1*). In the next step, his team aims to characterize the heart valves' biomechanical properties (e.g., hemodynamics, durability) and regenerative capability in a heart valve bioreactor. This project has a significant clinical impact to fabricate off-the-shelf heart valves that can facilitate translation from bench to bedside.

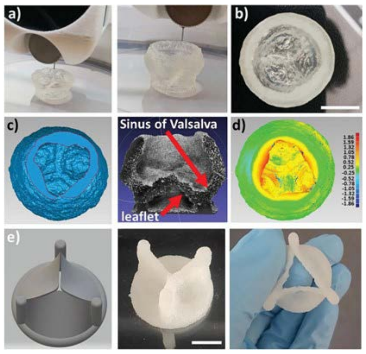


FIG. 1: FORMULATION AND EVALUATION OF PVA/GELATIN/CARRAGEENAN INKS FOR 3D PRINTING AND DEVELOPMENT OF TISSUE-ENGINEERED HEART VALVES.

In addition to engineering artificial tissues for implantation, Dr. Savoji's team strives to generate physiologically relevant 3D in vitro models to study structure-function relationships and drug toxicity testing as intermediates between animal and clinical trials. Engineered miniaturized tissues have enormous value for drug discovery and screening since drug-related adverse events are significant problems in drug development. Although using 2D models enable toxicity investigation at the cellular level, these models lack suitable environmental factors, including 3D extracellular matrix (ECM)-cell and cell-cell interactions and microstructure to properly mimic native tissues. His team is currently developing engineered functional heart tissues (i.e., "heart-on-a-chip") for detecting the cardiotoxic effects of drugs. Using patient-derived induced pluripotent stem cells (iPSC), engineered 3D cardiac tissue will also present potent models for studying congenital heart disease in children. His team has recently developed photo-cross-linkable bioinks containing alginate methacrylate and gelatine methacrylate to create 3D bioprinted miniaturized cardiac tissues-on-a-chip for drug discovery, screening, and disease modeling applications (*Figure 2*).

In addition to the above projects, Dr. Savoji's team is working on the applications of microfluidics and advanced 3D biofabrication technologies (e.g., 3D bioprinting, melt electrowriting, sound-induced morphogenesis, among others) for one of the most highly demanding markets such as drug discovery, screening, and transplantation. For example, some of the other active projects in his group include the development of a female reproductive system-on-a-chip, tumor-on-a-chip, vascularized thick cardiac patch, artificial esophagus, and large-scale biomanufacturing of stem cells, among others.

Overall, by combining advanced 3D biofabrication strategies, functional biomaterials, and stem cell technology, Dr. Savoji's team develops clinically relevant functional tissues that can be used to regenerate, repair or replace tissues or generate physiologically relevant organ-on-chip models for drug discovery, screening, and disease modeling applications.


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Dr. HOUMAN SAVOJI, PhD

*Dr. Savoji is an Assistant Professor at the Institute of Biomedical Engineering at the University of Montreal. He is also a Principal Investigator at the Research Center of the Sainte-Justine University Hospital and a Research Chair in 3D Bioprinting and Regenerative Medicine at the Montreal TransMedTech Institute. He has published 40 publications and 7 book chapters, presented at more than 40 conferences, and given more than 25 invited talks at national and international conferences. His laboratory receives funding from the NSERC, CIHR, FRQNT, FRQS, TheCell Network, iTMT, Quebec Government and is equipped with various equipment and facilities designated for advanced biofabrication strategies, 3D bioprinting, microfluidics, organ-on-a-chip technology, biomaterial development, and characterization.*

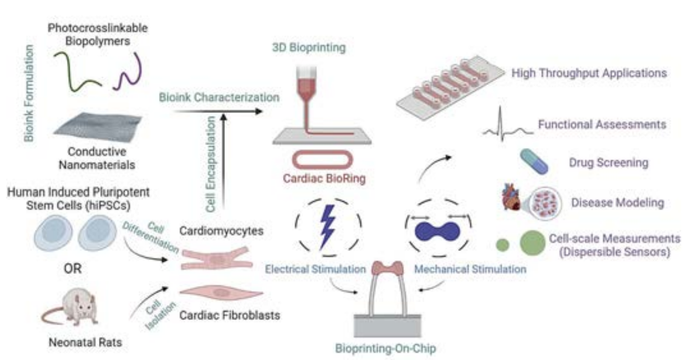



FIG. 2: DEVELOPMENT OF 3D BIOPRINTED HEART-ON-CHIP FOR DRUG DISCOVERY, SCREENING, AND DISEASE MODELING APPLICATIONS.

IMAGES COURTESY OF THE RESEARCHERS

# University of Guelph Dr. Huiyan Li

## *Engineering highly sensitive multiplexed biochips*

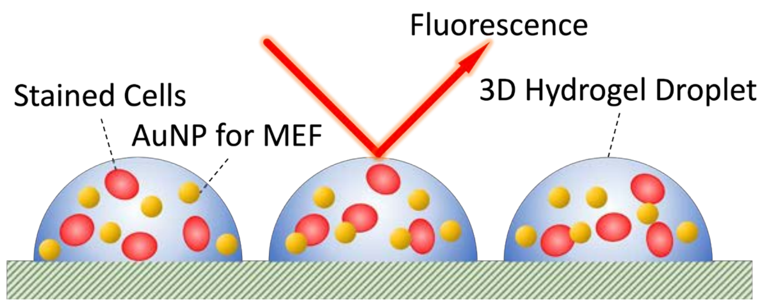
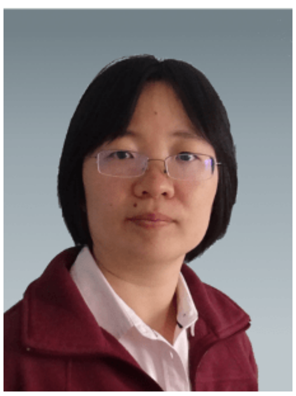



FIG. 1. HYDROGEL DROPLET MICROARRAY ENTRAPPING GOLD NANOPARTICLES FOR HIGHLY SENSITIVE PROTEIN ANALYSIS IN INTACT CELLS. REPRODUCED FROM REFERENCE[3].

A bioassay is the measurement of the concentration of a specific biomolecule in a biological sample (e.g., blood). In biomedical research, multiplexed bioassays are often required to simultaneously measure multiple biomolecules to gain more comprehensive insights into complex biological and clinical problems. However, deployment of conventional multiplexed bioassays like microarrays, while effective, is challenged by intricate fabrication processes, limited scalability, high cost, and low sensitivity (i.e., low-abundant substance cannot be detected), curtailing their broader applications. Dr. Li's research group is interested in developing innovative lab-on-a-chip technologies towards highly sensitive multiplexed bioassays, aiming to contribute to more effective disease management and food safety. To improve the sensitivity and affordability of multiplexed bioassays, Dr. Li's group has developed two innovative technologies via engineering new formats of microarrays.



Dr. HUIYAN LI, PhD

*Dr. Li obtained her PhD in Biomedical Engineering at McGill University. Afterwards, Dr. Li joined the Biomedical Engineering group as a postdoctoral fellow at Harvard Medical School – Massachusetts General Hospital, where she developed several technologies for the analysis of exosomes. In 2020, Dr. Li joined the University of Guelph and started her BioMed Innovation laboratory. Her research focuses on developing micro- and nano-technologies for the study of health and diseases, with a particular interest in the analysis of exosomes for cancer management. Her work has been highlighted in top journals and major scientific magazines.*

One technology involves using 3D paper membranes[1,2] and hydrogel droplet arrays[3] with gold nanoparticles to create highly sensitive optical biosensors to detect very low concentrations of biomolecules of interest (*Figure 1*). The approach harnesses enhanced fluorescence signals from localized surface plasmon resonance of the gold nanoparticles, coupled with the high molecular binding capacity of the 3D membrane or hydrogel, to achieve high assay sensitivity. These platforms have been used for multiplexed protein analysis in plasma, cells, and exosomes, surpassing the sensitivity of gold-standard methods like ELISA by up to four orders of magnitude. Their ease of operation, compatibility with conventional assays, and cost-effectiveness make them suitable for widespread adoption in biological/biomedical laboratories, offering the potential to expedite advancements in life science.

The other technology, compartmentalized linker array (CLA), revolutionizes the creation of biomolecule microarrays. Unlike the conventional method involving the printing of delicate biomolecules in nanoliter volumes, which can lead to damage and loss of bioactivity, CLA patterns biomolecules by incubating bioreagents with pre-prepared chemical linker molecules4 (*Figure 2(a) and 2(b)*). Moreover, the compartmentalization approach not only overcomes cross-reaction issues in conventional microarrays, enhancing accuracy and scalability, but also simplifies the fabrication process. Conventional microarray spotting requires a complex microarray spotter, often unavailable to many labs. In contrast, CLA utilizes standard pipettes for bioreagent transfer and incubation, preserving bioactivity. CLA has been used for multiplexed sandwich immunoassays, achieving low pg/mL sensitivity for cancer-related proteins (*Figure 2(c)*). Its user-friendly nature makes it a promising technology for widespread adoption.

These advancements have significantly improved sensitivity, usability, and cost-effectiveness, addressing the limitations associated with traditional multiplexed bioassays to enable more profound insights into complex biological and clinical contexts. Ongoing research at the lab continues to innovate on biosensing platforms with better assay performance for a diverse range of samples. Dr. Li has also collaborated with clinicians from the Institute for Comparative Cancer Investigation and the Cardiovascular Centre in Guelph to apply these technologies in managing cancer and cardiovascular disorders. These adaptable and cost-effective technologies hold potential for widespread applications in fields such as molecular biology, clinical diagnostics, regenerative medicine, food safety, and environmental monitoring.

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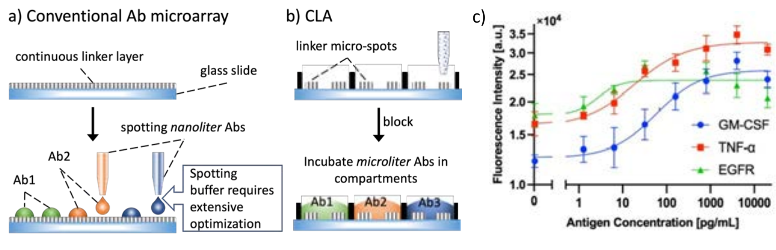


FIG. 2. SCHEMATIC OF CLA COMPARING TO THAT OF CONVENTIONAL ANTIBODY MICROARRAYS (A-B) AND STANDARD CURVES OF THREE PROTEINS MEASURED BY A MULTIPLEXED SANDWICH IMMUNOASSAY USING CLA (C). REPRODUCED FROM REFERENCE[4].

# University of Toronto
# Dr. Kevin Golovin

## *Liquid-like polymer brushes as a replacement for "forever" chemicals*

Perfluoroalkylated substances (PFAS), the infamous "forever" chemicals, are still found in over 200 use categories, such as water-repellent apparel, nonstick cookware, electric vehicle batteries, and food packaging.[1] This is problematic as PFAS have been linked to several diseases, forms of cancer, and birth defects.[2] PFAS contain thermodynamically stable carbon-fluorine bonds that are responsible for their environmental persistence and eventual bioaccumulation in humans. However, this bond stability also gives PFAS their excellent surface properties. PFAS-treated surfaces exhibit the lowest surface energy of any substance and were thought to be the only materials that could exhibit oil, grease, and broad chemical repellency. Replacement technologies are urgently needed.

Prof. Golovin's DREAM Lab is developing PFAS replacement technologies from sustainable and biologically inert materials. The most promising PFAS replacement is a nano-engineered version of the everyday material silicone. Silicone is made from polydimethylsiloxane (PDMS) and is a liquid at room temperature commonly found in cosmetics, shampoos, and synthetic motor oil. Solid silicone rubber can only be produced by crosslinking multi-functional, reactive PDMS chains. However, liquid PDMS dissolves other oils and solid silicone rubber is swollen by oils and many solvents, so at first glance, PDMS would not be suitable as an oil-repellent, PFAS replacement.

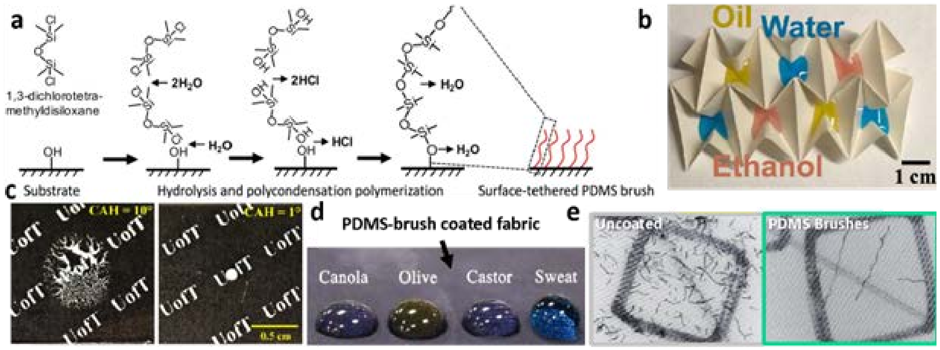


FIGURE 1. (A) SYNTHESIS OF PDMS BRUSHES.[4] (B) PDMS BRUSH COATED PAPER AS A MICROTITER PLATE.[7] (C) FOULING OF HIGH AND LOW CONTACT ANGLE HYSTERESIS (CAH) PDMS BRUSHES.[5] (D) PFAS-FREE, OIL-REPELLENT FABRIC.[8] (E) MICROFIBRES SHED FROM WASHED FABRICS, EITHER BARE OR COATED WITH PDMS BRUSHES.[12]

The DREAM Lab has instead engineered a nanoscale form of PDMS that exhibits properties of both liquid silicone oil and solid silicone rubber. Termed PDMS 'brushes', single polymer chains are grafted orthogonally from a substrate (*Figure 1*) but are not crosslinked or connected except at the surface. Accordingly, the polymer retains many of its liquid-like properties even though it cannot physically flow. Surface nanoconfinement combined with the liquid-like state prevents nearly all other liquids from wetting PDMS brushes. For example, toluene readily dissolves silicone oil and is absorbed into silicone rubber, yet it is easily repelled by PDMS brushes.[3]

The DREAM Team studies both the fundamental nature of PDMS brushes and their industrial applications. Their liquid-like properties were first quantified by Zhao et al. in 2021,[4] and their tribological performance by Khatir et al. in 2023.[5] Back in 2020, Khatir, Shabanian, and Golovin[6] figured out how to attach PDMS brushes onto many different substrates, and this enabled the creation of PFAS free grease-resistant paper,[7] oil-repellent textiles,[8] chemical resistant fabrics,[9] and anti-icing coatings.[10] In collaboration with chemists at the University of Victoria, PDMS brush mechanical durability has also been enhanced.[11] Quite intriguingly, earlier this year Lahiri and co-authors[12] showed that the release of microplastics during clothes laundering could be effectively prevented by grafting PDMS brushes to textiles.

In 2023 the European Union proposed a complete ban on all chemicals containing a C–F bond, which would substantially disrupt many industries worldwide.[13] PDMS brushes are emerging as suitable PFAS replacements for some applications, but their complex and fascinating liquid-like properties, in addition to their general "brush" morphology and surface arrangement, require further study. If humanity wishes for the forever chemicals to be forever gone, more research in this area is needed. But if we can DREAM it, we can achieve it.

*References page 22*


Dr. KEVIN GOLOVIN, PhD

*Dr. Golovin is an Assistant Professor in the Department of Mechanical & Industrial Engineering at the University of Toronto. Golovin holds a Bachelor's from Cornell University and a PhD from the University of Michigan, both in Materials Science & Engineering. Professor Golovin is the principal investigator of the Durable Repellent Advanced Engineering Materials (DREAM) Laboratory, and together with the affectionately named DREAM Team, investigates coatings, surface modification, the mechanics of interfaces, and sustainable methods for achieving solid and liquid repellency.*

PROFESSOR GOLOVIN OBSERVING HOW WELL A WATER-REPELLENT FABRIC PERFORMED, HAVING BEEN TREATED WITH THE PFAS-REPLACING, LIQUID-LIKE PDMS BRUSHES.

IMAGES COURTESY OF THE RESEARCHERS

# École de technologie supérieure
# Dr. Giuseppe Di Labbio

## *Pulsed Fluid Jets: Fundamental Physics to Industrial Innovation*

When you think of a pulsed fluid jet, what comes to mind? In aquatic life, the sudden or repeated expulsion of fluid mass represents a common mode of propulsion and locomotion. Squids, for example, can rapidly propel themselves by forcefully ejecting water out from their mantle.[1]

Now what about arrangements of two or more pulsed jets? We know rather little about the fluid dynamics, yet they are just as important in nature, engineering and medicine.[2] Some aquatic animals, such as salps and siphonophores, form colonies and maneuver as a single organism by individually modulating their jet strength and timing.[1] Our bladders fill intermittently via two pulsed ureteral jets.[3] Even our hearts are home to a variety of conditions involving two or more pulsed jets. One such condition is aortic valve regurgitation, where leakage of the aortic valve results in a second jet within the left ventricle as it fills.[4]

Fascinated by the plethora of applications, Dr. Di Labbio investigates the fluid dynamics of pulsed jet arrangements, from fundamental physics to the development of innovative engineering and medical solutions. Fundamental research of the fluid dynamics requires the investigation of a rich parameter space, including jet placement, orientation, strength, phase and time history. Using particle image velocimetry (PIV) and direct numerical simulation (DNS), his research group is exploring the effects of this parameter space on thrust characteristics and wake dynamics for arrangements of two pulsed jets. The physics hidden behind the complexity of these flows are extracted using MAT*fluids*, an advanced fluid dynamics data analysis suite (open source) continuously developed by Dr. Di Labbio. MAT*fluids* incorporates a broad range of modern flow analysis methods, including coherent structure detection and reduced-order modelling.

Though this research is ongoing, interesting phenomena are being observed and put into practice. For example, an augmentation in thrust can be achieved using an optimal phase delay between pulsed jets. In figure 1, two synchronous (left) and asynchronous (right) pulsed jets are compared. In the asynchronous case, the delayed vortex ring is slowed down further by the presence of the downstream vortex ring. The added resistance to the motion of the delayed ring is felt as an increase in the total pressure force exerted on the wall, as evidenced by the larger blue region in figure 1. Such practical observations directly guide the development of bio-inspired pulsed jet thrusters for aquatic vehicle propulsion and locomotion in Dr. Di Labbio's group. Pulsed jets are an interesting alternative to propellers, offering more efficient propulsion with fewer operational problems (e.g., cavitation, jamming).[5]

Dr. Di Labbio is also interested in applications of pulsed jet arrangements beyond aquatic propulsion, such as for batch mixing and aerodynamic flow control. In particular, he continues to research physiological flows, now leveraging the physics of pulsed jet arrangements to better understand certain cardiac and urogenital flows. The goal is to develop a fluid-dynamics-informed means of evaluation for specific diseases, dysfunctions and implantable medical devices. Currently, his research group is developing an in vitro urinary bladder flow simulator to study the filling dynamics in the bladder resulting from two ureteral jets. Some urogenital conditions, such as chronic kidney disease and kidney stones, are expected to produce quantifiable changes in bladder flow patterns that can be leveraged for diagnosis (e.g., total viscous dissipation). Given that ureteral jets are observable via classical bedside ultrasound,[3] Dr. Labbio aims to extract global flow-centric indicators of urogenital system health from the in vitro model for direct use in clinical practice.


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Dr. GIUSEPPE DI LABBIO, PhD

*Dr. Labbio is an assistant professor and experimental fluid dynamicist in the Department of Mechanical Engineering at the École de technologie supérieure. His research group is exploring the fluid dynamics of pulsed jet arrangements and its applications in aquatic propulsion, physiology, mixing and flow control. In 2019, as a Vanier scholar, he earned his PhD from Concordia University where he explored the fluid dynamics in the heart's left ventricle resulting from aortic valve regurgitation using a custom-designed cardiac simulator. He then pursued his FRQNT and NSERC postdoctoral fellowships at Polytechnique Montréal, where he studied the low frequency unsteadiness of separated flows.*


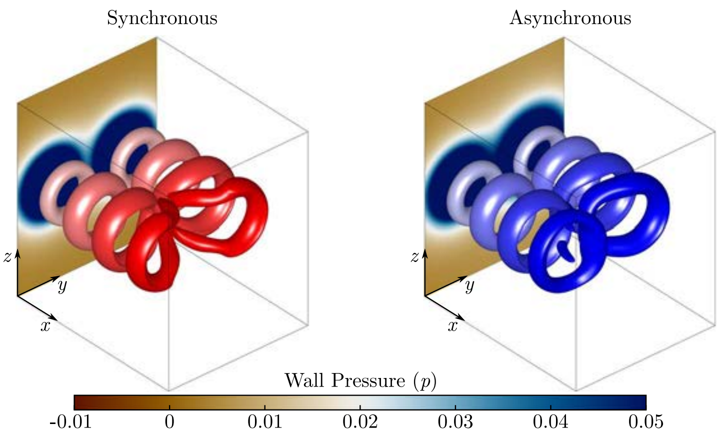


FIGURE 1 – EFFECT OF PHASE DIFFERENCE ON PRESSURE THRUST BEHIND TWIN SINGLE-PULSE JETS. ON THE LEFT, THE JETS ARE SYNCHRONOUS WHEREAS ON THE RIGHT, THE FAR JET IS BRIEFLY DELAYED. THE EVOLUTION OF THE VORTEX RINGS PRODUCED BY THE JETS IS DISPLAYED AT EQUAL INTERVALS, FROM FAINT TO DARK COLOURING. THE PRESSURE CONTOURS ON THE WALL BEHIND THE ASYNCHRONOUS JETS (RIGHT) ARE SLIGHTLY LARGER IN AMPLITUDE AND ENCOMPASS A LARGER AREA, REPRESENTING AN OVERALL INCREASE IN THE FORCE APPLIED TO THE WALL (THRUST). THE SAME COLOUR SCALING FOR PRESSURE IS USED IN BOTH SUBFIGURES. THE SPATIAL DOMAIN IN EACH SUBFIGURE MEASURES (*X, Y, Z*) = (5, 4, 5). ALL VARIABLES ARE SCALED WITH RESPECT TO THE JET DIAMETER AND CENTRE VELOCITY.

# STUDENT AFFAIRS CSME REPORT

A MAJOR FOCUS OF THE STUDENT AFFAIRS Committee continues to be growing our network through Local Student Chapters and the professional development/networking events that they are targeting to hold. In August we held a meeting with the active local student chapters from the University of Toronto and the University of Alberta to brainstorm local events at both institutions. Beyond this, we have also begun discussing a national online event across a range of institutions and chapters to promote student networking and cover a relevant topic among the student community (e.g. graduate studies, preparing for a future career in industry). A number of other institutions have begun expressing interest in activating their local chapters again and we hope to grow the network even further over the coming year. Keep an eye out for upcoming online events across the country! For any questions surrounding local CSME Student Chapters, please feel free to reach out to Dan Romanyk directly (dromanyk@ualberta.ca).

On a final note, I would like to draw your attention to the National Design Competition (NDC) that is held annually in the spring (https://csme-ndc.ca). The NDC is open to undergraduate mechanical engineering students in teams of up to eight, and could be for a project completed as a part of a design course or student group/club. The 2024 NDC will be administered through an online format that will be augmented with other opportunities to engage in person at the 2024 CSME Congress at the University of Toronto for interested teams. We will be reaching out again very soon with more information, so please stay tuned, but feel free to contact the NDC Coordinator, Grant McSorley (gmcsorley@upei.ca), in the meantime with any questions.

## FEATURE *continued . . .*

*Dr. Grecov, Green nano-lubricants for sustainable engineering (p. 14)*

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## SPOTLIGHT *continued . . .*

*Dr. Golovin, Liquid-like polymer brushes as a replacement for "forever" chemicals (pg. 20)*

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# Q&A

Dr. AMIR SEYFOORI, PhD

*Dr. Seyfoori is a highly accomplished and driven professional with an extensive background in research and academia. Holding a PhD in Materials Science, he currently serves as the Founder and CEO of Apricell Biotechnology Inc., where his primary focus is on pioneering cutting-edge solutions to address critical challenges within the field of human-derived diseased tissue models for preclinical drug testing. During his tenure at Apricell Biotechnology Inc., Dr. Seyfoori has demonstrated an unwavering commitment to making a meaningful global impact. With his profound knowledge and experience in materials science and related fields, he is dedicated to realizing a more sustainable future for all. Throughout his illustrious career, Dr. Seyfoori has consistently delivered exceptional research outcomes, taken the lead on pivotal projects, and contributed to esteemed publications in renowned journals such as Small, Lab on Chip, Advanced Healthcare Materials and Bioactive Materials. His expertise spans a wide spectrum, encompassing biomaterials, tissue-engineered models, medical devices, and microfluidics.*

***Congratulations on starting your own company and all the success coming with it!***

***Q: Can you tell us a bit about your academic background and the focus of your PhD research?***

I earned my Bachelor of Science in materials engineering from Iran University of Science and Technology, my alma mater in my motherland. During my undergraduate years, I was fascinated with researching new materials that could be applied in the biomedical field. After completing my bachelor's degree, I pursued a Master's degree in Biomedical Engineering with a focus on developing biodegradable metals with a novel surface coating that could aid in bone regeneration. My interest in materials that are biologically relevant and their interface with physiological systems led me to pursue a PhD in biomaterial engineering.

Throughout my doctoral research, I concentrated on developing smart microgels that were incorporated into magnetic tweezer microfluidic devices to detect liquid biopsy-based markers. Specifically, my work centred on magnetic-based detection and isolation of circulating tumor cells from the peripheral blood of cancer patients. This research could potentially help with early cancer diagnosis and better monitoring of the patient's response to treatment.

Also, I had the privilege of collaborating with clinicians during my PhD thesis, leading to research papers, patents, and knowledge translation outcomes. My academic journey has been driven by a deep passion for materials engineering and biomedical research. I am committed to contributing meaningful insights to the field through my ongoing PhD research.

***Q: Your academic career started with a degree in Materials engineering. What motivated you to transition from this background into bioengineering and biomedical engineering?***

My academic journey began with a degree in Materials Engineering, a field that captivated me with its applications in various industries. I have always been fascinated by how nature and human biology can inspire the design of more functional materials and as I progressed in my studies and gained exposure to different scientific disciplines, I discovered a profound interest in the intersection of materials science with biology and medicine.

One of the most important factors that motivated my transition into Bioengineering and Biomedical Engineering was the interdisciplinary nature of the bioengineering field, where I could apply my materials engineering knowledge to solve complex biological and medical challenges. It offered an exciting blend of engineering principles with life sciences.

Moreover, the potential to contribute to advancements in healthcare and people's lives and well-being was a compelling incentive for my transition to this field. Also, the growing demand for professionals with expertise in biomedical engineering and bioengineering was another motivating factor that made me start this journey.

***Q: One of your major research focuses is cancer-on-a-chip. Can you tell us what motivated you to spend most of your time in this area?***

Cancer is undeniably one of the most fear-inducing words that can resonate within any household during their lifetime. My passion for battling against cancer led me to initiate a solution to help cancer patients find better and more accurate treatment options. I had just graduated from the university with a master's degree in Biomedical Engineering when my closest friend was diagnosed with lung cancer. Although doctors had started the standard chemo treatment as soon as diagnosis, he couldn't survive more than a year. He was unsuccessful in the first line of treatment and couldn't resist the burden of the treatment in the second line. Missing a close friend of mine at that time was the greatest driving force for me to help people with cancer find a more accurate solution for cancer treatment. Eventually, after several years of research in the interdisciplinary fields of biology and bioengineering, I reached a solution that enabled us to grow a lab-grown mini tumor as a small footprint of the real tumor tissue in the patient, called cancer on-a-chip.

***Q: How can miniaturized tumor avatars reduce cancer mortality in clinics?***

Human mimicked tissue models are the miniaturized version of the real tissue and its environment in the human body. If we need to predict the interaction of cells within the tissue with specific drugs or interventions, we need to be able to mimic the real tissue environment outside of the body. We made small chips that can be used for making many of these miniature tissues. This will lead the way to the goal of making different human organs on small chips which represent and recapitulate various functions of the human body. It sounds amazing to have small-sized human organs on a small chip. We mimic the cancerous tissues on our small (microchips) to predict the effect of different treatments, including chemo drugs, on cancer tissues more accurately and cheaply. These small organs (we call them organoids) can be made in the lab to open new horizons in human biology on Earth and in space.

*....continued next page*

***Q: What is your opinion on the outlook for entrepreneurship in biotechnology in Canada and how can engineers contribute to this field?***

Canada is a growing hub for biotechnology and life sciences entrepreneurship. One of the factors which is contributing to this positive environment is the government initiatives that turn Canada into one of the strongest ecosystems in biotech. The Canadian government has actively invested in biotech and life sciences through programs and grants. Initiatives like the Strategic Innovation Fund and the National Research Council's Industrial Research Assistance Program (IRAP) supported innovation in the sector. Additionally, cutting-edge research in areas like genomics, stem cell and tissue engineering research, and drug discovery provided a strong foundation for biotech entrepreneurship. Engineers can play a crucial role in the biotechnology entrepreneurship field in various ways. Engineers can design and develop innovative biotech products and medical devices, contributing to advancements in diagnostics, treatment, and patient care. Especially in my field of interest, engineering concepts can be merged with biological phenomena to develop micro-physiological systems through which different diseases can be modelled for faster and more precise drug development. Additionally, engineers can design and implement automated systems to improve accuracy and throughput. Finally, engineers can help biotech companies navigate complex regulatory requirements by ensuring that products and processes meet safety and quality standards.

***Q: How did your academic experiences or research inspire you to venture into entrepreneurship and start your own company?***

My academic experiences and research journey played a pivotal role in inspiring my entrepreneurial path. During my academic pursuits in biomedical engineering, I encountered problem-solving that ignited my passion for entrepreneurship. This problem-solving mindset is invaluable in entrepreneurship. Academic research trains individuals to become problem solvers. Whether it was conducting experiments, analyzing data, or developing new theories, I honed my ability to approach complex issues systematically and find creative solutions. Moreover, some of my academic research projects had the potential for real-world impact and commercialization. When I was researching on making cancer tissue models in the lab during my PhD and my postdoc fellowship, recognizing the practical applications of my research, I saw an opportunity to bridge the gap between academia and industry through entrepreneurship. During my PhD and postdoc, the research environment motivated me to pursue innovation relentlessly, leading me to entrepreneurship where I could bring my ideas to life.

***Q: What challenges did you face during the transition from academia to the business world, and how did you overcome them?***

Transitioning from academia to business is not a straightforward process as the nature of my business always depends on research and development. However, as a CEO, there are certain requirements that must be met, and this transition comes with its own set of challenges. The first and most significant challenge is the shift in mindset. In academia, the focus is primarily on research, while in business, the focus is on solving real-world problems profitably. To overcome this challenge, I immersed myself in business literature, attended numerous entrepreneurship programs held by different startup incubators and accelerators across Canada, and sought mentorship to align my thinking with entrepreneurial goals.

In addition, transitioning from an academic environment to the uncertainty of entrepreneurship requires a significant shift in risk tolerance and stepping out of one's comfort zone. To address this, I conducted extensive market research, developed a robust business plan, and assembled a support network of advisors and mentors who could provide guidance and mitigate risks.

Another challenge I faced was a lack of networking in the business ecosystem, and I realized that building a network and acquiring customers required a different skill set than academic research. To overcome this, I recognized the importance of resilience, continuous learning, and seeking support from mentors and peers in the entrepreneurial community.

***Q: How have you applied your research or expertise in your company's products/services? Can you provide some examples of how your PhD work has influenced your business decisions?***

Of course. At Apricell, we have a strong dedication to applying the knowledge and expertise I obtained during my research to create practical products that can solve real-world problems. My academic work at the University of Tehran and Victoria, along with my time spent working with my supervisors, gave me a thorough understanding of the complex subject matter related to bioengineering and tissue modeling. This knowledge formed the foundation for our innovation efforts at Apricell. Our current microfabricated 3D tissue culture plate products are a prime example of the cutting-edge technologies and methodologies we developed during my PhD and postdoc work.

Furthermore, the process of my research emphasized on the importance of data analysis and evidence-based decision-making. We apply this approach to collect and analyze data on customer behavior, market trends, and product performance. Additionally, since research in microscale technologies such as microfluidic and organs-on-a-chip technologies requires precision and attention to detail, we remain committed to delivering top-quality products to our customers.

***Q: Looking ahead, what are your long-term goals and aspirations for your company? How do you envision its growth and impact in the future?***

Apricell's long-term goal is to expand its partnership deals with several of the largest scientific biotechnology and life science distributors in order to make our technology accessible to cancer researchers all around the world. We also aim to provide advanced 3D tumor modeling contract research services to biotechnology companies and researchers who want to test their novel therapeutics but lack the necessary internal resources or know-how. As part of this further development, we plan to create new intellectual property (IP) in the area of cancer and normal organoid protocols. In general, Apricell envisions pursuing the goal of delivering facilities and services that enable human-mimicked tissue models for advancing cancer medicine.

# MECHATRONICS PROGRAM AT WESTERN UNIVERSITY

MECHATRONIC SYSTEMS ENGINEERING (MSE) was created at Western in 2010, and the first class joined in the fall of 2011. Because Western has a common first-year, students entering the MSE program started their second-year in the fall of 2011. Our first accreditation visit from the Canadian Engineering Accreditation Board was in the fall of 2013, and the first class graduated in 2014.

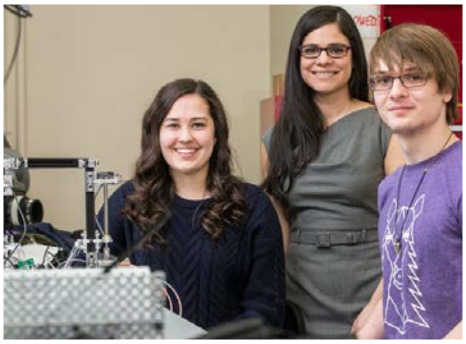
MSE was created as a joint venture between two departments at Western Engineering: Electrical and Computer Engineering (ECE) and Mechanical and Materials Engineering (MME). Negotiations over curriculum started in 2008 with a joint curriculum committee of like-minded faculty members who had research interests in mechatronics and robotics, and we have retained the program's interdisciplinary nature to this day. Officially, the program is housed in ECE, but the courses the students take are divided roughly in half between ECE and MME faculty. The curriculum committee has equal representation from both departments, and we have developed a tradition that the post of Program Director passes back and forth between ECE and MME faculty members.

Our initial vision was that Mechatronics would be a "boutique" program. We planned to accept a maximum of twenty-five students per year. Partly, this was because of resource constraints. We were getting only one dedicated 1000 sq. ft. teaching lab and a small number of new faculty members to support the new program, so we wanted it to be small. But our vision was also that the program should be small in focus. We imagined a small, tightly-knit group of like-minded students working on multi-year design projects. We built a design focus into the curriculum, with students working on open-ended Mechatronic design projects each year, and we had a vision that a student team would work on refinements of the same project as their knowledge grew.

And in the beginning, that's what we had. Our first-class had only twenty-three students, and the small size of the group meant that our design program in the early years involved a large amount of interaction between student teams and faculty members, as they solved a variety of open-ended design challenges, mostly grouped into the broad area of rehabilitation technology.

Then, probably because of our students' excellent work, Mechatronics became "cool." Students in first-year engineering at Western can choose their discipline, and MSE rapidly became the most hotly demanded choice. We had to expand, and expand, and expand. Our newest Engineering building, the Amit Chakma Engineering Building, was primarily driven by the need for new facilities to house our expanded research and teaching activities in MSE. In our current strategic plan for the faculty, we expect at least 100 new students each year in mechatronics. MSE is now a fully mature program within the Faculty of Engineering. We have many students each year engaged in our joint degree programs, including Mechatronic Systems Engineering with Business (a joint degree with the Ivey School of Business), Mechatronic Systems Engineering and Bioengineering (a dual degree program in which students learn applications of mechatronics that are specific to health care applications) and Mechatronic Systems Engineering and Artificial Intelligence Systems Engineering (a joint degree in which students learn to apply modern AI techniques to problems in Mechatronics). Most of our MSE students complete a twelve- or sixteen-month industrial placement between the third and fourth years in sectors as varied as industrial automation, automotive design, embedded systems programming, renewable energy, and software development.

Even as we have grown, we have kept mechatronic design at the core of the curriculum. In the second year, students build a mobile robot platform to a specification, then enhance it with additional components to address a specific design challenge that changes from year to year. Our capstone design students present their work in a public showcase, where interested parties (other students, faculty judges, and industry visitors) can interact with functional prototypes. We don't have the small boutique program we envisioned, but what we have is thriving and exciting.



Dr. KENNETH A. McISAAC, PhD, P.Eng.

*Professor McIsaac received the BASc degree from the University of Waterloo in Computer Engineering (1996) and the MSc (1998) and PhD (2001) degrees from the University of Pennsylvania. He joined Western ECE in January 2001. From 2010-2013, he served as the first Director of Western's Mechatronic Systems Engineering program and since 2013, he has served as Chair of Electrical and Computer Engineering. When his term as Chair ends in summer 2024, he is looking forward to getting back to solving problems in robotics and computer vision.*

PHOTOS COURTESY OF WESTERN UNIVERSITY

DALHOUSIE UNIVERSITY

## Assistant Professor of Mechanical Engineering (Controls and Mechatronics)

The Department of Mechanical Engineering invites applications for one probationary tenure-track faculty position at the rank of Assistant Professor. The successful candidate will integrate with the marine/ocean technology and/or manufacturing research groups in the Faculty with demonstrated expertise in the area of controls and mechatronics.

Candidates must provide evidence of demonstrated excellence in, and commitment to, research and teaching. The candidates will be expected to establish a strong externally funded research program, supervise graduate student research, participate in service activities at the Department level and beyond, and foster existing and new collaborations with government and industry, as well as collaborate with members of Dalhousie's research community.

The candidates must have a bachelor's degree and a doctorate in Mechanical Engineering, or a closely related engineering discipline. **The successful candidates must be eligible for and committed to registration as a Professional Engineer in Nova Scotia**.

The Department of Mechanical Engineering has established research strengths in the areas of marine/ocean engineering, energy and thermal fluids, materials engineering, controls and mechatronics, and design. Applications from candidates in the field of intelligent controls, mechatronics and robotics are encouraged. Research areas that are of particular interest include (i) artificial intelligence/machine learning (development, application, integration), (ii) autonomous systems, and (iii) automation (manufacturing, process control). The successful candidate will also be able to teach a broad range of undergraduate courses in Mechanical Engineering and advanced topics related to their research activities at the graduate level.

Review of applications will begin after December 31, 2023 and continue until the position is filled. **It is anticipated that the position will begin on July 1, 2024.** Those wishing to be considered for this position should apply at: https://dal.peopleadmin.ca/postings/14539

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

Dalhousie University commits to achieving inclusive excellence through continually championing equity, diversity, inclusion, and accessibility. The university encourages applications from Indigenous persons (especially Mi'kmaq), persons of Black/African descent (especially African Nova Scotians), and members of other racialized groups, persons with disabilities, women, and persons identifying as members of 2SLGBTQIA+ communities, and all candidates who would contribute to the diversity of our community. For more information, please visit **www.dal.ca/hiringfordiversity**.

UNIVERSITÉ Concordia UNIVERSITY

GINA CODY
SCHOOL OF ENGINEERING AND COMPUTER SCIENCE

Department of Mechanical, Industrial and Aerospace Engineering

## Assistant Professor, Robotics and/or Mechatronics

The Department of Mechanical, Industrial and Aerospace Engineering at Concordia University invites applications for a tenure-track position in the areas of Robotics and/or Mechatronics, including, but not limited to, robotic and intelligent mechanical systems, reinforced machine learning and artificial intelligence for robotics, soft robotics, haptics, bio-mechatronics, mechanical design of mechatronics systems, assistive and interactive robotics, etc.

Duties include research, teaching at both the graduate and undergraduate levels, and service to the institution. This is a tenure-track position at the rank of Assistant Professor, but exceptional candidates at the Associate Professor level may also be considered.

Application deadline: November 30, 2023
Advertised until: Position is filled

For further details:
www.concordia.ca/ginacody/about/jobs/miae/2023/assistant-professor-robotics-mechatronics.html

## Assistant Professor, Space Engineering

The Department of Mechanical, Industrial and Aerospace Engineering at Concordia University invites applications for a tenure-track position in the area of Space Engineering, including but not limited to: spacecraft (including design, structures, thermal management, mechanics, materials); spacecraft manipulators (kinematics, dynamics & guidance control and autonomous systems) and satellite design including CubeSats and nanosatellites; and technologies for miniaturised space systems and robotic and human exploration of space.

Duties include research, teaching at both the graduate and undergraduate levels, and service to the institution. This is a tenure-track position at the rank of Assistant Professor, but exceptional candidates at the Associate Professor level may also be considered.

Application deadline: November 30, 2023
Advertised until: Position is filled

For further details:
www.concordia.ca/ginacody/about/jobs/miae/2023/assistant-professor-space-engineering.html

# TECHNICAL COMMITTEE REPORTS

### Advanced Energy Systems

The main activities of the CSME Advanced Energy Systems (AES) Technical Committee (TC) over the past six months include:

- Supported the CSME International Congress 2023 held at the Université de Sherbrooke by organizing the Symposium on Advanced Energy Systems.
- Supported the *CSME Transactions* published through the Canadian Science Publishing (CSP) by handling the review of submissions in the field of energy systems.
- Support the preparation of the Spring 2024 issue of the *CSME Bulletin*, which will be dedicated to sustainable energy systems. The AES TC Chair is serving as a guest editor.

– *Dr. Xili Duan*, FCSME

### Biomechanics and Biomedical Engineering

Dr. Hossein Rouhani from the University of Alberta serves as the Chair, and Dr Thomas Jenkyn, from Western University, serves as the Vice-Chair of this technical committee.

Similar to previous years, this TC has been responsible for reviewing the submissions to CSME Congress (30 abstracts and papers in CSME2023 Congress) and managing the symposium for Biomechanics and Biomedical Systems at the Congress. The TC Chair and Vice-Chair are currently serving as the Co-Chairs for the *Biomechanics and Biomedical Engineering Symposium*, together with a local Co-Chair, at the CSME 2023 Congress at the University of Sherbrooke. The TC members have also been reviewing submissions to *CSME Transactions*.

— *Dr. Hossein Rouhani*, MCSME

### Engineering Analysis and Design

- The TC Chair, Vice Chair and members are in place.
- Thanks to Dr. Zengtao Chen who ably acted as 2023 Symposium Vice-Chair for the Engineering Analysis and Design TC.
- TC Chair **Aman Usmani** and Vice-Chair **Hamid Akbarzadeh** held a meeting to discuss and plan for the TC activities such as topical seminars and the 2024 Symposium.
- A Zoom meeting of the full TC is being planned in November.
- Attempt is underway to identify and nominate local Symposium Vice-Chair from the University of Toronto for the 2024 Congress.
- Professor Akbarzadeh and I confirmed to Prof. **Ali Dolatabadi** as Vice Chair and Chair of the Engineering Analysis and Design TC. to actively participate in the 2024 Congress.

***Activities by Dr. Aman Usmani***

- A seminar on Overview of CANDU Reactor Design was prepared and presented through zoom on Jan 12, 2023.
- CNS CANDU Maintenance and Nuclear Component Conference (April 24-27, 2023) in Toronto the following two papers were prepared and presented.
- 'Seismic Ruggedness Evaluation of Flexible hoses", A. Usmani
- "Thermal Analysis of a steel frame with Embedded Polyethylene Shielding", Mohammadreza Noban, A. Usmani
- As Deputy-Chair of the Structural Mechanics in Reactor Technology (SMiRT), International Conference in August 2025 in Toronto is being planned.
- Obtained an article on "Canada's nuclear industry can backstop the future of transportation" by John Gorman, President & CEO, Canadian Nuclear Association for the CSME Spring *Bulletin*.

***Activities by Dr. Hamid Akbarzadeh***

- Co-editing the Spring edition of CSME *Bulletin* and inviting three new Faculty members to contribute to New Faculty Spotlight.
- Preparing an article on "Shellular Metamaterials" in Spring edition of CSME *Bulletin*.

***Activities Planned for 2023-24***

- A CSME seminar on "Seismic Design of Nuclear Power Plants" by Aman Usmani is planned for Fall 2023.
- More seminars are being planned

– *Dr. Aman Usmani*, FCSME

### Heat Transfer

- The Heat Transfer Committee nominated two keynote speakers and organized one panel at 17th International Heat Transfer Conference (Cape Town, Aug. 2023).
- The Heat Transfer Committee continues to support the *Transactions of the Canadian Society for Mechanical Engineering*.
- The Heat Transfer Committee will be working with the organization committee of the CSME 2024 to organize the heat transfer symposium.

– *Dr. Sunny Li*, MCSME

### Manufacturing

- Serving as an associate editor for the *Transactions of the Canadian Society for Mechanical Engineering* (TCSME).
- Organizing the CSME webinar series on Manufacturing.

*Future activities:*

- Organizing the Manufacturing symposium at the 2024 CSME Congress at the University of Toronto.
- Continuing to serve as an associate editor for *TCSME*.
- Continuing the CSME webinar series on Manufacturing, featuring both international and national invited speakers.

– *Dr. Farbod Khameneifar*, MCSME

## WELCOME NEW CSME / SCGM MEMBERS

***1 May 2023 - 30 September 2023***

Mr. Caine Benham, *Nordmin Engineering*
Prof. Roger Carrick, *University of Toronto*
Dr. Ebenezer Essel, *Concordia University*
Dr. Amin Etminan
Prof. Ramona Fayazfar, *Ontario Tech University*
Dr. Ramin Ghoreishi, *Concordia University*
Mr. Lyle Hemingway, *IAI*
Dr. William Hinman, *University of Calgary*
Prof. Osezua Ibhadode, *University of Alberta*
Dr. Jorge Palacios Moreno, *University of Alberta*
Dr. Babak Soltannia, *University of British Columbia (Vancouver campus)*
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CALL FOR SUBMISSIONS

# SUSTAINABLE ENERGY SYSTEMS

As the editors of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*, we would like to invite you to submit any of the following items for consideration for publication in the next CSME *Bulletin* issue.

The next issue focuses on **Sustainable Energy Systems** and will be published in May 2024. The guest editors of this issue will be the chairs of the Advanced Energy Systems and Heat Transfer CSME Technical Committees, Profs. **Xili Duan** and **Sunny Li**.

- **Feature articles:** The aim of the featured articles is to give our readers an overview of a given sub-topic of the theme (*Sustainable Energy Systems)*, the most recent advancements in the area, and finally, the most critical aspects for future research. The article should be 1,200 words (9,000 characters including spaces) long. If you are interested in submitting a featured article, please submit an Expression of Interest (EoI) by sending a 300-word abstract of the article and a 50-word biography to either Marc Secanell (secanell@ualberta.ca) or **Ryan Willing** (rwilling@uwo.ca) by January 31st, 2024. The most significant contributions will be invited to submit a full featured article that will be due on April 1st, 2024.
- **Faculty spotlight:** This section highlights new faculty in the Mechanical Engineering Departments across Canada within four (4) years of their appointment, ideally working on the topic of the issue (though not essential). The aim of this section is to introduce new faculty members to the CSME community; therefore, the article should provide a short biography, an introduction to your research (What is the topic of your research? Why is the research topic important?), and a description of your laboratory including past and future work. If you are eligible and interested in submitting an article, please submit an Expression of Interest (EoI) by sending a 100-word abstract and a 50-word biography to either **Marc Secanell** (secanell@ualberta.ca) or **Ryan Willing** (rwilling@uwo.ca) by January 31st, 2024. The most significant contributions will be invited to submit a full article (500 words or 4,000 characters) that will be due on April 1st, 2024.
- **Short news items** items of interest to the ME community prior to March 15th, 2024.
- **Recognitions:** Highlighting the achievements of ME peers (not self) prior to March 15th, 2024.
- **In memorials:** Recognizing the passing of ME members prior to March 15th, 2024.

For examples of the above, please see previous issues at www.csme-scgm.ca/bulletin.

Thank you for your consideration. We look forward to hearing from you soon.

**Marc Secanell**, PhD, P.Eng.
Professor, Department of Mechanical Engineering, University of Alberta
Editor, Canadian Society for Mechanical Engineering (CSME) *Bulletin*
Email: secanell@ualberta.ca

**Ryan Willing, PhD, PEng**
Associate Professor, Department of Mechanical and Materials Engineering, Western University
Associate Editor, Canadian Society for Mechanical Engineering (CSME) Bulletin
Email: rwilling@uwo.ca

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