

Conférence annuelle sur la recherche des **matériaux fonctionnels**

Nov.6, 2020

Advanced Materials

Annual Conference



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Commanditaires

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Horaire

Vendredi 6 novembre, 2020

9h00- 9h30 : Mots de bienvenue

Theo van de Ven, *McGill*, directeur du CQMF

Bruce Lennox, *McGill*, Membre du CQMF et Doyen de la faculté des sciences

Janice Bailey, *FRQNT*, directrice scientifique

9h30-10h30 : Conférence plénière **Reiko Oda**, *IECB Bordeaux, France* - *De la molécule chirale aux nanoobjets fonctionnels chiraux*

10h30-10h45 : Pause-café commanditée par Prima

10h45-11h00 : Présentation Prima commandite **OR**, **Sébastien Garbarino**, conseiller en innovation et infrastructures – *Les matériaux pour avancer*

11h00-12h30 : Séances thématiques AM

12h30-13h15 : Lunch commandité par SFR

12h45-13h15 : Lunch&learn SFR webinaire, **Samrat Dutta**, applications scientifique - *Étude des processus dynamiques par AFM à haute résolution spatio-temporelle et microscopie optique simultanée.*

13h15-14h15 : Conférence plénière, **Noémie-Manuelle Dorval Courchesne**, Université McGill, Québec - *Matériaux protéiques fonctionnels produits par des bactéries modifiées génétiquement*

14h15-14h30 : Présentation SFR commandite **Platine**, **David Polcari**, directeur des affaires Québec- *Instruments de pointe pour la caractérisation des matériaux.*

14h30-15h30 : Séances thématiques PM

15h30-15h45 : Pause-café commanditée par SnowHouse/Molecular Vista

15h45-16h00 : Présentation SnowHouse/Molecular Vista commandite **OR**, **Derek Nowak**, directeur des applications - AFM couplé à la spectroscopie vis-IR à l'échelle nanométrique par le biais de microscopie à force photo-induite

16h00-16h30 : Séances thématiques PM (suite)

16h30-16h45 : Réserve de temps pour pallier les retards éventuels

16h45-17h45 : Conférence plénière, **Vincent Chevrier**, *3M Minnesota, États-Unis*, *Alliages de Si nanostructurés pour les batteries Li-ion*

17h45-18h00 : Mots de la fin et annonce des prix pour les meilleures présentations

Schedule

Friday November 6, 2020

9:00- 9:30: Opening remarks

Theo van de Ven, *McGill*, QCAM director

Bruce Lennox, *McGill*, QCAM member and Dean of Science

Janice Bailey, *FRQNT*, scientific director

9:30-10:30: Plenary lecture, **Reiko Oda**, *IECB Bordeaux, France - Chiral molecule to chiral functional nanoobjects*

10:30-10:45: Coffee break sponsored by Prima

10:45-11:00: **GOLD** sponsor Prima presentation, **Sébastien Garbarino**, infrastructure and innovation advisor – *Advanced Materials Moving Forward*

11:00-12:30: AM parallel sessions

12:30-1:15pm: Lunch sponsored by SFR,

12:45-1:15pm: Lunch&learn SFR webinar, **Samrat Dutta**, Applications Scientist - *Investigating Dynamic Processes using High-Spatiotemporal Resolution AFM with Simultaneous Optical Microscopy*

1:15-2:15pm: Plenary lecture, **Noémie-Manuelle Dorval Courchesne**, McGill University, Québec - *Functional protein materials produced by engineered bacteria*

2:15-2:30pm: **PLATINUM** sponsorship SFR presentation, **David Polcari**, Quebec Business Manager - *Advanced Tools for Materials Characterization.*

2:30-3:30pm: PM parallel sessions

3:30-3:45pm: Coffee break sponsored by SnowHouse/Molecular Vista

3:45-4:00pm : **GOLD** sponsor SnowHouse/Molecular Vista presentation, **Derek Nowak**, director of applications - *AFM plus Nanoscale vis-IR Spectroscopy via Photo-induced Force Microscopy*

4:00-4:30pm: PM parallel sessions continue

4:30-4:45pm: Buffer time

4:45-5:45pm: Plenary lecture, **Vincent Chevrier**, *3M Minnesota, United States - Nanostructured Si Alloys for Li-ion batteries*

5:45-6:00pm: Closing remarks and announcement of the best presentations

Conférences plénières / Plenary lectures



Vincent Chevrier, 3M Minnesota, États-Unis

Titre/Title

Nanostructured Si Alloys for Li-ion batteries.

Résumé/Abstract

Increasing the energy density of Li-ion cells through the use of silicon has been an ongoing challenge across academia and the Li-ion industry for more than a decade. Successful implementation of Si-based materials is a surprisingly complex problem requiring consideration of challenges spanning multiple length scales from the nanoscale up to system-level interactions within the cell, while remaining cost compatible with a competitive industry. Solutions centered on nanostructured Si alloys will be discussed including recent findings on the evolution of the morphology of nanostructured Si alloys during cycling in a Li-ion cell.

Bio

Vincent Chevrier, Ph.D., Advanced Research Specialist, Corporate Research Systems Laboratory, 3M

Vincent Chevrier completed a PhD in Physics at Dalhousie University with Prof. Dahn and a post-doc on computational studies of energy materials at MIT with Prof. Ceder. Vincent joined 3M in 2010 and focused on the optimization, production and commercialization of Si-based nanostructured alloys for high energy density Li-ion batteries. Topics of interest included alloy design, nanostructure characterization, failure mechanisms, particle and electrode design, cell optimization, and high precision coulometry and calorimetry. He is currently working on Material Informatics in 3M's Corporate Research Systems Laboratory.



Reiko Oda

Chimie et Biologie des Membranes et des Nanoobjets (CBMN), CNRS - Université Bordeaux - Bordeaux INP, UMR 5248 r.oda@cbmn.u-bordeaux.fr

Titre/Title

Chiral molecule to chiral functional nanoobjects

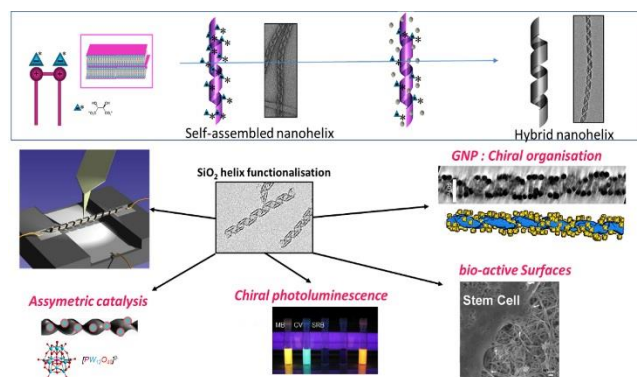
Résumé/Abstract

Recently, there are many reports on biologically inspired helical structure obtained by polymers, foldamers and low molecular-weight molecules. The helices with controllable pitches are attractive not only to mimic nature, but also for the wide range of applications in materials sciences, chemical and biomaterial sensing, and enantioselective catalysis. We have reported that chiral supramolecular assembly system can be achieved from non-chiral cationic surfactants with chiral counterions,¹ the role of the latter is extremely important to control the intimate morphologies of these chiral nanostructures. In this talk, I would like to discuss how such structures can then be used as scaffold to obtain hybrid organic/inorganic nanohelices,² which can then be used as a) nano-sensors, b) biomimicking objects, or c) the chiral environment of which can be used to organize nanoparticles or chromophore³ and thus induce chiroptical signals.

Keywords: Chirality, Self-assembly, Nanomaterials, Hybrid materials.

References

- ¹ a) Oda, R.; Huc, I.; Schmutz, M.; Candau, S. J.; MacKintosh, F. C. *Nature* 1999, 399 (6736), 566–569.; b) Brizard, A.; Aimé, C.; Labrot, T.; Huc, I.; Berthier, D.; Artzner, F.; Desbat, B.; Oda, R. *J. Am. Chem. Soc.* 2007, 129 (12), 3754–3762.
- ² a) Sugiyasu, K.; Tamaru, S.; Takeuchi, M.; Berthier, D.; Huc, I.; Oda, R.; Shinkai, S. *Chem. Commun.* 2002, No. 11, 1212–1213.; b) Delclos, T.; Aimé, C.; Pouget, E.; Brizard, A.; Huc, I.; Delville, M.-H.; Oda, R. *Nano Lett.* 2008, 8 (7), 1929–1935. ; c) Okazaki, Y.; Cheng, J.; Dedovets, D.; Kemper, G.; Delville, M.-H.; Durrieu, M.-C.; Ihara, H.; Takafuji, M.; Pouget, E.; Oda, R. *ACS Nano* 2014, 8 (7), 6863–6872.
- ³ Cheng, J.; Le Saux, G.; Gao, J.; Buffeteau, T.; Battie, Y.; Barois, P.; Ponsinet, V.; Delville, M.-H.; Ersen, O.; Pouget, E.; Oda, R. *ACS Nano* 2017, 11 (4), 3806–3818.; b) Ryu, N.; Kawaguchi, T.; Yanagita, H.; Okazaki, Y.; Buffeteau, T.; Yoshida, K.; Shirosaki, T.; Nagaoka, S.; Takafuji, M.; Ihara, H.; Oda, R. *Chem. Commun.* 2020, 56 (53), 7241–7244.; c) Liu, P.; Chen, W.; Okazaki, Y.; Battie, Y.; Brocard, L.; Decossas, M.; Pouget, E.; Muller-Buschbaum, P.; Kauffmann, B.; Pathan, S.; Sagawa, T.; Oda, R. *Nano Lett.* 2020. <https://doi.org/10.1021/acs.nanolett.0c02013>; d) Scalabre, A.; Gutiérrez Vilchez, A. M.; Sastre-Santos, A.; Fernández-Lázaro, F.; Bassani, D. M.; Oda, R. *J. Phys. Chem. C* 2020. <https://doi.org/10.1021/acs.jpcc.0c06847>; e) Yospanya, W.; Nishijima, M.; Araki, Y.; Buffeteau, T.; Pouget, E.; Wada, T.; Oda, R. *Chem. Commun.* 2020. <https://doi.org/10.1039/D0CC04198J>.





Noémie-Manuelle Dorval Courchesne, McGill University, Québec

Titre/Title

Functional protein materials produced by engineered bacteria

Résumé/Abstract

Protein-based materials represent sustainable and easily customizable alternatives to conventional synthetic polymers. With their biocompatibility, bioactivity and genetic tunability, proteins can be customized for a range of applications. Specifically, protein materials that self-assemble into macromolecular structures and can be produced at large scale are of interest for deployment into wearable devices, tissue scaffolds, and alternatives for commodity materials like plastics, textiles and electronics. Curli fibers produced by *Escherichia coli* bacteria represent a very promising protein scaffold due to their unique physicochemical properties. Once secreted by bacteria cells, CsgA subunits, the self-assembling repeats of curli fibers, form fibrous structures that can further aggregate and gel into macroscopic materials.

In this talk, I will describe advances from our group to engineer curli fibers and confer them with properties relevant for biosensing devices and porous mineralization scaffolds. First, I will present a strategy to fabricate wearable sensors made of genetically engineered curli fibers embedded in a textile matrix. Second, I will describe how the self-assembly mechanism of curli fibers can be utilized to drive the assembly of small peptides into supramolecular materials. Among other functionalities, we have genetically encoded in CsgA the ability to fluoresce in response to pH changes, and the ability to nucleate mineral particles. These functional protein constructs serve as proof-of-concept for the development of biocompatible scaffolds and sensing platforms and expand the diversity of functional protein-based devices.

Bio

Noémie-Manuelle Dorval Courchesne joined McGill University as an Assistant Professor of Chemical Engineering at in 2017. Previously, she completed her PhD in Chemical Engineering at MIT, and her postdoc at the Wyss Institute for Biologically Inspired Engineering at Harvard. She is a multidisciplinary chemical, materials and biological engineer, with expertise in self-assembly of biological and organic molecules. In her research, she integrates synthetic biology with scalable assembly processes, to fabricate functional materials. Prof. Dorval Courchesne is actively involved in industrially-relevant research, with the goal of introducing biologically-derived technologies in real-world products. Among other projects, she has an ongoing collaboration with the company lululemon, and she is part of an NSERC CREATE on Sustainable Electronics and Eco-Design (SEED). She is a member of several research networks including the Quebec Center for Advanced Materials (QCAM) and the Research Center for High Performance Polymer and Composite Systems (CREPEC). In 2020, she was recognized for her research potential as the recipient of the Christopher Pierre Award for Research Excellence (Early Career) at McGill. She was also recently named one of three “Emerging Leaders in Chemical Engineering” at the Canadian Chemical Engineering Conference (CCEC 2020).

Exposés éclairs / Flash talks

Nous avons reçu 16 excellentes vidéos. C'est maintenant à vous de décider qui se méritera le 1er prix. Vous avez jusqu'au 6 novembre, 16h45, pour soumettre votre vote sur le lien [suivant](#).

We received 16 excellent videos. It is now up to you to decide who will win the 1st prize. You have until November 6, 4:45 p.m. to submit your vote. Please follow [the link](#).

Alex Brice Pougoué Mbeunmi (UdeS)

Croissance directe de cellules solaires à base de GaAs sur substrat de Si via une couche tampon de Si mésoporeux
Direct growth of GaAs solar cells on Si substrate via mesoporous Si buffer

Alexis Loiseau (UL)

Des nanoparticules d'or ultrastables et mucoadhésives pour accélérer la guérison des plaies cornéennes grâce à l'encapsulation de la combinaison synergique C646 et SC79

Ultrastable and mucoadhesive gold nanoparticles to accelerate corneal wound healing through encapsulation of C646 and SC79

Chloé Paquet (UL)

Revêtements auto-réparateurs pour planchers / Self-healing coating for wood flooring

Dalia Jane Saldanha (McGill)

Développement de composites intelligents protéine-textile pour la détection du pH cutané
Development of Smart Protein-Textile Composites for Detection of Skin pH

Erman Eloge Nzaba Madila (UQTR)

Matériaux de cathode pour batteries sodium-ion: $\text{Na}_2\text{Co}_{1-x}\text{M}_x(\text{PO}_4)_2$ (M=Mn, Ni and x=1.0-4.0)
Cathode Materials For Sodium-Ion Batteries: $\text{Na}_2\text{Co}_{1-x}\text{M}_x(\text{PO}_4)_2$ (M=Mn, Ni and x=1.0-4.0)

Fangzhou Zhao (McGill)

"Impression" de motifs de brins d'ADN sur des petites molécules
"Printing" DNA Strand Patterns on Small Molecules

Kwan Ming Tam (Concordia)

Application de l'effet de sélectivité du spin induite par la chiralité
Applying the Chirality Induced Spin Selectivity Effect

Marie-Pier Cote (UL)

Développement de nanostructures coeur-satellites à l'aide de la technique Langmuir-Blodgett
Development of core-satellite nanostructures with the Langmuir-Blodgett technique

Exposés éclairs (suite) / Flash talks cont.

Mariia Kiseleva (UL)

Étude in vitro d'un système hydrogel-nanoparticules imprimé 3D pour le traitement localisé du cancer du col de l'utérus
In vitro evaluation of a 3D-printed hybrid hydrogel-nanoparticle formulation as a localized delivery system for cervical cancer therapy

Maxime Parot (UL)

Transformation de copeaux de bois en fibres de carbone / Transformation of wood into carbon fibers

Ravi Prakash (UQTR)

Hydrogen Storage in Metal Hydrides / Hydrogen Storage in Metal Hydrides

Roya Koshani (McGill)

Nanoingénierie Une boîte à outils de celluloses nanocristallines velues avec chiralité structurelle réglable
Nanoengineering a toolbox of hairy nanocrystalline celluloses with tunable structural chirality

Shubham Bhagat (Concordia)

Dépôt de semi-conducteurs polymères par électrospray sous ultravide
Electrospray deposition (ESD) of polymeric semiconductors under ultra-high vacuum (vacuum) conditions

Siamak Motahari (UQAC)

Aérogel de silice - Composites en fibre de verre comme pare-feu
Silica Aerogel–Glass Fiber Composites as Fire Shield

Somaiyeh Charoughchi (Concordia)

Molécules avec un centre de cyclopropane pour une utilisation en tant qu'accepteurs électroniques puissants dans les matériaux semi-conducteurs organiques
Cyclopropene-Core Based Molecules as Strong Electron Acceptors in Organic Semiconductors

Tao Liu (UQAM)

Électrodéposition de pérovskites inorganiques aux halogénures de plomb et de césium
Electrodeposition of Inorganic Cesium Lead Halide Perovskites

Séances thématiques présentations étudiantes

Parallel student presentations

Séance/Session AM organisateur.rice /chair	Polymères Polymers Prof. Adam Duong	Biomédicale Biomedical Victor Quezada	Nanoscience Yasmine Benabed
Lien Zoom link	Regardez/Watch	Regardez/Watch	Regardez/Watch
11h00-11h15	Yuan Fang (invitée)	Amélie Augé (invitée)	Jean-Claude Chartrand (invité)
11h15-11h30	Arnaud W. Laramée	Dalia Jane Saldanha	Gabriella Tessitore
11h30-11h45	Faezeh Hajiali	Dongjin Shin	Imane Haddadou
11h45-12h00	Hannes Hase	Phan Huu Trong	Mohammadreza Shamshiri
12h00-12h15	Solène Pellerin	Samira Ravanbakhsh	Sagar Prabhudev
12h15-12h30	Yao-Yu Xiao	Sophie Lemay	Samaneh Heydarian Dolatabadi

Séance/Session PM organisateur/chair	Auto-assemblage/Durabilité Self-Assembly/Sustainability Matteo Duca	Énergie Energy Chenghao Liu	Nanoscience/Biomédicale Nanoscience/Biomedical Arnaud Laramée
Lien Zoom link	Regardez/Watch	Regardez/Watch	Regardez/Watch
14h30-14h45	Ilknur Eryilmaz (invitée)	Laurence Savignac (invitée)	Amin Valiei
14h45-15h00	Martin Sichinga	Ivonne Monje	Yani Pan
15h00-15h15	Mohsen Ketabi	Mira Rupp	Gabrielle Raîche-Marcoux
15h15-15h30	Roya Koshani	Mohamed Fatahine	Xiaolei Hu
16h00-16h15	Hassan Fakih (invité)	Najmeddine Ferhi	Laurianne Gravel Tatta
16h15-16h30	Pedro Donnaruma	Tao Liu	Safa Ladhari

Résumés des présentations étudiantes

Student presentations abstracts

Biomedical applications/Applications biomédicales

Invited speaker: Amélie Augé, Franck Camerel, Apolline Benoist and Yue Zhao.

Université de Sherbrooke

UCST-Nanogels Crosslinked Using NIR-Dye Monomer Based on Nickel Bis(dithiolene) Complex and Evaluation of their Photothermal Efficiency

The existence of therapeutic window for which biologic tissues absorb and diffuse a little the near-infrared radiation (NIR), constitutes a major opportunity for non-invasive medicine and particularly for phototherapy. The combination of both thermosensitive and photothermal materials seem as an interested choice for controlled release induced by NIR-light. We report the synthesis of nanogels having a positive thermosensitivity (UCST) and crosslinked with a nickel bis(dithiolene) complex. The rising of temperature, allowing the nanogels volume transition, take place by exposure of sample to NIR light. This transition is explained by the ability of crosslinker based on nickel bis(dithiolene) complex, to absorb radiative energy and convert a part of this energy to heat. The photothermal conversion efficiency was studied by temperature and transmittance measures under irradiation using several light power densities. The photothermal conversion term, corresponding to ratio between dissipated energy as heat and radiative energy absorbed, was evaluated using the energy balance model. Several light power densities, particles concentrations and solvents were tried and our systems are able to reach an efficiency of 64.9%, ranking them among the most efficient systems. Finally, the controlled release was investigated using Nile Red as hydrophobic model.

Development of Smart Protein-Textile Composites for Detection of Skin pH

Wearable skin sensors enable patients to access relevant clinical data from sweat in a convenient and rapid manner. One essential hallmark of epidermal health is its pH, which ideally ranges from 4.5 – 7.0. Deviation of skin pH from this range could be an indicator of several dermatological ailments, ranging from acne to eczema. In this work, we report an engineered protein-textile composite for fluorescent sensing of skin pH. We fused the self-assembling protein CsgA with a pH-responsive red fluorescent protein, pHuji, to express responsive and chemical resistant polymeric hydrogels. We then integrated these functional hydrogels with porous and non-woven acrylic matrices through a simple vacuum filtration process to create protein-textile composites. These composites are mechanically stable, vapor permeable and stable against several harsh chemical environments. We demonstrated that the protein-textile sensors showed increased fluorescence intensity with increasing pH and could retain their responsive behaviour for a span of days. We also showed that our system exhibits reversible behaviour and could potentially be applied for continuous monitoring purposes. In conclusion, this biosensing platform can be used as stand-alone diagnostic skin patches or can be scaled-up in the future to develop intelligent clothing with diverse functionalities.

Design of a microchannel emulsification device for thermosensitive chitosan-based MSCS microencapsulation

Mesenchymal stromal/stem cells (MSCs) have shown significant therapeutic potential due to their immunomodulatory functions and capacity to promote tissue regeneration. MSC retention and survival at the implantation site represents a significant clinical challenge. We have developed thermosensitive chitosan hydrogels allowing localized MSC delivery [1]. They improve the retention of encapsulated cells but can also lead to MSC hypoxia in the time period prior to graft vascularization. Here, we propose to immobilize MSCs in chitosan microbeads to protect the cells from shear stress during injection while maximizing the surface area for bidirectional diffusion of oxygen, nutrients, and therapeutic substances. In the previous research, we developed chitosan microbeads but with significant size dispersion [2]. Therefore, a new method is required to produce mono-dispersive microbeads for better injectability and cell survival. We designed a novel microchannel emulsification device that can produce mono-dispersive microbeads with controlled sizes through a scalable production method. The design aims to generate uniform thermosensitive chitosan beads without coalescence by (1) providing sufficient space for a complete gelation and (2) incorporating a heating/cooling system to control the temperature-dependent gelation kinetics. Ease of device manufacturing and operation were also considered. We integrated a continuous flow system to facilitate phase separation and automate the bead collecting process. Microchannel emulsification is a promising method for clinical-scale MSC microencapsulation to promote tissue regeneration and various applications in regenerative medicine, pharmaceutical, and food industry.

Phytoglycogen Nanoparticles: Natural Candidate for Pulmonary Delivery of Therapeutics

The human lungs present many advantages as a drug delivery route: a high surface area (ca. 70 m²) for the adsorption of molecular species and particles, a thin epithelial barrier, abundant underlying vasculature, and low acidity. Inhalation delivery is expected to be an ideal approach for the treatment of lung cancer and associated pulmonary infection as it allows the site-specific physical delivery of chemotherapeutics and antibiotics. Nanoparticles carriers are broadening the options for targeted drug delivery systems with advantages including: high stability/long shelf life and high carrier capacity. In the alveoli, inhaled nanoparticles interact with lung surfactants, a lipid/protein mixture that lines the alveolar air/fluid interface and serves as a primary barrier to uptake. The physical/chemical interaction of the nanoparticles with the surfactants will determine their clearance, retention and translocation. We propose to use novel phytoglycogen nanoparticles for the pulmonary delivery of therapeutics. Phytoglycogen is extracted from non-GMO corn, making it safe, natural and eco-friendly. Before determining the efficacy of phytoglycogen nanoparticles to serve as organic nanocarriers for the aerosol delivery of therapeutics, their impact on the biophysical properties and phase structure of lung surfactants must be characterised. The objective of the research is to investigate the interaction of phytoglycogen nanoparticles of different surface chemistry and charge with lung surfactant membranes and their effect on the surface activity and morphological reorganisation during expansion/compression cycles. Isotherms (surface pressure vs molecular area), BAM (Brewster Angle Microscopy) images and diffraction patterns obtained by GIXD (Grazing Incidence x-Ray Diffraction) allow analysis of phytoglycogen nanoparticles toxicity on pulmonary surfactants. The combination of recent results brings us closer to being able to classify phytoglycogen nanoparticles as toxic or benign.

Switchable lipids provide fluidity to lipid vesicles selectively at acidic pH

Many anti-cancer drugs such as chemotherapeutic agents, proteins, DNA, short interfering RNA (siRNA), act on their intracellular targets. Therefore, to achieve the desired therapeutic effects, these molecules need to be transported to their sites of action in the cytosol. The pH-sensitive lipid nanoparticles are designed by adding a pH-sensitive unit in lipidic bilayer to trigger delivery of encapsulated drug under acidic condition. This design is highly beneficial to the cytosolic delivery of genetic material via endosomal escape, which has been clinically validated (Onpattro and mRNA-1273). Recently, we reported two pH-sensitive switchable lipids for the intracellular delivery of cell-impermeable compound and siRNA, which have shown high performances in vitro and in vivo. However, the process by which the pH-sensitive lipids facilitate endosomal escape and intracellular delivery remains unclear. In this study, we provide a clear evidence that, on the planar model system – Langmuir monolayer, the pH-sensitive switchable lipids (C12NDiMe and CSL3) undergo a molecular size transformation in a pH-dependent manner. Based on microscopic observations (Cryo-TEM, FF-SEM, AFM, Confocal imaging), the mechanism of membrane destabilization is proposed whereby upon acidification, the molecular size change of the pH-sensitive lipids could cause defects in bilayer structure (outward, inward or cracked structures) of lipid nanoparticles, which leads to the leakage of lipid nanoparticle cargo.

Improving the radiopacity of bio-absorbable Fe-based alloys by Fe-Mn-C-W magnetron sputtered coatings

Fe-Mn-C alloys are promising materials for bio-absorbable alloys in stenting applications. They allow the fabrication of thin-walled stents, and they can biodegrade over time. However, compared with the conventional Co-Cr stents, these alloys have low radiopacity. Therefore, this lowest visibility in X-ray imaging can impede their efficient visualization during the implantation procedure and for follow-up procedures. Tungsten, a high-density biodegradable element (19.3 g.cm^{-3}) with high X-ray attenuation coefficient, could be used as a coating to enhance the visibility of stents in X-ray. In the present work, Fe-Mn-C-W coatings were deposited on Fe-Mn substrates by magnetron sputtering plasma deposition, to enrich the base alloy with W. Magnetron sputtering is a plasma-based deposition technique which has been used for biomedical applications because of its potential to produce a uniform coating with a good level of adhesion to the surface of the implant at low temperature. To study the effect of tungsten on the properties of the coatings, different chemical compositions of coatings (20, 40 and 70 at.% W) were prepared using three different sputtering powers for tungsten (P100, P200 and P400) and three different thermal treatments (25°C, 300°C and 600°C). The effect of the presence of tungsten on the microstructure, roughness, corrosion behavior and radiopacity of the coatings were investigated. The results showed that coatings fabricated with 70 at. % W (i.e. P400) showed different microstructure for this sample (figure1). P400 had different crystallographic structures compared to the P100 and P200 and the presence of carbides was observed in this sample. The carbide peak was not observed after thermal treatment at 600°C. Corrosion studies (Hank's modified solution, OCP: 20min followed by PDP from -0.5 to +0.5 V) confirmed the impact of tungsten in the accelerating the degradation behavior of the coating and corrosion potential. P400 showed better results for the radiopacity. Thermal treatment results showed that P400 thermally treated at 600°C could be a promising candidate for a radiopaque coating application.

A 3D printed cell-laden hydrogel eye model for brachytherapy applications in vitro

Uveal melanoma (UM) is the most frequent type of eye cancer and 80% of these tumors are located in the choroid. UM is usually treated by brachytherapy or external radiotherapy. In this treatment, an episcleral plaque containing radioactive sources is placed on the patient's sclera through surgery. UM is known to be a type of cancer that shows a wide range of radiosensitivity among the different cells that composes a tumour. However, radiosensitivity data are not taken into account in the current dosimetry models used to prepare the treatment. This project aims at developing, by 3D printing, an eye-shaped cell-laden hydrogel scaffold that could be used for studying the effect of radiotherapeutic treatments on different types of cells that are associated with different radiosensitivity levels. The developed hydrogel formulation was composed of collagen type I (COL), alginate (ALG) and xanthan gum (XG). ALG and XG are improving the mechanical and printing properties of the hydrogel and COL is naturally found in the eye. The hydrogel was printed with the bioprinter (BioX, Cellink, Sweden) on a custom half-sphere lattice supports with a diameter of 25 mm, close to the diameter of human eyes. Three cancer cell lines with different radiosensitivity levels (92.1, M μ 2 and Mel270) and choroidal fibroblasts were used. Cell viability by live/dead tests were done in the non-printed cell-laden hydrogel at different time points (day 0, 4 and 7). Different hydrogel concentrations were tested to optimize its viscosity. Optimal viscosity was found to be 1.35% (w/v) ALG, 1.7% (w/v) XG and 1 mg/ml COL. The print code was adapted to allow the printing on half-sphere lattice supports and a custom petri dish was created. A first prototype of this model has been successfully printed without cells. Cell viability of cell line Mel270 was $(83.6 \pm 3.1) \%$ after a period of 7 days in the hydrogel. Future work will include the printing of the cell-laden hydrogel scaffold and the investigation of cell viability post-printing. Overall, this project aims at evaluating the impact of cellular radiosensitivity on the response of UM treatment.

Imine-bearing Block Copolymer Nanoassemblies: Synthesis and Enhanced Drug Release

Effective approaches to synthesize acid-responsive degradable block copolymers through the incorporation of acid-labile imine bonds have been extensively explored for developing smart drug delivery systems with controlled/enhanced drug release. A general method to synthesize imine-containing block polymers is the post-modification reaction, which is usually associated with the challenges such as low conjugation efficiency, batch-to-batch variation and scale-up complexity. We have reported a new approach utilizing a direct polymerization that allows for the synthesis of a novel PEG-based amphiphilic block copolymer bearing imine pendants in hydrophobic block (named ImP). In response to tumoral pH 6.5-6.9 and endosomal/lysosomal pH = 4.5-5.5, pendant imine linkages underwent acid-catalyzed hydrolysis to generate corresponding aldehydes and amines. This process caused the dissociation of nanoassemblies, leading to the enhanced/accelerated release of encapsulated Doxorubicin (an anticancer drug in clinical use) in acidic pH conditions. Given our results, we anticipate that acid-degradable pendant imine-bearing nanoassemblies have a great potential for intracellular drug delivery for cancer therapy. In vitro (cell lines) and in vivo (mouse model) experiments are currently in progress.

Protein Assisted Fabrication of Metallic Nanostructures and Applications in Electrocatalysis

Inspiration from nature has driven the development and application of greener nanomaterials prepared using bio-templates in the field of nanoscience. Compared to traditional chemical routes, bioinspired nanomaterial synthesis holds the advantage of mild synthetic conditions such as aqueous environment, ambient temperature, and no requirement for organic capping agent. In addition, the structures of some biomolecules make it possible to fabricate nanomaterials with complex and interesting morphology that are difficult to achieve through chemical methods. Recent years have witnessed a rapid development of applying these bio-templated nanomaterials in various research areas such as sensing, drug delivery and catalysis. In this study, tobacco mosaic virus coat protein (TMV cp) was investigated as a versatile template to mediate the synthesis of metallic nanorings and nanoparticles under neutral and alkaline conditions, respectively. The as synthesized materials were further utilized as electrocatalysts for renewable energy applications. While the prepared silver nanorings displayed superior selectivity (95% CO Faradaic Efficiency) and stability of catalyzing CO₂ electroreduction, the platinum nanorings showed excellent electrocatalytic activity for methanol oxidation. Spherical Pt nanoparticles synthesized under alkaline condition were also investigated to study the protein template effect.

Invited speaker: Laurence Savignac, John M. Griffin and Steen B. Schougaard.

Université du Québec à Montréal

How the Study of Li^+ Transport in LiFePO_4 Yielded to a New Electrode Design

As ultrafast charging cathode material, LiFePO_4 has asserted his commercial use for a wide range of applications. Undergoing a two-phase mechanism does not slow down the insertion and deinsertion process. As such, there is a keen interest to understand how Li^+ transport within this material. In this study, we investigate the transport progression by using metastable $\text{Li}_{0.6}\text{FePO}_4$ solid solution that phase separates spontaneously at room temperature. The kinetic profile of the transformation was acquired by X-Ray diffraction while more localized changes were probed using solid state nuclear magnetic resonance. When the sample is stored into a commercial electrolyte, an increase in phase separation kinetics indicated a surface transport process. While the nature of the coating at the surface is of essential concern for phase separating materials, a new design of a free-standing electrode has been developed. Major features of this composite imply a conducting polymer network as well as the integration of recycled carbon fibers, a challenge overcome for the first time in the formulation of a positive electrode.

In-situ formed Nitrogen-doped carbon/silicon-based materials as negative electrode for lithium ion batteries

New negative electrodes materials having performance better than those currently used in Li-ion technology has been a major focus of recent battery research. Here, we report on the synthesis and electrochemical evaluation of *in situ*-formed nitrogen-doped carbon/SiOC. The materials were synthesized by a sol-gel process using 3-(aminopropyl)triethoxysilane (APTES), sodium citrate and glycerol based on modified procedures for the synthesis of Si nanoparticles and N-doped graphene quantum dots. The electrochemical performance of pyrolyzed materials were studied using poly(acrylic acid) binder and commercial organic electrolyte. Our reported approach enable change of both the amount of nitrogen doping and the morphology as function of the molar ratio APTES:citrate and reaction time. Spherical-shaped NC/SiOC delivers a delithiation capacity of 622 mAh/g at 0.1 A/g and an initial coulombic efficiency (ICE) ~ 63%, while in the large-bulk material 367 mAh/g at 0.1 A/g and ICE ~55% was obtained. After 1000 charge/discharge cycles at 1.6 A/g the latter material exhibit 98% of the initial capacity once returned to lower current cycling. Overall, our results indicate that NC/SiOC materials are quite promising for electrochemical application since both the large capacity and stability demonstrate the superior performance compared to traditional graphite. Moreover, our synthesis is simple, facile, and more importantly, low-cost and environmentally friendly chemical such as sodium citrate and glycerol are used.

Photocatalytic hydrogen evolution under red light using ruthenium(II) pyrimidyl complexes as photosensitizers

The photocatalytic reduction of water to form hydrogen gas is a promising approach to collect, convert, and store solar energy. Typically, ruthenium tris-bipyridine and its numerous derivatives are used as photosensitizers (PSs) in a variety of photocatalytic conditions. The bis-terpyridine analogs, however, have only recently gained attention for this application due to their poor photophysical properties. Yet, by introducing electron donating or withdrawing groups on the terpyridine ligands, the photophysical and electrochemical properties can be improved significantly. In this study, a series of substituted 2,6-di(pyridin-2-yl)-pyrimidine ligands with peripheral pyridine substituents has been prepared and used to prepare ruthenium(II) complexes. The presence of the pyrimidine ring stabilizes the lowest unoccupied molecular orbital (LUMO), leading to a red-shifted absorption and emission and prolonged excited-state lifetimes as well as higher luminescence quantum yields compared to analogous terpyridine complexes. Furthermore, all complexes are easier to reduce than previously reported bis-terpyridine complexes used as PS. An interesting correlation between substitution pattern and properties of the complexes was observed and further investigated using TD-DFT. In hydrogen evolution experiments under blue and red light irradiation, all investigated complexes exhibit a much higher activity compared to previously reported ruthenium(II) bis-terpyridine complexes but none of the complexes is as stable as the literature compounds, presumably due to an additional decomposition pathway of the reduced PS competing with the electron transfer from the reduced PS to the catalyst.

Étude par dilatométrie électrochimique d'électrodes à base de lithium métallique pour batteries Li / S

L'utilisation d'anodes de lithium métallique dans des batteries rechargeables, telles que les systèmes lithium-soufre et lithium-air, pose un défi en raison de la formation incontrôlée de dendrites de lithium lors des cycles de charge/décharge, entraînant des problèmes de sécurité et de faibles rendements coulombiques. Différentes techniques de caractérisation ont été utilisées pour étudier la formation des dendrites de lithium telles que la microscopie électronique à balayage et la microscopie optique. La grande majorité de ces études ont été réalisées ex-situ ou in-situ mais dans des conditions statiques (pas de cyclage) ou en utilisant des cellules ouvertures nécessitant un électrolyte non-volatil, donnant des informations limitées sur la dynamique de croissance du Li dans des systèmes réels. Récemment, la tomographie aux rayons X synchrotron a été utilisée pour visualiser in-situ l'évolution morphologique d'électrodes de Li métallique dans diverses configurations de cellules (par exemple, cellule Li-S). Cependant, l'accès limité à des sources RX synchrotron et les défis liés au traitement complexe des données (segmentation des images, reconstruction du volume, minimisation des artefacts, etc.) sont des inconvénients majeurs. Dans la présente étude, une méthode simple et peu coûteuse est utilisée pour étudier le processus de déposition / dissolution du lithium métallique. Cette technique, appelée «dilatométrie électrochimique», consiste à intégrer un capteur au sein de la cellule électrochimique pour mesurer le déplacement vertical de l'électrode de travail lors de son cyclage. Cette méthode a été récemment appliquée avec succès pour étudier la variation volumique d'électrodes à base de silicium pour les batteries Li-ion. A notre connaissance, la dilatométrie électrochimique n'a jamais été appliquée à l'étude d'électrodes de lithium métallique. Dans la présente étude, cette technique est utilisée pour étudier les variations volumiques associées à la déposition/dissolution répétée du Li métal dans un électrolyte pour batteries Li/S dépendamment de la nature/géométrie du substrat (i.e. feuille 2D de cuivre versus papiers carbone 3D poreux).

PANI /MOF-808 Composite for High Capacitance Supercapacitor Electrodes

Metal-organic frameworks are a combination of organic ligands and metal ions or clusters to form multidimensional porous networks. Among their promising applications and properties in different areas, they emerge as promising alternative electrode materials aiming to overcome the disadvantages of low capacity and short life cycle. Although the potential of MOFs that lies in their adjustable pore structure, morphology, crystallinity and high surface areas, porous coordination polymers have the drawback of their low conductivity. In that context, composites with conductive matrices, including conductive polymers, have proved to enhance the electrochemical properties of MOFs and their structural stability in the long-term cycling process compared to the pristine MOF. In this work, we have chosen the well-known MOF-808 as porous material because of its resistance to strong acidic media in a post-synthetic modification process. As a conductive agent, we have selected polyaniline (PANI) due to its high stability and facile synthesis. The new obtained composite may increase the charge transport properties of PANI through the crystalline structure of the material with a multi-modal porous structure. The synthesized new material has been characterized by FTIR, powder XRD, UV-vis, SEM and TEM. Adsorption properties for CO₂ gas has been also investigated for MOF-808 and the new composite.

Electrodeposition of Inorganic Cesium Lead Halide Perovskites

Cesium-based halide perovskites have attracted tremendous interest for stable and efficient photovoltaics due to their tunable optical and electronic properties. Among the preparation methods of perovskites, Electrodeposition has been demonstrated as a scalable and reproducible technique to fabricate high performance solar cells. Herein, electrodeposition and chemical conversion were combined to access inorganic cesium lead mixed-halide perovskites (CsPbX_3 , $X = \text{I}, \text{Br}, \text{Cl}$ or their mixture). Their bandgap (E_g) was tuned from 2.3 eV to 2.9 eV by controlling the halide stoichiometry in the thin films, which was achieved by varying the solution composition used during chemical conversion. The study of (Photo)electrochemical activity of as-prepared CsPbX_3 thin films showed that CsPbCl_3 had a large stability window of ~ 2.0 V and a high photocurrent of $400 \mu\text{A}/\text{cm}^2$ under 405 nm light-emitting diode (LED). This electrodeposition-based method offers new opportunities for fabrication of high-performance and stable perovskite devices.

Invited speaker: Ilknur Eryilmaz, Giorgio Mattana, Benoit Piro and Emanuele Orgiu.

INRS-EMT

Ink-jet Printing of Flexible Organic Thermoelectric Devices

Tomorrow's electronics will certainly be wearable, implantable, and suited for Internet of Things (IoT) applications. However, this goal requires putting a significant effort on materials and processing thereof. In this context, developing devices that are wearable and capable of supplying power is of utter importance. Thermoelectric generators (TEGs) transform waste heat into electrical energy through the Seebeck Effect; they are able to supply power to integrated low-power devices on the spot. A thermoelectric material that features a good figure-of-merit ($zT = \sigma S^2 T / \kappa$) possesses high electrical conductivity and low thermal conductivity. My work focuses on ink-jet printing of p- and n-type semiconductors to develop flexible thermoelectric generators. As ink-jet printing allows the creation of desired patterns with a continuous drop-casting system, this technology has thus far been used to fabricate electronic devices mainly. We employed a p-type polymer, iso indigo-based IIDDT-C4, and an n-type polymer, P(NDI2OD-2T) and explored the conductivity properties upon doping. The ink formulation was therefore an essential and primary step in the ink-jet process to obtain uniform droplets while achieving film formation on flexible polyimide substrates. Hence, we studied the inks' rheological properties; and dopant effects on film formation. This research showed that ink-jet printed organic thermoelectric devices are promising vertical flexible TEGs. P(NDI2OD-2T) films were uniform, although IIDDT-C4 required polystyrene additive to establish uniformity. Future studies will focus on the further development of inks for better electrical conductivity properties.

Treeyon: An eco-friendly one pot oxidative synthesis of imine carboxymethyl dialdehyde cellulose for applications in textile

Cellulosic products continue to advance the replacement of non-renewable polymeric products and provide a source of biobased materials. The quest to efficiently produce renewable and sustainable functional cellulosic products has prompted the development of an environmentally sensitive and cost-effective method to produce multi-functionalized cellulosic fibres for application in the textile industry. Current cellulose-based textiles, mainly manufactured by the rayon process, in which carbon disulfide, a highly toxic product, is used. In addition, textile dyeing is one of the most polluting processes in this industry. Therefore, to tackle these drawbacks, Treeyon has been developed. One form of Treeyon is an imine carboxymethyl dialdehyde modified cellulose (ICDAMF) material, multi-functionalized in a sequential single-pot synthesis to obtain desired beneficial properties, without isolating and purifying intermediate products. Multi-functionalization allows for covalent addition of dye, thereby preventing leaching during the textile filament spinning process and products' lifetime use. Therefore, the present research explores color addition and wet textile spinning without production of waste. In addition, rheology and dye adsorption kinetics of modified fibres has been studied using break through curves, to optimize reaction conditions.

Graphene Bio-Inks for Green and Flexible Humidity Sensors

Graphene has been one of the most studied materials as a multipurpose 2D material due to its remarkable properties. For example, graphene-based inks were investigated extensively as a replacement for the metallic inks (copper and silver inks) in the development of flexible and printed electronics because of the exceptional mechanical, electrical and chemical properties. However, the use of toxic and high boiling point solvents (DMF, NMP and terpineol) is a challenge that persists prior to their wide deployment in industry. Consequently, we dedicated this work to develop green and eco-friendly aqueous graphene inks, namely graphene bio-inks, obtained in water as a solvent and binding with bio-degradable polymers such as triton X-100 and tween-20. The finished product will be recyclable and/or biodegradable to limit the release of toxic and harmful materials upon their degradation in the environment leading to reduce the accumulated e-waste in nature. We conducted graphene bio-inks (pure and gelatin modified inks) to print flexible humid sensors by using aerosol printer. In this area, we carried out a systematic study to determine the optimal printing pattern (structure and dimension) and electrode type. Later, we studied sensors' efficiency in environments with relative humidity (RH) in the range of 10%-90% and room temperature. Graphene sensors showed a proportional relationship between relative humidity and electrical resistance; the electrical resistance increases along humidity increase and vis versa. The project is still running and further studies are planned for graphene sensors including, but not limited to, sensors sensitivity to other gases, the sensing performance in cycled dry/humid environments and the determination of the sensing mechanism.

Nanoengineering a toolbox of hairy nanocrystalline celluloses with tunable structural chirality

Hairy nanocrystalline celluloses (HNCs) are developed via the chemical nanoengineering of cellulose, the most abundant biopolymer in the world, overcoming the structural and chemical limitations of conventional nanocelluloses. Electrosterically stabilized nanocrystalline cellulose (ENCC) is a member of this universal family that by taking advantage of the amorphous cellulose chains protruding from both ends, bears an exceptional carboxylic acid density ($\sim 6 \text{ mmol g}^{-1}$) compared to conventional homologues ($< 1 \text{ mmol g}^{-1}$). Despite the admirable performance in addressing many technological and environmental challenges, little is known about its structural organization. Via engineering a cellulose-based nano-toolbox ranging from 120-220 nm and $2.5\text{-}5 \text{ mmol g}^{-1}$, we show that the size and surface charge of ENCC can be easily fine-tuned by acid-mediated trimming of the hairs. Here, for the first time, we also report the structural chirality of ENCC on a single particle level observed by induced circular dichroism. We experimentally show that an individual ENCC particle has a left-handed twist, in contrast to other right-handed nanocelluloses. ENCC synthesis causes oxidation-induced peeling of the outer layer of a nanocellulose particle. The result is consistent with Quantum Mechanical Computational modelling developed by us before, which indicated that chains at the surface of nanocrystals were right-handed, while most chains in the interior were left-handed. These findings suggest how manipulating HNCs enables accessing a collection of nanocrystals with desired colloidal properties and the capability of reversing their structural twist. This facilitates developing chirality-dependent hierarchical supramolecular structures from cellulose.

Invited speaker: Jean-Claude Chartrand, Thomas Putaud, Clément Wespiser, Armand Soldera, Yulia Kalugina, Pierre-Nicholas Roy, Xavier Michaut and Patrick Ayotte.

Université de Sherbrooke

Étude spectroscopique infrarouge des isomères de spins nucléaires de l'eau confinée dans le fullerène C₆₀: Assignment spectrale et analyse des cinétiques d'interconversion

La molécule d'H₂O possède deux atomes d'hydrogène indiscernables ayant un spin nucléaire non nul. Ainsi, le principe de Pauli stipule que deux isomères de spin existent : ortho-H₂O et para-H₂O. Même si leur interconversion est interdite par symétrie dans la molécule isolée, des variations des populations relatives des deux isomères de spin sont observées lors de changements de température lorsque la molécule d'eau est piégée en milieu dilué et ce, même à des températures aussi basses que 4K. Nous avons étudié un milieu de confinement inusité, rendu accessible depuis 2011, alors que la première synthèse de l'endofullerène H₂O@C₆₀ a été rapportée par Murata. Nous avons examiné des mélanges binaires C₆₀ : H₂O@C₆₀, préparés en phase solide par sublimation sous vide, à l'aide de la spectroscopie infrarouge ce qui nous permet, avec le modèle quantique du rotateur asymétrique confiné, de sonder le potentiel de confinement, ses effets sur la dynamique rotationnelle, et de sonder les cinétiques de conversion des isomères de spin nucléaire, afin d'élucider les mécanismes sous-jacents. Une analyse spectroscopique et cinétique sur la gamme de température 5K-60K, et pour des taux de remplissage en molécules d'eau des cages de C₆₀ de 1% à 50%, a été réalisée permettant de lever le voile sur les mécanismes de conversion des isomères de spin nucléaire de H₂O. De plus, plusieurs comportements inattendus des transitions ro-vibrationnelles seront présentés, observations qui pourraient révéler le rôle des interactions intermoléculaires entre les molécules d'eau H₂O@C₆₀.

A mechano-bactericidal property of nanopillars caused by external forces

Natural and synthetic surfaces textured with high-aspect-ratio nanopillars have been shown to damage and kill attached bacteria. However, the “mechano-bactericidal” mechanism by which cells are killed on nanopillars remains unclear. In this study, we identify and investigate the critical role of external forces that arise during standard sample handling and imaging that can drive mechano-bactericidal behavior. *Pseudomonas aeruginosa* was deposited on several nanopillar surfaces with established mechano-bactericidal capacities and assayed for viability and morphological damage using real-time fluorescent microscopy and scanning electron microscopy. Surprisingly, maintaining cells in immersion throughout the experiment virtually eliminated the expected mechano-bactericidal effects, but the passage of an air-liquid interface across the sample caused considerable cell death. Reasoning that normal forces arising from surface tension may drive mechano-bactericidal activity, we developed a computational and experimental model to estimate and manipulate normal forces during air-liquid interface movement, and independently tested the effects of normal forces on mechano-bactericidal activity. These experiments together reveal that each of the nanopillar surfaces tested here do not cause cell death in the absence of external normal forces; and that a critical level of external force is required to impart significant deformation and eventual rupture of a bacterial cell. This improved understanding of nanopillar-mediated antibacterial activity hence suggests that mechano-bactericidal surfaces should be designed in combination with mechanisms to apply such normal forces, to ultimately implement these surfaces in practical real-world applications.

The Key Role of Intrinsic Lifetime Dynamics from Upconverting Nanosystems in Multiemission Particle Velocimetry

Measuring the particle velocity at the nano- and microscale can be challenging with the actual velocimetry techniques based on luminescence probes. The major drawback of their use resides in the requirement for calibration of the emission profiles, which limits their use to the specific experimental conditions used for the calibration. The proposed multiemission particle velocimetry method guarantees accurate velocity measurements, independent of the particle concentration or experimental setup, and without need for calibration. The used nanoprobe is a core-shell upconverting nanoparticle co-doped with Yb^{3+} , Tm^{3+} and Tb^{3+} . Upon excitation with a focused near-infrared pulsed laser, these nanoparticles emit photons at different wavelengths. The time interval between these successive emissions is independent of the local environment or particle velocity. The velocity of the particles is calculated by measuring the distance between the maxima of two different emissions and dividing it by this known difference in luminescence lifetimes. This method was proved accurate by using simple digital imaging of nanoparticles flowing in 75–150 μm diameter capillaries with a phone camera and an inexpensive experimental setup. The relative standard deviation of the experimental velocities with respect to the theoretical ones was 5% or lower without any calibration.

Étude de l'encapsulation et du relargage de médicaments par des nanoparticules d'or pour la thérapie oculaire

Malgré la grande concentration en agents thérapeutiques des gouttes ophtalmiques, plus de 99,9% de ces molécules sont éliminées lors de l'application topique. L'augmentation de la biodisponibilité de l'agent actif doit passer par l'optimisation de la mucoadhésion du vecteur du médicament. Les nanoparticules d'or sont des candidates prometteuses grâce à leur mucoadhésion, leur non-toxicité et leur ultrastabilité. Le flurbiprofène et le kétorolac sont des anti-inflammatoires vendus en gouttes ophtalmiques qui sont souvent prescrits à la suite d'une chirurgie de la cataracte et qui doivent être appliqués entre trois et huit fois par jour par le patient. L'hypothèse de recherche propose que les nanoparticules d'or mucoadhésives peuvent encapsuler et relarguer le flurbiprofène et le kétorolac afin d'améliorer, à terme, leur efficacité thérapeutique lorsqu'ils sont administrés par voie topique. L'objectif était de développer des protocoles afin de doser les molécules encapsulées et relarguées par des nanoparticules d'or mucoadhésives. Les cinétiques d'encapsulation des molécules thérapeutiques ont été mesurées par spectroscopie d'absorption en UV-visible en suivant le déplacement du sommet de la bande plasmon grâce à la dérivée première du spectre. Deux plateaux d'encapsulation ont été observés pour les deux molécules, ce qui démontre la capacité des nanoparticules d'or à encapsuler le flurbiprofène et le kétorolac. Par la suite, le dosage indirect de l'encapsulation des médicaments a été effectué par chromatographie liquide à haute performance (HPLC) après immunoprécipitation des nanoparticules d'or. Il a été observé que le pourcentage d'encapsulation du kétorolac varie avec le ratio nanoparticules:médicament. Finalement, un protocole de relargage a été mis en place et les molécules relarguées ont été mesurées par HPLC. Selon les conditions expérimentales utilisées, il est possible de moduler l'encapsulation et le relargage du le flurbiprofène et le kétorolac en utilisant des nanoparticules d'or en tant que vecteurs de médicaments ophtalmiques.

One-step green synthesis of carbon dots from biomass wastes

Carbon quantum dots (CDs) are zero-dimensional carbon-based nanomaterials with interesting properties for various applications, such as, metal sensing, detection and inhibition of microorganisms. These fluorescent nanoparticles are a good alternative to conventional semiconductor quantum dots due to their nontoxicity, high solubility, and easy functionalization. In this study, we prepare high luminescent CDs from biomass solid waste powder (potato, almond and pumpkin peels and pumpkin seeds) using a microwave and ultrasound assisted process. The synthesized CDs were characterized by UV-visible, fluorescence, Fourier transform infrared (FT-IR), dynamic light scattering (DLS) and zeta potential measurements. The effect of the carbon precursors, the chemical structure and the concentration of CDs on their optical properties (photo-fluorescence) were studied. CDs show a favorable optical properties and present surface-bound oxygen-containing groups (carboxyl and hydroxyl) and thus could act as an antimicrobial agent (rapid detection and efficient inhibition of microbial growth).

A survey of stimuli-responsive coatings with icephobic applications

The stimuli-responsive icephobic coatings have attracted a lot of interest over the last decades owing to their potential use for the combating icing. They are designed to respond to a change in their surrounding conditions in the predictable way. The stimuli-responsive icephobic coatings, or in the other word, the smart icephobic coatings are able to feel their environment and give a desirable response to those stimuli. The stimuli can be changed in pH, pressure, temperature, light or even electric or magnetic field variations, which can be responded as changes in size, surface area, shape, temperature, mechanical properties and so on. Depending on the types of stimuli and response, smart icephobic coatings can be classified into different categories. Some of them, such as thermo-responsive coatings generate heat, as a response to stimuli, that could be utilized for anti-icing purposes. In electro-mechanical de-icing systems, mechanical pulses can be generated to decrease ice adhesion. In this work, two different smart icephobic categories, namely aqueous self-lubricating coatings as well as icephobic coatings containing phase change materials (PCMs) will be investigated as smart icephobic strategies.

Nanotechnology Application toward SARS-CoV-2 (COVID-19)

The raging human coronavirus epidemic, widely referred to as the COVID-19 pandemic, has thrown the entire planet into a significant challenge to global economy and welfare, affecting more than 216 nations. The causative agent of COVID-19 is a novel severe acute respiratory syndrome coronavirus-2 known as SARS-CoV-2, which emerged with unknown origin in Wuhan city of China in December 2019, affiliated with the Huanan Seafood Wholesale Market. Because of its high morbidity aspect and risk of causing pneumonia, mortality rates stood at 3.24% of infected persons. Researchers have been working to find a new drug to combat the virus since the outbreak started in late 2019, but there are currently no successful drugs to control the SARS-CoV-2, which makes the situation riskier. Nanotechnology has received much interest and application over more than two decades to particles with dimension(s) falling within the range of the nanometer (10⁻⁹ or 1 billionth of a meter) due to their unique properties. The potential of metal nanoparticles for early detection, diagnosis, and treatment of disease was explored in medicine to solve several specific health issues. In this presentation, we review an up-to-date drug design strategy against SARS-CoV-2, including the development of novel drugs and repurposed product potentials where useful, and successful drugs discovery is a constant requirement. The use of nanomaterials in treatment against SARS-CoV-2 and their use as carriers for the transport of the most frequently used antiviral therapeutics are also discussed. We also address the possibilities of practical applications of nanoparticles to give the status of COVID-19 antiviral systems.

Engineering Compositionally Controlled Gold-Palladium Electrocatalysts with the use of Electrochemistry

Curbing CO₂ emissions through clean energy has never been more important considering the dramatic rise in fossil-fuel related emissions that has exceeded over 33.1 gigatons (Gt). One key research area that is leading the future low-carbon energy sector is electrocatalysis, involving development of advanced catalytic nanomaterials towards fuel cells and electrolyzers. The recent development of gold-palladium (Au-Pd) alloy nanoparticles outlines a contemporary strategy in combining the synergistic effects of a more electrochemically stable gold (Au) metal with catalytically active palladium (Pd). Unfortunately, not all compositions are optimal, which requires further fine-tuning - a task that seems impracticable with the prevalent wet-chemical synthetic methods. Here we present a new approach for fine-tuning surface composition in Au-Pd catalytic nanoparticles *via* a procedure involving selective diffusion of Pd atoms as a result of electrochemical processing in alkaline media. As shall be presented, a series of characteristic fingerprints were captured with the help of cyclic voltammetry and electrochemical polarization. The metal redox peaks that were suggestive of an Au-rich surface gradually evolved into bearing of a Pd-like character with subsequent cycling. The detailed electrochemical analyses were corroborated with advanced light-scattering, X-ray and electron spectromicroscopic tools, and mathematical analyses. Going forward, a similar technique can be more generally applied towards development of 'self-healing' electrocatalysts – ones that can alter properties suiting different external requirements with a simple switching of voltage, or a controlled pre-treatment.

Fabrications and Anti-icing Characteristics of Slippery Liquid Infused surfaces

The issue of ice formation on solid surfaces is a serious issue in terms of safety and cost for many applications, including transportation, power plants, wind turbines, railways, and telecommunication systems. To protect solid surfaces from ice coverage and prevent related damage, much effort has been devoted to the academic and industrial sectors to develop various strategies against ice buildup such as developing icephobic surfaces. Recently, the slippery liquid-infused porous surfaces (SLIPS) have been introduced by inspiration from Nepenthes pitcher plants. These surfaces are demonstrated to possess advantages of low sliding angle and contact angle hysteresis to repel various liquids like water. So, they can be considered as a proper and noble candidate for solving the problem of ice accretion in various area from the chemical industry to transportation and energy production. The evaluation of fabrication methods and anti-icing characteristics of SLIPSs verified that how morphology of the substrate, including creating textured by various method like chemical etching or using cross-linked polymers, affects anti-icing results. In this regard, use of a superhydrophobic surface is the most well-known method for the fabrication of slippery coatings in which a textured structure is utilized to hold an infusing oil. Another approach to obtain slippery surfaces is through lubricant-infused polymeric systems. Such crosslinked polymers have very low ice adhesion strength, and infusing oil into polymers decreases ice adhesion considerably and provides an appropriate matrix for blocking and encapsulating the lubricant over an extended period. So, this research focus on introducing the various fabrication methods that can be utilized in field of slippery oil infused surfaces and their icephobic characteristics.

Invited speaker: Yuan Fang and Dmitrii Perepichka

McGill University

2D Poly(arylene vinylene) Covalent Organic Frameworks via Aldol Condensation of Trimethyltriazine

Designing structural order in electronically active organic solids remains a great challenge in the field of materials chemistry. Now, 2D poly(arylene vinylene)s prepared as highly crystalline covalent organic frameworks (COFs) by base catalyzed aldol condensation of trimethyltriazine with aromatic dialdehydes are reported. The synthesized polymers are highly emissive (quantum yield of up to 50%), as commonly observed in their 1D analogues poly(phenylene vinylene)s. The inherent well-defined porosity (surface area ca. $1000 \text{ m}^2\text{g}^{-1}$, pore diameter ca. 11\AA for the terephthaldehyde derived COF1) and 2D structure of these COFs also present a new set of properties and are likely responsible for the emission color, which is sensitive to the environment. COF-1 is highly hydrophilic and reveals a dramatic macroscopic structural reorganization that has not been previously observed in framework materials.

Electrospinning of Highly Crystalline Polymers for Strongly Oriented Fibers

Electrospun nanofibers (NFs) are unidimensional nanostructures formed upon the solidification of a thin electrified jet drawn from a viscous polymer solution. They often demonstrate an exponential increase in mechanical properties at reduced diameters, making them promising candidates for a wealth of applications related to fields such as tissue engineering, actuation, and selective filtration. Grasping how polymer chains alter their conformation and orient themselves during the electrospinning process is crucial for understanding the origins of the fibers' resulting properties. Therefore, experimental quantification of molecular orientation is essential for the development of optimized nanomaterials. In this work, polarized confocal Raman spectroscopy reveals that fibers of highly crystalline poly(ethylene oxide) (PEO) maintain a high orientation over a broad range of diameters, in strong contrast with the usual exponential trend. This observation stands for five electrospinning solvents of widely different properties. By comparison, poly(oxymethylene) (POM) NFs also show a high orientation at low diameters but it decreases substantially for diameters larger than ~ 1400 nm, a result attributed to the lower crystallinity of POM compared to PEO. The results show that the exponential orientation dependence on fiber diameter is not universal and stress the importance of polymer crystallinity on the structure and properties of electrospun nanofibers. This work guides the preparation of fibers with optimal orientation-dependent properties and shows that high crystallinity can afford more robust materials whose performance is less affected by variations in experimental conditions, a valuable feature for most applications.

Thermally Recyclable Bio-Based Cross-linked Polymers Containing Dynamic Networks

Advanced thermosetting composites play an important role in construction, aerospace, manufacture and transportation industries owing to their excellent mechanical properties, low density, heat resistance and versatile designability. Currently, recycling and recovery of industrial thermosetting polymers still have significant challenges. Highly cross-linked polymers require harsh conditions like aggressive chemicals, high pressure and relatively high temperatures (>200°C) for a long time in order to be recycled by conventional methods. Recently, a new kind of thermoset material called vitrimers was presented, which can be thermally or photochemically reprocessed using exchangeable chemical bonds. In this study, we explore the reaction between β -ketoesters derived from commercially available (2-acetoacetoxy) ethyl methacrylate (AAEMA), incorporated into a bio-based polymer chain containing isobornyl methacrylate (IBOMA) and a bio-based bi-functional amine to synthesize catalyst-free vitrimers. Vitrimer nanocomposites were obtained by the incorporation of amine-functionalized polyhedral oligomeric silsesquioxane (POSS-NH₂) at different loadings (0, 5, 10 and 20 wt%). Incorporation of 20 wt% POSS-NH₂ improved tensile modulus (from 96 to 176 MPa), tensile strength (from 2.5 to 5 MPa) and decomposition temperature (225 to 255 °C), and increased relaxation rate and apparent activation energy of stress relaxation compared to the neat vitrimer. We further show that bio-based vitrimers and the nanocomposites containing vinylogous urethane cross-linking networks can be un-cross-linked by dissolving in excess mono-functional amine at 65 °C or recycled by grinding and remolding at 125 °C without compromising the mechanical properties.

Formation of Ion Pairs and Charge-Transfer Complexes in the p-Doping of Organic Semiconductors.

The formation of ion pairs (IPAs) through integer-charge transfer and ground-state charge-transfer complexes (CTCs) with only fractional charge transfer are the two known mechanisms in the molecular doping of conjugated polymers and molecules, which form the material class of organic semiconductors (OSCs). As it entails no immediate ionization of the OSC, CTC formation is regarded as detrimental to the doping efficiency. For IPA formation to occur, a match between the electron affinity (EA) of the p-dopant and the ionization energy (IE) of the OSC is expected as crucial, while their pronounced frontier molecular orbital overlap should promote CTC formation instead. To explore these complementary scenarios, we first studied the thermal de-doping of the prototypical conjugated polymer poly(3-hexylthiophene) (P3HT), p-doped with the common strong electron acceptor tetrafluoro-tetracyanoquinodimethane (F4TCNQ). We combined grazing incidence X-ray diffraction (GIXRD) with Fourier-transform infrared spectroscopy (FTIR) to determine the microstructure, and absorbance spectroscopy (UV-vis/NIR) to observe the spectral fingerprint of the two doping scenarios. We found two microstructural environments through their distinguished thermal stabilities where the dopants were observed (i) alternatingly stacked with the polymer backbone as well as (ii) dispersed in its side-chain region. From FTIR and UV-vis/NIR we deduce that all dopants are fully ionized, although packing between dopant and polymer backbone would be expected to favor CTC formation instead. Notably, while characteristic shifts of the mid-infrared cyano-stretch modes of TCNQ derivatives are known to well indicate the degree of charge transfer, we show here that they allow further to assess the dopant site in the polymer environment. We further investigated the influence of EA with respect to IE by contrasting F4TCNQ with its derivatives of lower degree of fluorination, which translates into reduced EA while leaving the spatial aspects of the dopant largely intact. We find that using F2TCNQ and FTCNQ still results in ample IPA formation in spite of $EA < IE$, which we understand through the lower degree of spatial, and therefore energetic order in OSCs as compared to inorganic semiconductors, which therefore possess no sharp band edges. Surprisingly, at high doping concentrations (additional) CTC formation occurred for all the differently strong dopants, which highlights the complexity of these systems going beyond the sole impact of the energetics of the individual constituents. Finally, we juxtaposed the known tendency of small molecular OSCs to form CTCs and that of polymer OSCs to form IPAs. To maximize the comparability with P3HT, alkylated oligothiophenes of different length were synthesized in-house (from 4 to 10 thiophene repeat units) and doped with F4TCNQ. For the longest oligomer, we were able to observe the switch from the CTC regime into that of IPA, i.e., we approach the doping behavior polymer limit. Knowing this threshold is valuable for applications in organic electronics where vacuum processible small molecular OSCs are preferred over polymers, which are only processible via solution-based methods.

Incorporation de monomères phosphate-acrylates dans des vernis photopolymérisables et retardateurs de flamme pour le bois d'intérieur

Avec l'essor des préoccupations environnementales, le bois est plus que jamais devenu un matériau de choix pour la construction. Utilisé depuis longtemps pour son aspect et pour ces bonnes propriétés mécaniques, l'industrie du bâtiment est confrontée à certaines limites de ce matériau renouvelable dont notamment sa tenue au feu. L'application d'un revêtement retardateur de flamme à la surface du matériau est une des méthodes d'ignifugation possible. Toutefois peu d'études traitent de l'efficacité d'ignifugation de vernis photopolymérisables transparents pour le bois. Cette étude vise à comparer des monomères phosphorés acrylates et méthacrylates. Les revêtements formulés sont composés d'un oligomère époxy-acrylate, d'un monomère acrylate phosphoré ou non et d'un photoamorceur. Les monomères phosphorés sont ajoutés dans la formulation à taux de phosphore équivalent (3,2%). La structure des composés phosphorés synthétisés a préalablement été confirmée par FTIR, RMN et ICP. L'ajout de phosphore dans la formulation améliore le pourcentage de masse résiduelle à la fin des analyses thermogravimétriques (de 7% sans à 33% avec). Les composés phosphorés se dégradent et réagissent pour former des produits stables à 800°C. Cette décomposition a lieu vers 350°C avant celle de la résine qui a lieu à 450°C. Des analyses au calorimètre à perte de masse ont complété l'étude du comportement au feu des revêtements. L'ignition des revêtements modifiés a lieu avant celle du revêtement ne comprenant pas d'éléments phosphorés. Leur pic de débit calorifique est toutefois moins important. Les analyses au calorimètre à perte de masse ont également montré l'importance du substrat choisi.

Asymmetrically configured liquid crystal network-based actuators

Liquid crystal network (LCN) actuators have emerged as a promising material of choice for building next-generation soft robots, because of their reversible and large deformation upon liquid crystal (order)-isotropic (disorder) phase transition. Their actuation modes can be customized by adjusting the liquid crystal (LC) alignment and polymer chain crosslinking that locks the LC order. Here, in an attempt to explore more possibilities of attainable actuation modes via asymmetrically configuring LCN-based actuators, we developed a bilayer "Janus" soft robot and a monolithic desynchronized LCN with deformation reversal capability. On the one hand, integrating both passive and active layers, we converted a monodomain LCN that can only contract/elongate into a reprogrammable "Janus" soft robot capable of various complex motions while having opposite deformations on its two parts. Based on this design, we devised a variety of self-locking grippers, crawlers, walkers and pushers, mimicking the diversiform movements of worms, animals and even humans. On the other hand, we demonstrated a novel actuation behavior, i.e., deformation reversal behavior, through desynchronizing the actuation response of a uniaxially stretched monolithic LCN via asymmetrically actuator processing. The desynchronized LCN actuators, compared with the existing LCNs which switch between two shapes corresponding to the LC and isotropic states, exhibit a reversal of deformation direction within half the actuation cycle and allow transformation among three shapes. This atypical actuation behavior enables multi-stage bidirectional shape changes and the corresponding multi-mode locomotion from the same LCN actuator.

Invited speaker: Hassan Fakh, Adam Katolik, Elise Malek-Adamian, Johans J. Fakhoury, Masad J. Damha and Hanadi F. Sleiman.

McGill University

Sequence Specific DNA-Polymer Conjugates and Their Applications in Drug Delivery

Nano-sized drug delivery systems have emerged as promising technologies to guide nucleic acid therapeutics to targets beyond the liver. Nanoparticles can encapsulate various drugs including combination therapies and incorporate targeting ligands that allow them to specifically bind to disease cells. Spherical nucleic acids (SNAs) are promising nanocarriers for nucleic acid therapeutics. They consist of a nanoparticle core (liposomal, metallic, polymeric etc.) and a dense nucleic acid corona. This 3D structure has unique biological and physiological properties, such as higher affinity to their target, increased nuclease stability, uptake by many cell lines, and lower toxicity/immunogenicity. In some cases, they have favourable biodistribution beyond the liver in vivo (brain, skin, etc.). We previously developed a class SNAs by adapting DNA solid-phase automated synthesis: hydrophobic monomer units are attached in a sequence-controlled fashion to a growing oligonucleotide chain using phosphoramidite chemistry. This method allows for near infinite variation in polymer chemistry and sequence. One of these conjugates that contains 12 units of dodecanediol, spontaneously assembles into SNAs: we previously showed that these SNAs can encapsulate small molecule drugs, have a favourable biodistribution profile in mouse models and do not solely localize in the liver. However, our SNAs, as well as most SNAs reported in literature lack chemical modifications to the nucleic acids, beyond a simple phosphorothioate backbone. One key sugar modification is the 2'-deoxy-2'-fluoro- β -D-arabinonucleic acid (FANA), which is compatible with both antisense (ASO) and short interfering RNAs (siRNA). The FANA ASO modification increases stability and decreases immune side-effects and toxicity. Importantly, it increases both binding affinity to the target mRNA and recruitment of RNase-H for its destruction, thereby improving its activity. Furthermore, carrier-free cellular-internalization (gymnosis) of FANA-ASOs permits the sequence-specific silencing of multiple targets in many cell types in vitro. This work combines the powerful FANA chemical modification with the promising properties of SNAs. We find that a cleavable 4-nt DNA spacer between the FANA strand and the polymer-conjugate is essential for reaching full activity of the SNA. With this structural feature, the FANA-SNA shows improved activity at lower concentrations compared to free FANA-ASO up to 72-hrs. The SNAs are also unique in their modularity, as we switched the sequence to successfully target another endogenous target (survivin) showcasing adaptability. Importantly, under gymnotic conditions, FANA-SNA displays improved genesilencing activity compared to free FANA-ASO. Combined with their stability, monodispersity, improved biodistribution and design simplicity, we anticipate that FANA-SNAs will be powerful gene silencing tools with a simple translation path to the clinic.

Design, Synthetic Optimization, and Characterization of a new Rare-Earth Metal–Organic Framework

Metal–organic frameworks (MOFs) are a family of structurally diverse, self-assembled materials built up from inorganic and organic units. The most prominent feature of MOFs is the existence of permanent pores in their structures, which in turn makes them very attractive materials for wide ranging applications, from gas adsorption to photocatalysis. Hexanuclear rare-earth (RE) clusters offer unique opportunities as MOF nodes and open the door towards the synthesis of a new class of functional RE-MOFs. Using linear linkers, it is possible to use these clusters to build a new series of RE-MOFs related to the archetypical UiO-66, originally made out of Zr-hexanuclear clusters and terephthalic acid linkers. The design and optimization of synthetic protocols for MOFs is key to obtaining pure and high-quality materials. There are many parameters that govern the formation of a specific MOF and all of them can be impactful in the final result. As such, it can be very challenging to understand concretely how the different parameters play out in the MOF formation process. This presentation will discuss the design and optimization process for the synthesis of a novel RE-MOF, including the sensitivity of the process to various factors like time, temperature, and reaction medium. Structural details, characterization of MOF properties, and potential applications will also be discussed.