McGill Engineering Research Showcase

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Poster Abstracts 2014

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ADVANCED MATERIALS AND NANOTECHNOLOGY

Novel Strategies towards the Development of Bio-Inspired Materials

By Seyed Mohammad Mirkhalaf Valashani, Professor François Barthelat

Biological materials boast remarkable combinations of mechanical properties arising from their sophisticated microstructures. Duplication of these intricate structures and their associated deformation and fracture mechanisms in engineering materials requires innovative fabrication methods which guarantee a high level of control over the morphology of the resulting material at different length scales. In this poster, some of the innovative pathways towards the development of bio-inspired materials which are developed in the Biomimetic Materials Laboratory at McGill are presented: Doctor blading of thin hybrid materials, self-assembly of microscopic inclusions and laser engraving of microstructures within the bulk of glass. The resulting materials show remarkable combinations of properties, making them attractive for applications in aerospace, construction and biomedical engineering.

Nano-Scale Surface Wrinkling in Chiral Liquid Crystals and Plant-Based Plywoods

By Pardis Rofouie and Professor Alejandro Rey

Varieties of functional surface nano-undulations have been observed in numerous biological materials such as DNA in human cells, cellulose in plant cell walls, chitin in arthropods cuticles, and collagen in human compact bones that display the twisted plywood architecture. These nano-structured surfaces in Nature which are responsible for their unique optical effects closely resembles the spontaneous free surfaces of cholesteric liquid crystals. To understand what is the origin of undulation length scales and which parameters control wavelength and amplitude, a theoretical scaling and computational analysis of the formation and structural characteristics of surface nano-wrinkling for a well-known cellulose chiral liquid crystals (LC) material model system is presented. To study the surface water-based actuation mechanism, the interaction of anisotropic interfacial tension, swelling through hydration, and capillarity at free surfaces are incorporated. These new finding can be used to characterize plant-based plywoods as well as in bio-inspired design of optical devices.

Structure Characterisation Method for Biological Plywoods

By Oscar Aguilar Gutierrez and Professor Alejandro Rey

The twisted plywood architecture is a ubiquitous biological and synthetic fibrous composite structure, analogous to that of cholesteric liquid crystals. Twisted plywoods can show ideal or non-ideal structures and are formed via equilibrium or non-equilibrium liquid crystal self-assembly processes. A key to the structure characterisation of plywood films is the specification of the local and global helix vector h(x) and pitch p(x) of the cholesteric order. Previous extensive work demonstrated that oblique cuts of the plywood give rise to arc-patterns that depend both on the unknown incision angle and the unknown pitch p(x), thus making the precise 3D cholesteric reconstruction ambiguous. We present an efficient method based on geometric modelling and new visualisation software that determines unambiguously the important characteristics of biological plywoods.

Nanoparticle/Liquid Crystal Hybrids based on Hydrogen Bonding Interactions

By Mahdi Roohnikan, Professor Linda Reven and Professor Alejandro Rey

The goal of this combined experimental/theoretical research project is to develop stable nanoparticle/liquid crystal (NP/LC) composites based on hydrogen bonding interactions. Hydrogen bonding is relatively strong non-covalent interaction, promoting stability, yet is still reversible, allowing the annealing of defects. Most work on LC nanocomposites has been based on thermally unstable gold nanoparticles.

Here highly stable monodispersed metal oxide nanocrystals (ZrO2, TiO2) synthesized by a non-aqueous hydrolysis method, will be dispersed into benzoic acid based LCs. Solid-state NMR, polarized optical microscope (POM) and transmission electron microscopy (TEM) will be the main analysis tools to study interactions, mesomorphical behavior and the dispersion properties of these nanocomposites.

Investigation of the Ideal Strength of Methane Hydrates using Density Functional Theory

By Zeina Jendi, Professor Alejandro Rey, and Professor Phillip Servio

Methane hydrates are crystalline compounds in which hydrogen-bonded water molecules entrap methane within cages. They exist abundantly in the Earth, and understanding their mechanical strength is essential for risk assessment during production.

Compressive and tensile tests are performed using Density Functional Theory. Uniaxial and shear tests are done in characteristic lattice directions by applying stresses or strains incrementally. The progression of the tests is followed with electron density plots that reflect the difference in bonding between compression and tension. The ideal compressive strength is found to be more than twice that in tension. The guest-to-cage ratio indicates instability upon compression, while the hydrogen bond length indicates cage breakage upon tension. This analysis reflects the stabilization mechanism of hydrates through attractive forces between the water molecules and repulsive forces between the guest and water molecules. Finally, the second-order elastic constants clearly violate their stability criteria as the ideal strength is approached.

Experimental Method of In-Plane Effective Diffusion Coefficient Measurements of Porous Media

By Rinat Rashapov and Professor Jeff Gostick

The gas diffusion layer (GDL) plays many roles inside the electrode of polymer electrolyte membrane fuel cells, including conduction of heat and electrons, provision of mechanical support, and mediation of liquid water flow. Their main purpose, however, is to disperse gaseous reactants from the flow channels to regions of the catalyst layer under the channel ribs. It is consequently of great importance to properly characterize the gas diffusivity of these materials, with the aim of reducing mass transport limitations and increasing fuel cell efficiency.

In this study, a new experimental technique to measure the in-plane component of the effective diffusivity tensor in thin fibrous porous media is developed and validated. This method provides accurate, fast, and repeatable in-plane measurements of effective diffusivity of oxygen in GDLs. Measurements have been made on different GDL materials, and at a range compression and PTFE contents.

Carbon Nanotube Nanofluids for CO2 Capture

By Larissa Jorge, Professor Sylvain Coulombe, and Professor Pierre-Luc Girard-Lauriault

In this work, we present aqueous nanofluids – engineered stable nanoparticle suspensions in host fluids - of ammonia-hydrocarbon plasma-functionalized multiwall carbon nanotubes (MWCNTs) that have enhanced CO2 absorption capacity. MWCNTs produced by chemical vapor deposition are treated in a non-thermal plasma in mixtures of ammonia and a hydrocarbon (ethylene or ethane). Chemical derivatization by TFBA was used to determine the composition of the samples by XPS. XPS measurements indicate that as the hydrocarbon content increases, more nucleophilic sites which may interact with CO2 are created on the MWCNTs. The nanofluids produced from these modified MWCNTs show good stability over a period of weeks. Using a gas bubble column to measure the CO2 absorption capacity of the nanofluids, it was observed that MWCNTs treated with ethylene perform better than the ones treated with ethane. This observation correlates with the XPS measurements showing more nucleophilic sites for samples treated with ethylene.

Substrate Interaction of Supported Lipid Bilayers and its Effect on Nanoparticle-Induced Membrane Disruption

By Nariman Yousefi and Professor Nathalie Tufenkji

Substrate-supported lipid bilayers (SLBs) are increasingly being used as model cell membranes for investigating the cytotoxity of engineered nanoparticles (ENPs). The cell membrane is a key barrier against ENPs; hence, systematic studies examining the interaction of SLBs and ENPs can be used to elucidate the mechanisms by which ENPs can impact cells. Although there exist many reports on the interaction of various ENPs with SLBs, the potential role of substrate/SLB interfacial adhesion as a major determinant of the mechanical properties and integrity of the bilayers is commonly neglected. A quartz crystal microbalance with dissipation monitoring (QCM-D) was used to monitor the interfacial adhesion of SLBs to metal oxide substrates. We demonstrate how the interaction of a SLB to metal oxides can be tuned by tailoring the net surface charge of the substrate and how this interfacial adhesion affects the nature of the interactions between SLBs and selected ENPs.

The Effects Dissolved Sulfide on Dechlorination of Chlorinated Solvents by Nanoscale Zero Valent Iron

By Sai Rajasekar Chandrasekar Rajajayavel and Professor Subhasis Ghoshal

Trichloroethylene is a widely used industrial solvent, and accidental spills and past improper disposal practices have led to widespread groundwater contamination Successful remediation of chlorinated solvent sites will protect critical and renewable resources of land and water, and human health. A promising technology for the clean-up of such sites is the sub-surface injection of nanoparticles of zero valent iron (NZVI) into the TCE-contaminated zones to enable rapid, in situ destruction of chlorinated compounds. NZVI is a strong reductant can effectively transform TCE and other chlorinated solvents to non-toxic end products such as ethene, acetylene, and ethane via surface mediated electron transfer and hydrogenation reactions. Although several studies have examined the reactivity of NZVI to chlorination aliphatic pollutants, there is limited knowledge on the effect natural of groundwater ions on the surface chemistry and reactivity of NZVI to these target pollutants. In this study we show that sulfide ions which are ubiquitous in groundwater environments may alter the reactivity of NZVI to a significant extent.

Non-Destructive Studies of Deformed Materials in Scanning Electron Microscope

By Shirin Kaboli, Hendrix Demers, Nicolas Brodusch and Professor Raynald Gauvin

This work presents the electron channeling contrast imaging (ECCI) technique in a scanning electron microscope (SEM) to study deformed microstructure. This technique provides non-destructive deformation studies at microscale and nanoscale spatial resolution, large field of view and statistically reliable information on bulk specimens. The primary electrons can channel in paths (i.e., channels) between various atomic planes as they travel into the depth of specimen. The intensity of collected backscattered electrons (BSEs) is modulated by the orientation of lattice planes with respect to incident electron beam such that more BSEs are collected in orientation I (non-channeling) as opposed to less BSEs in orientation II (channeling).

Protonated Li4Ti5O12 Mesoporous Nanosheet Material for Lithium-Ion Batteries

By Hsien-chieh Chiu, Xia Lu, Jigang Zhou, Joel Reid , Lin Gu, Raynald Gauvin, Karim Zaghib and Professor George Demopoulos

The presented work forms part of a PhD study focusing on developing nanostructured lithium titanate-LTO, Li4Ti5O12, as anode material for high power and safe Li-ion batteries. More particularly in this paper, spinel (Li1-xHx)4Ti5O12 (x=0.27) nanosheets (p-LTO-NS) grown by thermal conversion of aqueous synthesized lithium titanate hydrate are characterized by STM, EXAFS, synchrotron XRD and electrochemical tests, and their crystal structure features are correlated to electrochemical performance. The prepared p-LTO-nanosheets manifest excellent rate capability (~125 mAh/g @10C charge / 10C discharge) and cycling performance (87.6% capacity retention after 300 cycles at 1C rate).

Engineering the Sunlight Trapping Response of Random Mesoporous Networks of TiO2-Nanoparticle Based Photoelectrodes

By Ivonne Carvajal, Professor George P. Demopoulos and Professor Raynald Gauvin

Random mesoporous nanostructured media possess electromagnetic properties that greatly differ from those of ordinary bulk materials. The capacity to control the optical response of the material by tuning its internal structure has rendered these architectures into a promising light trapping technology for solar energy conversion. However, a rigorous electromagnetic computation of these structures in large-scale systems is computationally demanding and impractical. Here, we present a multiscale optical model approach that allows us to study random mesoporous networks (RMN) of TiO2-nanoparticles and nanowires for dye-sensitized solar cell (DSSC) applications.

Characterization and Modeling of Additive Manufacturing Processes

By Rodrigo Trespalacios, Jason Milligan, Yuan Tian, Andrew Walker, Jason Danovitch, David Walker, Justin Mezzeta, Abhi Gosh, Ryan Chou and Professor Mathieu Brochu

The aim of this research program is to fabricate parts, using an additive manufacturing (AM) process, that have equal or better material properties than those produced using conventional processes. Our group's focus is on difficult-to-weld alloys and the development of an AM process for them that prevents solidification cracking and that maintains a desired grain structure. To fabricate the parts we use an atmosphere-controlled powder-bed deposition unit, a wire deposition unit and an extrusion deposition machine, all developed in-house. By properly matching material selection with process inputs and printing process, effective control of the microstructure can be obtained.

Photoelectrochemical Water Splitting on GaN and InGaN/GaN Core/Shell Nanowires

By Bandar AlOtaibi, S. Fan, and Professor Zetian Mi

The application of photoelectrochemical (PEC) cells for direct conversion of solar energy to hydrogen is one of the viable approaches to overcome future fuel shortage [1]. Critical issue to this technology development is the exploitation of semiconductor electrodes that can lead to high efficiency and reliability. Previous works have focused largely on large bandgap metal-oxides, which characteristically exhibit low efficiency, due to the poor absorption of the visible and infrared solar spectrum. Recently, the use of III-nitride semiconductor materials for photoelectrolysis of water has received considerable attention. III-nitride materials have shown excellent corrosion resistance in aqueous solution. In this context, we have investigated the use of III-nitride nanowire arrays as photoelectrode in a PEC cell. Such 1-dimensional semiconductors are nearly free of dislocations. They can lead to significantly enhanced light absorption and rapid electron-hole separation, thereby promising improved solar-to-hydrogen conversion efficiency.

AlxGa1-xN Based Nanowire Ultraviolet Light Emitting Diodes

By Ashfiqua Connie, S. Zhao, Q. Wang, H. P. T. Nguyen, H. Guo, Professor Ishiang Shih and Professor Zetian Mi

Deep ultraviolet (UV) light emitting diodes (LED) have many potential applications, such as in the fields of sterilization, water purification, biochemical sensing, and medical diagnostics. However, deep UV emission is very challenging due to poor material quality, short diffusion length of Al adatoms, and difficulty in doping. The challenges of growth of III-nitride UV LEDs on foreign substrates can be addressed to a large extent by employing low dimensional structure, such as nanowires. By virtue of lateral stress relaxation, nanowires can accommodate the lattice mismatch strain effectively and results in drastically reduced dislocation density. The impurity doping and conductivity can be enhanced in nanowire structures due to the reduced formation energy for substitutional doping in the near surface region of nanowires. In this study, we demonstrate the growth, fabrication, and characterization of AlxGa1-xN based nanowire UV LEDs in UV-A (340 nm), UV-B (290 nm), and UV-C (210 nm) range. The UV LEDs demonstrate enhanced optical and electrical properties. The UV LEDs emitting at 340 nm and 290 nm demonstrate internal quantum efficiencies of 59% and 41%, respectively and low resistance values of ~50 ��and ~70 �, respectively which are comparable to the AlxGa1-xN based thin film UV LEDs in the same wavelength range. Most importantly, we demonstrate the emission at 210 nm from AlN p-i-n LED, which is the first demonstration of emission in such a short wavelength range employing nanowire structure.

AEROSPACE ENGINEERING

Cold Spray onto Carbon Fiber Reinforced Polymer for Lightning Strike Protection

By Hanqing Che and Professor Stephen Yue

Carbon fibre reinforced polymer (CFRP) is a very competitive alternative to aluminum for aircraft structures for lightweight purpose, but this leaves vulnerability against lightning strike. To make polymers lightning strike proof, a conductive media must be either embedded into or coated onto the polymers. Cold spray is one coating approach to achieve this. The aim of this work is to cold spray a metal coating with sound mechanical properties and good electrical and thermal conductivity on CFRPs used in aircraft for lightning strike protection.

Thermoplastic Composites Forming Technology for Complex and Integrated Aerospace Components

By Dominic LeBlanc, Benoit Landry, Gilles-Philippe Picher Martel, Marina Selezneva, Professor Pascal Hubert and Professor Larry Lessard

The need of lightweight structural parts is paramount in the aerospace industry and for this reason carbon-fibre reinforced polymer (CFRP) technologies have been the material of choice for several years. Conventional continuous fibres (CF) are difficult to form whereas injection moulding parts lack the mechanical properties. Lying between these two material configurations are randomly-oriented strand (ROS) composites. ROS composites are a bulk moulding compound type of material comprised of strands of unidirectional thermoplastic pre-impregnated tape that is processed using compression moulding. The main advantages of this material are its high formability but also increased mechanical performance due to high fiber volume fraction. The main focus of this project is to study the mechanical properties of ROS and the effect of processing conditions. Furthermore, flow and compaction behavior will be considered. Complex shapes will also be processed in the scope of this project.

Development of Multi-Functional Multi-Scale Composites for Aerospace Application

By Mostafa Yourdkhani and Professor Pascal Hubert

Carbon nanotube (CNT) addition to polymers is expected to enhance the multi-functional properties of the host material. To harness the full potential of CNTs, however, they should be uniformly dispersed within the material. The issue of dispersion is even more challenging when the nano-modified polymer is impregnated within the fibre preform, in which case the infiltration of nanoparticles deteriorates the dispersion quality. The other difficulty associated with the integration of nanotubes into polymers is the net impact that they have on the resin physicochemical properties, such as viscosity and curing behaviour. This often results in poor processability and prevents from using these products at the industrial scale.

The main objective of the present work is to investigate the processing and characterization of multi-scale composite laminates manufactured by the out-of-autoclave resin film infusion process (RFI) for aerospace applications.

Sustainable Manufacturing: Out-of-Autoclave Processing

By Adam Smith and Professor Pascal Hubert

Showcase of the work performed in the McGill Structures and Composite Materials Laboratory under the G8 Research Councils Initiative on Multilateral Research Funding, grant: Material Efficiency – A First Step Toward Sustainable Manufacturing.

Processing Study of Composite Bonded Repairs in Service Environment

By Mathieu Préau and Professor Pascal Hubert

In service, popular carbon-fibre-reinforced thermoset polymers experience damage and are in need of repair. Bonded scarf repairs provide excellent strength recovery; however, the processing of repairs in service environment is challenging. In particular, heat, air and moisture transport, evolving during the repair process, must be precisely assessed to ensure a reliable process with in service repair equipment. First, heat transfer and thermo-mechanical models are presented to simulate the repair process. They are used to provide repair depots with useful process charts to efficiently cure the repair patch and adhesive. Then, various air evacuation strategies are investigated to perform high performance repairs with recently developed vacuum-bag-only prepregs materials. Finally, the effect of pre-bond moisture on monolithic skins repairs quality and performance is presented.

Design of Composite Bolted and Bonded Hybrid Joints

By Kobye Bodjona and Professor Larry Lessard

Contemporary structural joining methods include (1) bonding and (2) bolting. The present research is investigating the merits of combining these techniques in what is known as a bonded and bolted hybrid (HBB) joint. Although superficially simple, this is in fact a complex problem that involves geometric and material nonlinearity, multiple load paths and contact. Furthermore, failure of HBB joints is complicated and still poorly understood. Improving this understanding constitutes the main scope of the project. Our poster presents an overview of the methodologies and findings - past and present - undertaken by the different research partners on the project.

Structural Health Monitoring (SHM) of Aircraft Composite Structures

By Mohammad Hossein Sherafat, Professor Larry Lessard and Professor Pascal Hubert

The use of composite materials in commercial aircraft primary structures has dramatically increased from nearly 5% in 1970 (Airbus 300) to about 50% in 2010 (Airbus 350, Boeing 787). Despite enhancements in terms of specific strength and stiffness, susceptibility to hidden damage in composites is still a major point of concern. Structural health monitoring (SHM) as a retrofitted version of traditional non-destructive testing (NDT) is proposed for inspection of these structures which would save the inspection cost as well as improve safety. The objective of this research is to evaluate composite structural health using guided wave propagation technique. Two cases namely simple composite plate and bonded joint made of carbon fiber reinforced polymer (CFRP) are considered. Artificial disbond and delamination are introduced by a circular Teflon tape. A rectangular piezoceramic is used to generate plane guided waves and non-contact measurement is performed using 3-D Laser Doppler Vibrometer to extract the required information for evaluation of quality of bond line. Results have shown that both delamination in plate as well as disbond in joint can be detected and characterized using guided wave behavior; and reflection and transmission coefficients for incident A0 and S0 modes are extracted in order to design the final SHM system.

System-of-Systems Optimization Approach to Air Transportation Design

By Gautam Marwaha and Professor Michael Kokkolaras

Aircraft sizing, route network design, demand estimation and allocation of aircraft to routes are different facets of the air transportation optimization problem that can be viewed as individual systems, since they can be conducted independently. In fact, there is a large body of literature that investigates each of these as a stand-alone problem. In this regard, the air transportation design optimization problem can be viewed as an optimal system-of-systems (SoS) design problem. The resulting mixed variable programming problem may not be solvable using an all-in-one (AiO) approach because its size and complexity grow rapidly with increasing number of network nodes. In this work, we use a decomposition-based nested formulation and the Mesh Adaptive Direct Search (MADS) optimization algorithm to solve the optimal SoS design problem. The two-stage expansion of a regional Canadian airline's network to enable national operations is considered as a demonstrating example.

Modeling and Optimization of Aerospace Product-Service Systems

By Cassio Goncalves and Professor Michael Kokkolaras

Many studies have been carried out during the years to support the design and development of Product-Service Systems (PSSs). Several authors have proposed different frameworks, developed different tools and practices to promote and support PSSs, however companies still do not see the development and implementation of such strategy as a straightforward process. In addition, new market trends impose these enterprises to make decisions towards service offers innovation, without having an effective structured way of developing and implementing the solution, exposing the business to a high risk of failure. This condition created the motivation to develop this research project where a comprehensive PSSs solution will be proposed to address the gaps identified in the literature. A quantitative approach will be developed to support engineers with the selection of optimal design alternative with the objective of creating the best PSSs model which meets customer value as well as target cost.

Mesh Morphing for Accurate Multi-Disciplinary CFD

By Andrew Pendenza, Professor Wagdi Habashi and Dr. Marco Fossati

The use of Computational Fluid Dynamics (CFD) in the design of ice protection systems and in the in-flight icing certification process of transport category airplanes has grown exponentially in the last few years. The quality of the CFD mesh, particularly at the progressively changing fluid-ice interfaces, is crucial for the accurate predictions of wall-based quantities such as heat flux and shear stress. As ice accretes on the aircraft surfaces, the geometry changes rapidly and requires a morphing body conforming mesh. A mesh deformation scheme, based on a structural analogy, is proposed to preserve good quality meshes during the growth of the very irregular iced shapes encountered in flight. It is robust enough to delay or altogether avoid re-meshing, and is first presented in the context of fluid-structure interaction and then applied to the aero-icing problem.

Local Reduced Order Modeling for Aerodynamics and In-flight Icing

By Zhao Zhan, Professor Wagdi Habashi and Dr. Marco Fossati

A modal-based Reduced Order Modeling, using machine-learning algorithms, has been developed to greatly simplify expensive 3D Computational Fluid Dynamics (CFD) parametric analyses. A limited set of 3D CFD solutions is first required to build the reduced model. Then, by using an unsupervised learning algorithm, solutions are automatically grouped into clusters of similar features. Proper Orthogonal Decomposition and multi-dimensional interpolation are used to extract modal functions from each such cluster, and solutions for any other non-calculated 3D CFD cases can then be obtained, quite accurately, in minutes rather than hours or days, as a linear combination of the basis vectors from the corresponding subregion. The aerodynamic loads on an aircraft, and a comprehensive exploration of the in-flight icing certification envelope, are presented as vivid examples of the approach.

Numerical Simulation of Tether-Nets for Space Debris Removal

By Eleonora Botta and Professor Arun Misra

Active space Debris Removal (ADR) has been proved necessary for the sustainable exploitation of Low Earth Orbits. A proposed device to capture spent satellites and launcher upper stages is tether-nets, flexible structures that are thrown towards the debris, entangle it and are used to tug it to a disposal orbit. Before employing tether-nets in ADR operations, it is necessary to accurately simulate the deployment, capture and disposal phases of the mission. In this work, a lumped parameters model for the numerical simulation of tether-net systems is presented; contact is handled by implementing a compliant formulation. Some preliminary results for the net's deployment and for simplified contact dynamics are shown, as obtained with a standalone Matlab simulation platform. Validation of the code is obtained by checking the symmetry of the results and the conservation of energy.

Modelling and Analysis Methods and Tools to Support Mobile Robotics Design and Control

By Bahareh Ghotbi, Professor Jozsef Kovecses and Professor Jorge Angeles

Many applications of wheeled robots include operation in unstructured environments. Optimizing vehicle mobility is of key importance in such applications. Reduced mobility can limit the ability of the robot to achieve the mission goals, and can even render it immobile in extreme cases. In this work the effect of system design and control parameters on its mobility are quantified by defining relevant performance indicators. The validity of these indices was assessed using both simulation and experimental results obtained for a six-wheeled rover prototype.

BIOENGINEERING

Microwave-Based Breast Cancer Detection

By Yunpeng Li and Professor Mark Coates

Early detection of breast cancer significantly increases the chance of recovery. Conventional screening methods including x-ray mammography have several drawbacks such as ionizing radiation, uncomfortable breast compression, and a relatively high miss rate. Our research team is developing a microwave-based breast cancer detection system as a low-cost screening tool that can complement existing technologies. The system uses an antenna array to propagate low-power microwave signals into the breast and records the scattered waveforms in order to detect malignancies. This poster focuses on the machine-learning architecture we have developed to process the recorded signals and to decide whether they correspond to a healthy breast. The architecture learns representative low-dimensional features from the raw signals and employs cost-sensitive ensemble classifiers to control the trade-off between the false-alarm rate and detection power. We demonstrate the performance of our methods using measurements collected using a 16-element antenna array prototype applied to tissue-mimicking breast phantoms.

Deep Brain Stimulation in Parkinson's Patients: Characteristics of the Microelectrode Recorded Signals in the Subthalamic Nucleus

By Kyriaki Kostoglou and Professor Georgios Mitsis

Subthalamic Nucleus (STN) Deep Brain Stimulation (DBS) is considered as the most effective surgical treatment for Parkinson’s disease symptoms. Good clinical results mainly depend on the exact implantation of the stimulation electrode inside the sensorimotor area of the STN. To this end, we analyzed the information obtained from resting-state microelectrode-recorded signals (MERs) and extracted the most significant features related with the clinical outcome of STN DBS. Such features can be used in the future as a control signal for closed-loop DBS.

Regional Variability of the Brain Hemodynamic Response to Spontaneous and Step-Induced CO2 Changes

By Prokopis Prokopiou and Professor Georgios Mitsis

The cerebral vasculature is exquisitely sensitive to arterial CO2 variations. This has been shown both using measurements of spontaneous cerebral blood flow velocity changes obtained with transcranial Doppler ultrasound, as well as spontaneous variations in the blood oxygen level dependent (BOLD) signal obtained with functional magnetic resonance imaging (fMRI). These effects are particularly important in respiratory related areas in the brainstem, where CO2 plays a major role. Here, we examine the waveform which quantifies the dynamic effects of CO2 changes on the BOLD fMRI signal in detail, as it provides more information regarding the magnitude and timing of these effects.

Specifically we estimate the hemodynamic response function (HRF) between CO2 and the BOLD signal in small voxel neighbourhoods using linear input-output models and functional expansion techniques. The results reveal regional variability of the characteristics of the HRF such as its peak value, time-to-peak and area.

Influence of Statin Therapy on Endothelial Cell Response to Wall Shear Stress

By Melissa Dick and Professor Richard Leask

Statins are the most widely prescribed drugs worldwide for the treatment and prevention of hypercholesterolemia, but their non-lipid-lowering benefits are not fully understood. This research studies how statin therapy influences endothelial cells (ECs), cells that line the cardiovascular system in a confluent monolayer and are exposed to wall shear stress (WSS) from blood flow. Using a 3D tissue culture model, ECs are grown, exposed to realistic levels of WSS within a flow loop, and treated with simvastatin for 24 hours. Statin treatment caused a significant rounding of ECs that was not completely abrogated by WSS, suggesting that statin-treated ECs are still able to respond to fluid forces. An analysis of the EC cytoskeleton showed that statin therapy causes a distinct disorganization of the F-actin structure. A better understanding of the non-lipid-lowering benefits of statins will help lead to more effective treatment options for individuals with high cholesterol levels.

Multilayered Mineral-Polymer Composites as Next Generation Bone Graft Materials

By Sacha Cavelier and Professor François Barthelat

On one hand, bone tissue engineering needs to satisfy three major requirements which represents the main challenge in this field nowadays: Mechanical properties close to those of natural bones; Degradability; And Osteoconductivity: Bone formation should be promoted by the material. Currently the materials destined to be used as bone graft have only two of these three characteristics. On the other hand, multilayered composites made of stiff inclusions inside a polymeric network expressed in the past their capability to deflect cracks and thus increase the fracture toughness of the material. Thus our study focuses on a new bone graft composite material made of calcium sulfate (stiff mineral inclusions) and gelatin (soft polymeric network). This composite already combines the degradability and osteoconductivity properties, but because of its microstructure shows mechanical properties superior to those of its components. This could represent a major breakthrough in the field of biomedicine and reconstructive surgery.

A Dense Collagen Hydrogel for the Investigation of Breast Cancer Metastasis to Bone

By Mark James-Bhasin, Peter Siegel and Professor Showan Nazhat

Malignancies arising in the mammary gland that metastasize to bone are associated with poor patient prognosis. This has resulted from a poor understanding of how metastatic cells interact with bone. It is currently known that bone-resorbing cells, osteoclasts, increase in differentiation in the presence of metastatic cells. Normally osteoclasts are at homeostatic balance with osteoblasts; cells associated with bone mineralization. With this balance broken, more bone is resorbed than is mineralized. Evidence has supported metastatic cells cannot only augment osteoclasts, but also interact with preosteoblasts preventing their differentiation. To understand this interaction, a three-dimensional dense collagen hydrogel model has been applied to recapitulate breast cancer metastasis to bone in vitro. Addition of MC3T3-E1 preosteoblasts and MDA-MB-231-derived 1833 highly bone metastatic cells to dense collagen constructs revealed that: 1) the presence of 1833 cell-conditioned media increased the proliferation of MC3T3-E1 cells; 2) this conditioned media or the presence of 1833 cells decreased MC3T3-E1 mineralization; 3) decreases in mineralization were independent of cell-to-cell contact. This model has thus shown that bone-mineral loss may be, in part, mediated independent of osteoclasts. This further may be achieved by a soluble factor released from metastatic cells. The novelty of this reductionist-level hypothesis-driven construct lies in its ability to negate extraneous variables and focus on effects mediated by cell types present and the construct. Use of this system to further elucidate currently unknown events in breast cancer metastasis to bone is thus warranted and underway.

Effect of Bifurcation Angle on the Functional Impact of Coronary Bifurcation Lesions

By Catherine Pagiatakis and Professor Rosaire Mongrain

The treatment of coronary bifurcation lesions is associated with high risks; overall, their dynamics are not well understood. The objective was to investigate the effect of bifurcation angle on the functional impact of bifurcation lesions. Four multilesional planar 3D synthetic lesion topologies (41-68% diameter reduction) within the bifurcation of the left main coronary artery (LMCA) into the left anterior descending artery (LAD) and the left circumflex artery (LCX) were coupled to an electrical analog model of the rest of the cardiovascular system using a partitioned geometric multiscale algorithm. The model was implemented within ANSYS Fluent (Canonsburg, PA, USA) through an in-house code and yielded accurate flow reductions and pressure drops. The LAD-LMCA and LCX-LMCA angles were varied between 0°-20° and 50°-73° respectively. It was found that bifurcation angle does not significantly affect the functional impact of such configurations; instead, lesion severity and topology appear to play a more important role.

Agent Based Model (ABM) of Tissue Inflammation and Healing in Vocal Folds

By Caroline Shung and Professor Luc Mongeau

Vocal fold scarring is one of the most functionally debilitating and pathologically perplexing voice disorders, often resulting in serious psychological, emotional, functional and economic consequences. In an attempt to better understand the highly diverse and unpredictable formation as well as treatment response of vocal folds scars, an agent based computational-model (ABM) characterizing the inflammatory and healing processes is being developed. The ABM can be used to reproduce human-specific mediator levels at 24 hours post-injury. Its ultimate application is a clinical tool to prescribe and optimize patient specific behavioral treatment. It can be expanded in the future to include mechanical and scaffold composition to optimize scaffold material design. Preliminary results suggest implementation of the ABM is better suited for graphics processing unit (GPU) where parallel computing can yield more than a 5-fold decrease in computation time.

Should activated sludge models consider influent seeding of nitrifiers? Field characterization of nitrifying bacteria

By Mauhamad Shameem Jauffur and Professor Dominic Frigon

This study revealed the presence of nitrifying bacteria in influent municipal wastewaters reaching full-scale biological wastewater treatment plants (WWTPs). Respirometric assays showed that the influent nitrifiers were active following a 5- to 8-hour period of metabolic induction. This also suggested that the nitrifiers in the influent stream likely seeded activated sludge bioreactors since the most abundant operational taxonomic units (OTUs) in the influent and mixed liquor were the same. Based on the estimated seeding intensity of 0.3 g of nitrifiers per day per gram of nitrifiers already present, the absolute minimum solids retention time was reduced by approximately 56% at 5°C as compared to non-seeding conditions. This can have important repercussions on the design and sizing of bioreactors operating in cold climate and call for a need to fine-tune process modelling by considering contribution of autotrophic nitrifying biomass from municipal influent streams.

The Kinetics of Laccase-Catalyzed Oxidation of Phenolic Trace Contaminants

By Stoyan Rangelov and Professor Jim Nicell

Oxidoreductase enzymes catalyze the oxidation of aromatic compounds and have the potential to be used to accomplish the treatment of phenolic trace contaminants before they are released in into the environment. An approach for exploring the feasibility of applying enzymes for this purpose is through the modeling of transient reaction kinetics, particularly in the low substrate concentration range. Laccase from *Trametes versicolor* was selected as a candidate enzyme because it is a robust enzyme with the ability to catalyze the oxidation of a wide-variety of substrates using freely available oxygen. Phenol was selected as a target substrate for model development. The model was successfully calibrated and validated and then extended to other substrates of interest. The model was applied to demonstrate its utility for predicting the quantity of enzyme and time required to achieve a desired level of oxidation of the substrate for varying initial concentrations.

An Automated Robotic System for High-Speed Microinjection of *Caenorhabditis Elegans*

By Xianke Dong and Professor Xinyu Liu

The nematode worm *C. elegans* has long been a popular model organism for biological studies in which worm microinjection plays a critical role. This research presents an automated robotic system for high-speed injection of *C. elegans* with an efficiency >10 times faster than a proficient injection technician. A multilayer, hydraulically-controlled polydimethylsiloxane (PDMS) microfluidic device is developed to rapidly load, immobilize, flush, sort and collect individual worms. A newly proposed contact detection algorithm is adopted to find the optimal injection position along the z axis within the microscope view field. The direction and location of the needle tip are identified online based on an effective image processing algorithm. Our system is able to perform microinjection at a speed of 6.6 worms per minute with a success rate of 77.5%. The superior injection performance provided by the system will significantly facilitate large-scale transgenic studies and biomolecule screening on *C. elegans*.

Paper-Based Piezoelectric Touch Pads with Hydrothermally Grown Zinc Oxide Nanowires

By Xiao Li, Yu-Hsuan Wang and Professor Xinyu Liu

This paper describes a new type of paper-based piezoelectric touch pads integrating zinc oxide nanowires (ZnO NWs), which can serve as user interfaces in paper-based electronics. The sensing functionality of these touch pads is enabled by the piezoelectric property of ZnO NWs grown on paper using a simple, cost-efficient hydrothermal method. A piece of ZnO-NW paper with two screen-printed silver electrodes forms a touch button, and touch-induced electric charges from the button are converted into voltage outputs using a charge amplifier circuit. A touch pad consisting of an array of buttons can be readily integrated into paper-based electronic devices, allowing user input of information for various purposes such as programming, identification checking, and gaming. This novel design features ease of fabrication, low cost, ultra-thin structure, and good compatibility with techniques in printed electronics, and further enriches the available technologies of paper-based electronics.

Acoustic Monitoring of *Pseudomonas aeruginosa* PAO1 Biofilm Growth and Viscoelastic Properties Using QCM-D

By Michael Mitzel, Professor Joann Whalen, and Professor Nathalie Tufenkji

Bacterial adhesion is known to be crucial for the development of biofilms, but remains poorly understood. Better understanding of the viscoelastic properties at the contact points between bacteria and surfaces during biofilm development will aid efforts towards improving biofilm control strategies on various surfaces. A quartz crystal microbalance with dissipation monitoring (QCM-D) was used to study bacterial attachment and subsequent biofilm growth of *Pseudomonas aeruginosa* PAO1 to a model silica surfaces. QCM-D provided direct, non-disruptive, in situ measurements offering new insights into the acoustic properties of the biofilm as it developed. Biofilm-surface bond maturation dynamics are identified and the molecular mechanisms behind the QCM-D measurements are investigated using mutant PAO1 strains and CLSM. Findings are interpreted and discussed in the context of well-known models (i.e., Voigt model, coupled-resonance model) to assess the applicability of the QCM as a 'mass sensor' versus an acoustic monitor in the context of biofilms.

Buckling of Human Aorta Segment

By Eleonora Tubaldi and Professor Marco Amabili

In biomechanics, human aortas, veins, pulmonary passages and urinary systems can be modeled as thin-walled shells conveying fluid. In human aortas, blood flow pressurization and through contact with the surrounding tissue cause large mechanical stresses on the aortic wall. In general, vascular diseases are associated with changes in the mechanical properties of the arterial wall. A severe and clinically challenging pathological condition is represented by the aortic dissection in which blood penetrates between layers of the aortic wall and creates a duplicate channel – the false lumen. The underlying mechanism of aorta dissection is poorly understood since direct measurements of the risk factors in vivo are not feasible. In this study, the nonlinear buckling (collapse) of the aorta is identified as a possible reason behind the appearance of high stress regions at the inner layer of the aorta wall that may be responsible for the initiation of dissection. The structural model assumes a nonlinear cylindrical orthotropic laminated composite shell composed of three layers representing the tunica intima, media and adventitia. Residual stresses because of pressurization are evaluated and included in the model. The fluid is formulated using a hybrid model that contains the unsteady effects obtained from linear potential flow theory and the steady viscous effects obtained from the time-averaged Navier–Stokes equations. Preliminary results suggest directions for further study in relation to the appearance and growth of dissection in the aorta. In particular, the introduction of a pulsatile time-dependent blood flow model would be appropriate to study the effect of pressurization by applying physiological waveforms of velocity and pressure during a heart beating period.

INFORMATION AND COMMUNICATIONS TECHNOLOGY

Execution Fingerprinting for Tunable Error Detection in Mission-Critical System

By Mojing Liu, and Professor Brett H. Meyer

Due to the decrease in transistor size and the resulting increase in transistor density, mission-critical systems (MCS) have become more vulnerable, not only to single bit, but also multi-bit transient upsets. Furthermore, at higher altitudes, MCS can be exposed up to +500x additional cosmic rays radiation as compared to sea level. Traditional protection techniques such as SECDED or dual modular redundant (DMR) processor pairs executing in lockstep not only come with high area overhead but are also inflexible in mixed-criticality systems where different criticality levels requires different levels of reliability. We therefore propose execution fingerprinting (EF). By compressing large amount of processor's execution behavior information into fixed-length words-fingerprints- for comparison with another redundant execution's fingerprints, overhead associated with error detection can be reduced and by choosing which data to compress, EF can tune its reliability level to comply with the criticality level of the task.

Photon Detection and Color Perception at Low Light Levels

By Mehdi Rezagholizadeh and Professor James J. Clark

The human visual system is able to work under different lighting conditions. It is desirable to have imaging devices, such as cameras and color appearance algorithms, be able to operate in similar light levels. The ability of the human visual system to work even under low light situations necessitates the importance of studying low light levels. A case in point is the tone mapping problem which should be informed by accurate color appearance models (CAM) in order that the perceptual fidelity of the rendering is maintained by the tone mapping transformations. Current tone mapping techniques, however, suffer from a lack of good color appearance models for low light levels. One of the most important challenges arises at low light levels is the issue of noise, or more generally speaking, low signal to noise ratio. Addressing low light, or more generally speaking, low signal to noise level situations has a wide range of applications in photography, designing biosensors, image processing, machine vision, and color science.

Mitigation of the Impact of Impulsive Noise on Wireless Technologies within Substation Environments

By Fabien Sacuto and Professor Fabrice Labeau

The advancement of Smart Grid technologies is seen as a major component to bringing more efficiency, resilience and ultimately sustainability to the power grid. In a smart grid context, the installation of Intelligent Electronic Devices (IED) for controlling and monitoring substation equipment requires reliable communication support. Broadband wireless communication emerges as a promising technology for this purpose; however impulsive noise in substations is problematic for wireless transmissions.

This research work is carried out in collaboration with Hydro-Quebec to study impulsive noise and to enhance the communication between different IEDs of the network. After a 2-year measurement campaign in Hydro-Quebec substations, we have collected more than 120 noise sequences at different locations of Hydro-Quebec substations and for different voltage levels. We have designed a Markov-Gaussian noise model that represents impulsive noise in wide band, which helps to mitigate the impact of the noise when implemented in an optimal receiver.

Uplink Cooperative Transmission for Modern and Future Cellular Networks

By Ahmad Abu Al Haija and Professor Fabrice Labeau

We propose a time-division uplink transmission scheme that is applicable to future cellular systems by introducing hybrid device-to-device (D2D) and infrastructure cooperation. The proposed scheme divides each transmission frame into three phases with variable durations. The two user equipments (UEs) partially exchange their information in the first two phases, then cooperatively transmit to the base station (BS) in the third phase. We study the proposed scheme from different aspects including the achievable rate region, optimal resource allocation for maximum throughput and the outage probability performance. Compared to non-cooperative schemes, results show that cooperation improves the achievable rate region even under half-duplex transmission. Moreover, the simple full decode-forward scheme is rate-optimal when the inter-user links are strong. Furthermore, cooperation can significantly reduce outage probabilities and achieve the full diversity order despite additional outages at the UEs. These characteristics make the proposed scheme appealing for deployment in future cellular networks.

Towards Next-Generation Coherent Receiver: Theory and Practical Consideration

By Thang Hoang and Professor David Plant

We form an unprecedented understanding on coherent receiver's realization by employing phase-shifting interference algorithm. With the proposed method, we show a novel system of approaches of coherent detection in presence of arbitrary optical hybrid. A generic close-form of field detection for arbitrary hybrid is derived in case of ideal hardware. Also, we outline the example of low-cost coherent receiver front end with the general 2x2 and 2x3 hybrid for both filtered and colorless reception. We show numerically that various type of receiver can achieve colorless reception of 10 x 112-Gb/s polarization-division-multiplexed quadrature-phase-shift-keyed channels with no penalty in the back-to-back operation. Numerical results strongly suggest that PSI-based hybrid is a promising candidate for next-generation coherent receiver.

Optimal real-time transmission of a Markov source under constraints on the number of transmissions

By Jhelum Chakravorty and Professor Aditya Mahajan

We consider a remote sensing system consisting of a sensor and an estimator. The sensor observes a first order Markov source and must communicate it to a remote estimator. Communication is noiseless but expensive. At each time, the sensor chooses whether to transmit or not. If the sensor does not transmit, then the estimator must estimate the Markov process using its past observations. In the infinite horizon discounted cost setup, we characterize the optimal policy and the optimal thresholds as a function of communication cost. We identify the value of the communication cost for which one is indifferent between two consecutive threshold based strategies and characterize the optimal thresholds as a function of the communication cost. The average cost problem is investigated as the limiting case of the discounted cost problem as the discount factor approaches one. The results are validated with an example of birth-death Markov chain.

Graphical User Interface for Multi-parameter Medical Sensor Device

By Mohammad Rahman, Quang Dung Ho and Professor Tho Le-Ngoc

The purpose of this research work is to design the Graphical User Interface (GUI) for the View and Control Terminal (VCT) of the Wireless Patient Monitoring System. The GUI will be used to observe the health conditions of the patient and control the device to act accordingly.

Acceleration of Umbrella Constraint Discovery in Generation Scheduling Problems

By Ali Jahanbani Ardakani and Professor Francois Bouffard

Security-constrained optimal power flow (SCOPF) and security-constrained unit commitment (SCUC) problems are necessary tools for system operators for operational planning and near to real-time operation. The solution time of these problems are challenging mainly due to their inherent large size. Previous studies have shown that relatively few of those problems' constraints serve to enclose their feasible set of solutions. Therefore, the constraints that do not contribute to the feasible set of solutions could be discarded to decrease the size of these problems and their associated solution times. Umbrella constraint discovery (UCD) has been proposed to identify and rule out redundant constraints in dc-SCOPF problems. In this paper, we propose an improvement over the original UCD formulation that exploits the structure of its parent SCOPF problem. This new partial UCD approach can lead to significant speed-ups in terms of UCD solution time and size. Based on the encouraging results for partial UCDon SCOPF, we apply the technique on SCUC. Alike in SCOPF, partial UCD can efficiently strip out non-umbrella constraints o SCUC. We find, however, that because of its structure, SCUC has a much lower proportion of non-umbrella constraints.

Spice Netlist Generation from Loewner Matrix State Space Models

By Marco Kassis and Professor Roni Khazaka

This research focuses on systematic algorithms to model linear networks from measured data. For many advanced technologies, such microwave components and microelectromechanical systems (MEMS), it is impossible to use analytical physics based tools to obtain an accurate model that is compatible with circuit simulators. Consequently, designers often resort to approximate models or spend a lot of efforts to develop models that are specific to a certain component. In our work we have developed a systematic algorithm based on Loewner Matrices that uses frequency domain measurements to generate time domain macromodels in the form of descriptor state space equations. These time domain equations are then converted into a spice netlist compatible with commercial circuit simulators. This approach was shown to scale very well compared to state to the art techniques available in the literature. In particular it shows considerably superior performance for very complex systems with a large number of ports.

SUSTAINABILITY IN ENGINEERING AND DESIGN

Designing Greener Plasticizers: Influence of Geometry of Central Group and Side Chains

By Hanno C Erythropel, Professor Richard Leask and Professor Jim Nicell

Plasticizers are important additives for rigid polymers like poly(vinyl-chloride) (PVC) to make them softer and more flexible. Plasticizers are not bound to the polymer matrix and leach into the environment. Di(2-ethylhexyl phthalate) (DEHP) and its toxic, stable metabolites, are ubiquitous environmental contaminants and have been banned in various jurisdictions. This has motivated efforts to design alternative green plasticizers, that don't exhibit the problematic properties of phthalate esters. Based on knowledge of the degradation behaviour of di-ester plasticizers, we have designed greener and more sustainable compounds that retain comparable plasticizing properties to DEHP, but which are more easily biodegraded by common soil bacteria. Mechanical testing of PVC formulations incorporating these and biodegradation studies of the pure compounds have shown linear succinate and maleate esters to be promising alternatives. The cost and life cycle of these materials will help reduce the overall impact on human health and our environment.

Modeling the Removal of Contaminants of Emerging Concern (CECs) and Toxicity for Improved Design of Wastewater Treatment Plants

By Zeina Baalbaki and Professor Viviane Yargeau

Several illicit drugs, pharmaceuticals and hormones are detected in treated municipal wastewater, which makes its way into the environment and ultimately impact quality of drinking water sources. In this study, an advanced sampling technique was utilized to better evaluate the removal of some target contaminants in various stages of different wastewater treatment trains, taking into account the residence time distribution in each unit of the treatment plant. The reliable experimental removal data obtained are instrumental to calibrate the model developed for the removal of these compounds in different treatment units and facilities. The model can then be utilized as a design and optimization tool to improve performance of wastewater treatment plants. Besides chemical analysis required for the modeling, samples are also tested for both general toxicity using Microtox and estrogenic activity using the YES assay, allowing the monitoring of an emerging measure of performance based on the minimization of toxicity.

Non-Stop Equity: Assessing Transit Accessibility and Social Disparity over Time

By Ehab Diab, Dea van Lierop, Myriam Langlois, Alexander Legrain and Professor Ahmed El-Geneidy

Public transportation systems generate economic benefits that can reduce social disparities between populations when distributed fairly within a region. However, the achievement of equity in the allocation of public resources is not easy to accomplish for land use and transportation planning agencies. This research seeks to determine whether people residing in socially disadvantaged areas in the Greater Toronto Hamilton Area (GTHA) experience the same levels of transit accessibility as those living in other areas over the course of a day. Comparisons are presented in terms of regional accessibility, trends by social decile, spatial distribution during the day, and impact on travel times. Findings show that residents in socially disadvantaged zones have equitable accessibility to jobs using transit, if not better than socially advantaged groups, and this is reflected in shorter travel times in comparison to all other groups in the region.

Extraboard Team Sizing: An analysis of Short Unscheduled Absences among Regular Transit Operators

By Ehab Diab and Professor Ahmed El-Geneidy

Several factors contribute to short-duration unscheduled absences of bus transit drivers. This article aims to understand these factors at the aggregate level and to anticipate future total absence that will need to be filled for a large-size transit operator. The aggregate level is defined as the total number of regular driver absences per garage, day of week and time period that need to be covered by the extraboards. This study analyses absenteeism data obtained from OC Transpo, the transit provider of the city of Ottawa, Canada. A multilevel regression model is generated to investigate regular drivers' absences. The short-unscheduled absence is estimated in relation to temporal factors, drivers' personal characteristics, aspects of assigned work, and service delivery characteristics. Furthermore, using the model's coefficients, sensitivity analyses are conducted to demonstrate the advantages of this technique over traditional ones adopted by various transit agencies.

Individual Exposure to Traffic Related Air Pollution across Different Land-Use Clusters

By Maryam Shekarrizfard and Professor Marianne Hatzopoulou

On-road traffic is the leading cause of urban air pollution. There is scant literature on the effects of the built-environment and personal attributes on the generation of -and exposure to- traffic related air pollution. We investigated the relationship between individual emissions of nitrogen oxides (NOx) and exposure to nitrogen dioxide (NO2) concentrations derived from a land-use regression technique. Factor analysis and clustering of land-uses were used to test the relationships between emissions and exposures in Montreal area. We observed that individuals who live in the suburbs generate higher emissions of NOx but are exposed to lower NO2 concentrations at home and throughout their daily activities. We also observed that for most individuals, NO2 exposures based on daily activity locations were often more elevated than NO2 concentrations at the home location. Our findings are relevant to the evaluation of equity in the generation of emissions and exposure to traffic-related air pollution.

Experimental Study and Thermodynamic Optimization of the K2O-Na2O-CaO-MgO-Al2O3-SiO2 System

By Dong-Geun Kim and Professor In-Ho Jung

The aim of this study is to develop a self-consistent thermodynamic database for the K2O-Na2O-CaO-MgO-Al2O3-SiO2 system, which is an important tool to design more sustainable mold fluxes for the steelmaking process. The newly developed mold fluxes with higher K2O and Na2O contents can reduce the use of environmentally hazardous materials such as fluorine (CaF2) in the conventional mold fluxes. Based on a critical review of the entire system coupled with key experiments, an accurate database with high predictability was developed and uncertainties in the experimental data from literature were successfully resolved. The accurate thermodynamic database enables to predict phase diagrams and thermodynamic properties for the entire system.

Metal Powders as Zero-Emission Energy Carriers

By Sam Whiteley and Professor Jeff Bergthorson

The present poster is a fundamental study into the use of metal as a high-density, non-polluting, carbon-free energy carrier. Aluminum-hydrocarbon mixtures are combusted to see the thermal and flame characteristics in a Bunsen-style flame. It was found that under a critical concentration the aluminum adds very little heat to the methane-air flame, and the flame temperature diverges from the predicted equilibrium concentration. Above the critical concentration, there is a sudden jump in the flame temperature caused by the aluminum reacting with water vapour and carbon dioxide, which are the products of the methane-air flame. A simple model based on the evaporation rate of aluminum works well to describe this behaviour.

Development of Bio-Composites from Flax Fibres and Bio-Epoxy

By Nils Cuinat-Guerraz, Professor Pascal Hubert and Marie-Josée Dumont

This project aims to develop a green composite based on a combination of bio-epoxy resins and flax fibre woven reinforcement. Flax fibre/bio-epoxy composites were manufactured using a Resin Transfer Molding process. The goal is to study the quality of the interaction between the natural fibres and the polymer, and its impact on the mechanical performance. Moreover, because natural fibres are hydrophilic, composites reinforced with flax fibres absorb more moisture than synthetic fibres reinforced composites. Therefore, post-cured composite samples will be conditioned and aged to various moisture levels to evaluate how the absorbed water degrades the mechanical properties and affect the fibre/matrix adhesion. Bio-composites show a lot of potential as high performance materials and a better understanding of the adhesion mechanisms between natural fibre and matrix is a key factor to their development.

Optimization of Tooth-root Profile for Maximum Load-carrying Capacity: Spur and Bevel Gears

By Mathew Shaker and Professor Jorge Angeles

A novel approach to the design of the tooth root profile of spur and bevel gears using cubic splines is reported in this research, the objective being to reduce the volume of the gear transmissions in Electric and Hybrid vehicles, without compromising their load carrying capacity. Bevel gears generated using the Tredgold approximation and the exact spherical involute profiles were considered. Spherical splines were used in the exact spherical involute case. To this end, the shape of the root profile was smoothed so as to endow it with G2-continuity, thereby reducing the stress concentration at the critical blending points. An iterative co-simulation procedure consisting of tooth-root profile shape synthesis via non-linear programming and finite element analysis was conducted. The proposed designs were verified to be capable of reducing the stress concentration by 15.9% for the Tredgold approximation and by 18.0% for the exact spherical involute.

The Development of an Innovative Two-DOF Cylindrical Drive: Design, Analysis and Preliminary Tests

By Thomas Friedlaender and Professor Jorge Angeles

The quest for ever faster pick-and-place robots has led to ingenious parallel robots with reduced mobility, e.g., capable of producing motions proper of SCARA systems: three independent translations and one rotation about an axis of fixed direction. These robots are also known as Schoenflies-motion generators (SMG). Recently, a two-limbed isostatic SMG system was proposed, which provides high rotatability of its gripper. This robot is driven by one C (cylindrical)-joint at each limb. As this joint allows for two degrees of freedom, it calls for two motors, that might as well be fixed to the base, which poses interesting design challenges. The poster reports a design solution based on a cylindrical differential mechanism of the RHHR type, with R standing for revolute, H for helical (or screw) joint. The design, kinematics and dynamics of the drive are discussed, along with a realization, and preliminary tests.

Team Optimal Control with Mean-Field Sharing: A Model Motivated by Smart Grids

By Jalal Arabneydi and Professor Aditya Mahajan

We investigate team optimal control of stochastic subsystems that are weakly coupled in dynamics (through the mean-field of the system) and are arbitrary coupled in the cost. The controller of each subsystem observes its local state and the mean-field of the state of all subsystems. Exploiting the symmetry of the problem, we identify an information state and use that to obtain a dynamic programming decomposition. This dynamic program determines a globally optimal strategy for all controllers. Our solution approach works for arbitrary number of controllers and generalizes to the setup when the mean-field is observed with noise. The size of the information state is time-invariant; thus, the results generalize to the infinite-horizon control setups as well. In addition, when the mean-field is observed without noise, the size of the corresponding information state increases polynomially (rather than exponentially) with the number of controllers.

Batch Q Learning for Energy Storage Management

By Mehnaz Mannan and Professor Aditya Mahajan

We consider the energy management system (EMS) of a sustainable house that contains a renewable generation unit (e.g., rooftop solar generation) and an energy storage device (e.g., battery). The house is connected to the electricity grid; the EMS can purchase electricity from the grid, but cannot supply electricity back to the grid. The renewable generation, the energy demand in the house, and the electricity price vary in a stochastic manner. At each decision epoch, the EMS must meet the demand using the renewable generation, the electricity grid, and the storage device. We investigate optimal decision strategies for the EMS that determine when and how much energy is purchase from the grid and is stored in the storage device. We present a dynamic programming decomposition of the problem and use batch Q-learning to obtain an iterative algorithm that converges to the optimal decision strategy without any knowledge of the probability distributions of the renewable generation, the demand, and the electricity price. In the future, we plan to investigate the performance of the proposed batch Q-learning algorithm on real generation, demand, and price data.

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