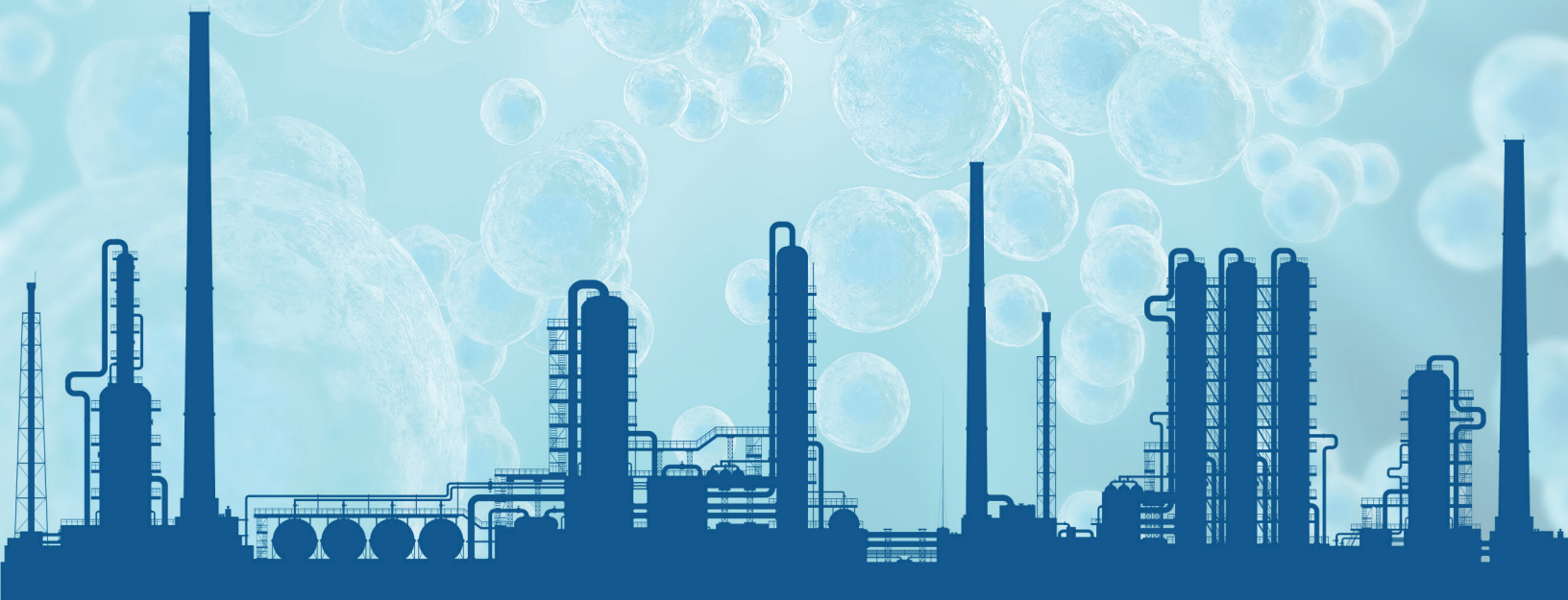
FAMU-FSU
College of Engineering

Department of Chemical and Biomedical Engineering

Research Day 2019

Friday, April 19
8:30 a.m. to 2:00 p.m.

Aero-propulsion, Mechatronics and Energy (AME) Building
Conference Room 106 and First-floor Atrium
2003 Levy Avenue, Tallahassee, FL 32310



Event organizers:

Jingjiao Guan, Associate Professor

Gena Thomas, Program Associate

Kimber Spann, Office Assistant

Yazmeen Torres, Office Assistant

Nastaren Abad, gradaute student and member of the Association for Chemical & Biomedical Engineering Graduate Students (CBEGS)

Shannon Helsper, gradaute student and member of CBEGS

Graphic design for flyer and program book cover:

Laurie Herring, Senior Designer, Office of the Dean

Jingjiao Guan, Associate Professor

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2:00 pm	Adjournment

Aero-propulsion, Mechatronics and Energy (AME) Building,
2003 Levy Avenue, Tallahassee, FL 32310

Keynote Presentation

Nanomaterials for Combination Therapies and Immunomodulation

Surya K. Mallapragada, Ph.D.

Department of Chemical and Biological Engineering, Iowa State University, Ames, Iowa

Abstract

This talk will focus on how nanomaterials can be designed and developed to deliver combination therapies for cancer treatment, as well as activate the immune system and serve as adjuvants for sub-unit vaccines. The first part of the talk will focus on how nanomaterials developed in our laboratory can be used to deliver combination therapies for the treatment of pancreatic cancer. Pancreatic cancer has a very high fatality rate, and the current treatment using gemcitabine (GEM) does not work effectively, partly due to desmoplasia. We have developed dual delivery nanoscale devices to deliver miRNA and GEM together, resulting in downregulation of the Sonic hedgehog signaling pathway and leading to inhibition of desmoplasia, pancreatic stellate cells and cancer stem cells. This, in turn, improved therapeutic outcomes of GEM in PC in mice through improving its perfusion in the tumor, and also led to significant reduction of metastasis**.** The second part of the talk will focus on nanovaccines that can deliver pathogenic proteins, activate the immune system, and act as vaccine adjuvants. Respiratory pathogens such as influenza affect large segments of the population. Universal influenza vaccines that can provide effective protection against various strains of the pathogen, and in elderly populations as well, are sorely needed. We have developed virus-mimicking nanomaterials or nanovaccines that provide a depot for the antigen and enhance and modulate the immune response by targeting immune cells. We have shown long-term sustained neutralizing antibody titers, reduction of viral loads and effective protection against viral challenge in both young and aged mice as a result of administration of the nanovaccines.

Short Biography of Dr. Surya K. Mallapragada

Dr. Surya K. Mallapragada is Anson Marston Distinguished Professor and Carol Vohs Johnson Chair of Chemical and Biological Engineering and the Associate Vice President for Research at Iowa State University (ISU). She received her chemical engineering education from IIT Bombay (B.Tech, 1993) and Purdue University (Ph.D., 1996). She has courtesy appointments in the Materials Science and Engineering department and the Neuroscience program at ISU. She served as Chair of the Department of Chemical and Biological Engineering from 2009-13. She is also currently a Senior Scientist and has served as Program Director of Materials Chemistry and Biomolecular Materials (2004-08) at Ames Laboratory, a US Department of Energy Laboratory. Her research interests are in the area of polymeric nanobiomaterials, specifically in drug/gene and vaccine delivery and neural tissue engineering, and in the area of bioinspired materials. She has authored over 160 publications and serves as an Editor of Materials Science and Engineering: R: Reports.

Her work has been recognized by several awards including a National Science Foundation Career award, a 3M Non-tenured faculty award, Iowa State University Foundation Early as well as Mid-Career Excellence in Research awards, a Big 12 Rising Star Award, an IIT Bombay Young Alumni Achievement Award and the Boylan Award for Outstanding Research. She was named one of the top 100 young innovators by MIT's Technology Review magazine and is an elected Fellow of the American Institute for Medical and Biological Engineering (2006) and the American Association for the Advancement of Science (2008). She is an elected Fellow of the National Academy of Inventors (2016) and the International Academy of Medical and Biological Engineering (2017). She was elected as Foreign Fellow of the National Academy of Sciences, India (2018).

Surya has served the Food, Pharmaceutical and Bioengineering Division of the American Institute of Chemical Engineers in several capacities, including chairing the division. She received the Distinguished Service Award from the American Institute of Chemical Engineers' Food, Pharmaceutical and Bioengineering Division in 2009 for sustained and committed leadership and service.

List of Student Oral Presentations

1. “Contrasting Melt-Memory of Homopolymers and Random Ethylene Copolymers Using Halogen Substitution with Precision Placement or Random Distribution” by Stephanie F. Marxsen
2. “Differential Effects of Extracellular Vesicles of Lineage-Specific Human Pluripotent Stem Cells on Cellular Behaviors of Isogenic Cortical Spheroids” by Mark Marzano
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Student Oral Presentation #1

Contrasting Melt-Memory of Homopolymers and Random Ethylene Copolymers Using Halogen Substitution with Precision Placement or Random Distribution

Stephanie F. Marxsen[1], Dr. Rufina G. Alamo[1]

[1] FAMU-FSU College of Engineering, Department of Chemical and Biomedical Engineering,

2525 Pottsdamer St, Tallahassee, FL, 32310

Abstract

Polyethylenes with Br, Cl, or F atoms placed at an equal distance of 21 or 15 backbone carbons are known to crystallize as homopolymers, accommodating the halogen in layered crystallites. In contrast, analogs with a random distribution display a crystallization path dominated by sequence-length selection. A consequence of the sequence selection of random copolymers is a constrained interlamellar region and broader melting peaks displaced at higher temperatures than systems with the precise placement. Precision and random ethylene-vinyl halides are excellent models to substantiate as a general behavior the strong melt-memory observed in random ethylene 1-alkene copolymers, which contrasts with a much weaker or lack of melt-memory seen in linear polyethylene. While precision polyethylenes with Br, Cl, or F placed on each 21st or 15th backbone carbon show negligible deviation in crystallization rate above the observed melting, the increase in crystallization rate of analogs with the random distribution is observed even from melts 60 degrees above the observed melting point. These data give further evidence of the sharp difference of melt-memory behavior between homopolymers and random copolymers, regardless of whether the co-unit participates in the crystalline regions. Differences in melt annealing behavior, and a recrystallization of precision polyethylenes that depends on the polymorph that melts prior to a subsequent cooling, are also highlighted.

Student Oral Presentation #2

Differential Effects of Extracellular Vesicles of Lineage-Specific Human Pluripotent Stem Cells on Cellular Behaviors of Isogenic Cortical Spheroids

Mark Marzano[1], Julie Bejoy[1], Mujeeb Cheerathodi[2], Li Sun[2], Sara York[2], Jing Zhao[3], Takahisa Kanekiyo[3], Guojun Bu[3], David G. Meckes Jr.[2, *], Yan Li[1, *]

[1]Department of Chemical and Biomedical Engineering; FAMU-FSU College of Engineering; Florida State University; Tallahassee, FL USA

[2]Department of Biomedical Sciences, College of Medicine, Florida State University, Tallahassee, Florida, USA

[3]Department of Neuroscience, Alzheimer's Disease Research Center, Mayo Clinic, Jacksonville, FL USA

Abstract

Extracellular vesicles (EVs) including exosomes are responsible for a variety of signaling processes and overall physiological and pathological states of stem cells and tissues. Human induced pluripotent stem cells (hiPSCs) have unique characteristics that can mimic embryonic tissue development. EVs derived from hiPSCs can be used as therapeutics, biomarkers, and drug delivery vehicles. One issue is that little is known about the characteristics of secreted EVs/exosomes by hiPSCs and paracrine signaling during tissue morphogenesis and lineage specification. In this study, the physical and biological properties of EVs isolated from (1) hiPSC-derived neural progenitors (ectoderm), (2) hiPSC-derived cardiac cells (mesoderm), and the undifferentiated hiPSCs, including (3) healthy iPSK3 line and (4) Alzheimer's disease associated SY-UBH line, were analyzed. Nanoparticle tracking analysis and electron microscopy results indicate that the derived EVs have the average size of 100-250 nm. Western blot analyses revealed that exosomal markers Alix, CD63, HSC70, and TSG101 were expressed in the derived EVs. MicroRNAs including miR-133, miR-155, miR-221, and miR-34a were differently expressed in different EV groups. Treating the cortical spheroids with different EVs *in vitro* showed the differential abilities of increasing cell proliferation (indicated by $BrdU^+$ cells) and axonal growth (indicated by β-tubulin III staining). For the Aβ42 oligomer treated cultures, the derived EVs increased cell viability and reduced oxidative stress differentially, showing neural protective ability. Our results demonstrate that the paracrine signaling provided by tissue context-dependent EVs derived from hiPSCs elicit distinct signaling to impact the physiological state of cortical spheroids. This study should advance our understanding of cell-cell communications in stem cell microenvironment and provide possible therapeutic options for treating neural degeneration.

This study was supported by NSF CAREER (1652992) and NIH R03NS102640.

Student Oral Presentation #3

Nitric Oxide Scavenging of Hydroxyl Radicals in a Nanosecond Pulsed Plasma Discharge Gas-Liquid Reactor

Radha Krishna Murthy Bulusu, Robert J. Wandell, Rachel Gallan, and Bruce R. Locke

Department of Chemical and Biomedical Engineering, Florida State University, 2525 Pottsdamer Street Tallahassee, FL 32310 USA

Abstract

Plasma discharges generated by moderate frequency, low energy pulses in a flowing gas-liquid (argon-water) reactor produce hydrogen peroxide (H_2O_2) at moderately high energy yields. The leading hypothesis is that the H_2O_2 is generated from the recombination of hydroxyl radicals (·OH) which are formed by the plasma electrons reacting with vaporized water. Experiments with carbon monoxide as an ·OH scavenger have shown that the primary yield of ·OH far exceeds what can be accounted for in H_2O_2. Similar to CO, NO can also be used as a gas phase ·OH scavenger leading to the formation of water soluble HNO_2 and HNO_3. Gas phase NO_2 can also be formed from reaction of NO and atomic oxygen, however because the atomic oxygen must ultimately come from H_2O in the Ar/NO/H_2O mixtures, this provides further insight into both the primary ·OH yield and reaction pathways for nitrogen fixation with plasma. The main objective of this work is to utilize NO/Ar mixtures (0-20000 ppm NO) to assess both the primary yield of ·OH and the roles of ·OH and atomic oxygen in the reaction pathways leading to NO_2^- and NO_3^-. A continuous gas-liquid film reactor with deionized water is utilized and the liquid phase (NO_2^- and NO_3^-) and gas phase (NO and NO_2) are analyzed using ion chromatography and FTIR, respectively. A variable nanosecond power supply is utilized to determine the effects of pulse width, frequency, and input voltage on the efficiency of ·OH generation. The plasma properties including gas temperature and electron density are also assessed using Optical Emission Spectroscopy. (This work was supported by the National Science Foundation, CBET 1702166 and Florida State University.)

List of Poster Presentations

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29. “Development of Microdevices for Photoelectrical Stimulation of Cells” by Wenhao Cheng
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Millimeter-Size Pickering Emulsions Using Large Amphiphilic Janus Particles

Bobby Haney, Subramanian Ramakrishnan

Department of Chemical and Biomedical Engineering, FAMU-FSU College of Engineering, Tallahassee FL

Abstract

Pickering emulsions, or particle stabilized emulsions, are important in systems where controlled encapsulation of an oil or water phase is needed. When added into systems containing immiscible water and oil, the particles move the interface of the fluids to form droplets. Amphiphilic, "Janus", particles with two distinct surface chemistries are ideal for stabilizing emulsions due to the ability to tune wetting properties by changing the chemistry. We use a special microfluidic method to synthesize our own amphiphilic particles that are able to stabilize liquid-liquid systems.

Microfluidic techniques were used to create 125 μm diameter Janus particles to form stable water in oil as well as oil in water Pickering emulsions. Flowrates in a glass capillary device were varied to show complete control over particle sizes and hydrophilic to hydrophobic domain ratios. Using UV light, these droplets were cross-linked via photo-polymerization to form fairly monodispersed particles. By manipulating the inner-phase flowrate, larger sized particles were made which lead to larger stable emulsions. By manipulating the ratio of inner-phase hydrophilic fluid to hydrophobic fluid, the sizes of the two individual sections of the Janus particle was changed. These particles were used to form emulsions in oil/water mixtures. Emulsion stability was tested via centrifuge at accelerated gravity. It was found that the smaller particles were in size and the more balanced in hydrophilic/hydrophobic volume ratio, the stronger emulsions were against coalescence. Use of these larger particles for stabilizing emulsions allowed easy visual observation of formed emulsions, which will lead to better interpretations on how factors such as the particle orientations at the L-L interface, particle concentration, temperature and pH changes, and particle solvent induced swelling, affect Pickering emulsion stability.

Bulk Assembly of Metal Halide Clusters with Tunable Photophysical Properties

Chenkun Zhou[1,2], Haoran Lin[2], Michael Worku[2], Jennifer Neu[2], Yan Zhou[2], Yu Tian[2], Sujin Lee[2], Peter Djurovich[3], Theo Siegrist[1], Mao-Hua Du[4], Biwu Ma[1,2]

[1]FAMU-FSU College of Engineering, [2]Florida State University, [3]University of Southern California, [4]Oak Ridge National Laboratory

Abstract

Organic-inorganic metal halide hybrids, consisting of a great variety of inorganic metal halide anions and organic cations, are an emerging class of functional crystalline materials with exceptional structural tunability. The family of organic-inorganic metal halide hybrids has been expanded from connected 3D networks to 2D layers, 1D wires and tubes, 0D mononuclear molecules, and 0D molecular clusters. Efficient luminescence was achieved in 0D metal halide clusters with high quantum yield and large Stokes shift. Here, synthetic control was also realized for the bulk assembly of metal halide clusters with tunable photophysical properties. Detailed structural and photophysical studies suggested that the color tuning between blue and green was achieved by controlling the crystal structures and mo-lecular environments for the light emitting $[Pb_3Cl_{11}]^{5-}$ species, which has two possible emitting excited state structures. These findings pave a new way to controlling the photophysical properties in bulk assembly of metal halide hybrids.

Reference

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Sex and Hemispheric Dependent DTI-based Network Analysis of an Alzheimer's Disease Mouse Model

David C. Hike[1,2], Casey Weiner[2], Scott E. Boebinger[1], Tara N. Palin[1], and Samuel C. Grant[1,2]

[1]Department of Chemical & Biomedical Engineering, FAMU–FSU College of Engineering, [2]National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL

Abstract

Alzheimer's Disease (AD) is the most common form of dementia, characterized by memory loss and changes in behavior[1]. The most prevalent preclinical model of AD is the APP/PS1 mouse expressing human genes for amyloid precursor protein (APP) and presenilin-1 (PS1). Clinically, MRI is used to diagnose AD by means of volumetric, mainly focusing on hippocampal atrophy[2]. In this study, diffusion tensor imaging (DTI) is applied to the 5xFAD variant of the APP/PS1 mouse model at 11.75 T. At multiple early time points, network theory was employed to examine alterations in structural connectivity as a function of age, sex and across hemispheres compared to wild-type controls. The investigation of hemispheric dependence in the loss of neural connectivity was partially motivated by a previous study that showed possible hemispheric differences in vascular pathology related to AD[3]. Current hemisphere-dependent data shows differences between hemispheres within age and phenotype for the parameters observed. This research could be used to detect and classify the progression of Alzheimer's Disease, potentially providing early hallmarks of structural connectivity changes that may be impacted by sex. Such classifications may assist in defining treatment regiments earlier in disease progression, possibly before hallmark symptoms present. Additionally, this work will help to expand the application of DTI and network theory to identification and assessment of progression of other neurodegenerative diseases.

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Cascades

Dr Eric Dolores[1], **Nathan Crock**[2], **Gordon Erlebacher**[2], **Jose L. Mendoza-Cortes**[1]
[1]Department of Chemical and Biomedical Engineering, [2]Department of Scientific Computing

Abstract

We aim to develop an algebra that describes interaction between neurons. An activation diagram is a spatio temporal representation of the neurons and the path of possible signals among them, see Figure 1. External activations are induced by environmental signals, and we consider those initial conditions. Internal activations are consequence of signals sent by neurons previously activated. We are interested in cascades which are activation diagrams with the property that the number of internal activations is larger than the number of external activations.

Following the recent algebraic[1,2,3] and algebraic topology[4] models of neural data, we introduce operations on cascades of neurons with one self-activation and one external activation. We describe cascades that are self-sustained, and we also give an algorithm to create finite cascades.

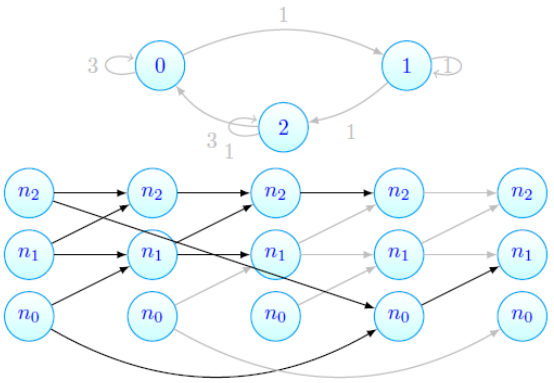

Figure 1 Above: a neural network. Below: an activation diagram with neurons externally activated at time 0.

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Quantitative Assessment of Cell Therapy Efficacy in Acute Ischemia using Perfusion & Diffusion Weighted MRI at 21.1T

F. Andrew Bagdasarian[1,2], Shannon Helsper[1], Xuegang Yuan[1], Jens T. Rosenberg[1,2], Nastaren Abad[1,2], Teng Ma[1], and Samuel C. Grant[1,2]

[1]Department of Chemical & Biomedical Engineering, FAMU–FSU College of Engineering
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Abstract

Stroke incidence, a leading cause of death in the United States, is expected to rise with an aging population. Previous studies have demonstrated therapeutic potential for 2D cultured human mesenchymal stem cells (hMSC) for ischemic stroke, and we have demonstrated that administration of 3D hMSC aggregates correlates to a reduced sodium volume over time highlighting recovery of cellular homeostasis, potentially due to their resistance in ischemic environments. Perfusion and diffusion weighted imaging provides internal biomarkers, demonstrating pathological evidence for ischemia and quantifying extent of the ischemic penumbra. This study extends the utility of perfusion and diffusion weighted imaging at 21.1 T to identify the pattern of potential recovery of cerebral blood flow (CBF) and apparent diffusion coefficient (ADC) in ischemic stroke with novel stem cell therapies using dissociated aggregate human mesenchymal stem cells (d-hMSC) in rodent models. Cells were transplanted via intracerebral ventricular or intra-arterial injection immediately after transient ischemia. All scanning was performed at 21.1 T with the goal of quantitatively assessing treatment efficacy longitudinally, spanning a week post ischemia. Results show long term increase of ADC in the ischemic region, as well as short term CBF equilibrium between hemispheres for both modes of injection.

Cerebellum organoid derivations and characterizations from human induced pluripotent stem cells

Thien Hua, Julie Bejoy, Liqing Song, Zhe Wang, Yan Li*, Qiang-Xian Amy Sang*

Department of Chemical and Biomedical Engineering, FAMU-FSU College of Engineering, Florida State University, Tallahassee, Florida, USA

Abstract

Human induced pluripotent stem cells (iPSCs) have high differentiation potential into three germ layers. Approaches have been made to explore their ability to generate organoids similar to human tissues for understanding organ development. However, there has yet been a successful model for the cerebellum. Most of the protocols involve costly chemicals including growth factors, neurotrophic factors, and signaling proteins that result with low yield of interested cells. One breakthrough is using fibroblast growth factor (FGF) 2, insulin, and transforming growth factor β inhibitor in the first week of human PSC aggregate formation followed by treating with FGF19 and stromal cell-derived factor 1 (SDF1A) in week 3 and 5 respectively. FGF2 and insulin promote the expression of FGF8 and Wnt1 for dorsal-caudal patterning similar to the isthmic organizer; whereas, FGF19 promotes caudalized patterning with the neural rosette formation. In addition, to mimic the cerebellum, SDF1A promotes self-organization to form the three layers including the molecular layer ($NEPH3^+$/$PTF1A^+$), the Purkinje cell layer ($OLIG2^+$), and the granule cell layer ($MATH1^+$). However, the number of progenitors of the Purkinje cells and the granule cells is low. Different morphogens can be used to modulate signal transduction pathways that are important for brain development and can be utilized to improve the differentiation. In this study, we focus on the effects of the wingless (WNT) pathway, the retinoic acid (RA) pathway, and the sonic hedgehog (SHH) pathway on the development of cerebellar spheroids from human iPSCs. WNT and RA pathway was respectively induced by CHIR99021 (CHIR) and RA on week 2; whereas the SHH pathway was induced by purmophamine (PMR) during week 5 of culture. Different combinations of the morphogens (RA/CHIR, RA/PMR, CHIR/PMR, and RA/CHIR/PMR) were utilized, and the spheroids were characterized for each cerebellum marker. Of all the combinations, RA/CHIR/PMR promoted both the Purkinje cell layer and the granule cell layer differentiation. Our results can enhance the understanding of the important role of different molecular pathways in the early stage of cerebellar spheroid differentiation.

Genomics Analysis of Metabolic Pathways of Human Stem Cell-Derived Microglia-like Cells and the Integrated Cortical Spheroids

Julie Bejoy[1], Liqing Song[1], Mark Marzano[1], Yan Li[1]
[1]Department of Chemical and Biomedical Engineering; FAMU-FSU College of Engineering; Florida State University; Tallahassee, FL USA

Introduction: Brain spheroids or organoids derived from human pluripotent stem cells (hiPSCs) are still not capable of completely recapitulating *in vivo* counterpart and one of the limitations is lack of microglia. To add build-in immune function, co-culture of the dorsal forebrain spheroids with isogenic microglia-like cells (D-MG) was performed in our study. The three-dimensional D-MG spheroids were analyzed for the transcriptome and compared with isogenic microglia-like cells (MG). Cortical spheroids containing microglial-like cells displayed different metabolic programming, which may affect the associated phenotype. The gene expression for glycolysis and hypoxia signaling was increased in co-cultured D-MG spheroids, showing the metabolic shift to aerobic glycolysis, which is in favor of M1 polarization of microglia-like cells. In addition, the metabolic pathways and the signaling involved in cell proliferation, cell death, PIK3/AKT/mTOR signaling, as well as Wnt and Notch pathways were analyzed. The results showed the activation of mTOR and p53 signaling, increased expression of Notch ligands, and the repression of NF-kB and canonical Wnt pathways in the co-cultured D-MG spheroids, which are consistent with the lower expression of cell cycle genes. These analyses indicate that physiological 3-D microenvironment can reshape the immunity of *in vitro* cortical spheroids and may better recapitulate *in vivo* brain tissue function for disease modeling and drug screening. **Materials and Methods:** Neural differentiation was induced using dual SMAD inhibitors LDN193189 (LDN) and SB431542 (SB) on human iPSK3 cells in low attachment plates. The neural progenitor spheres were treated with patterning factors cyclopamine (a sonic hedgehog inhibitor) and fibroblast growth factor-2. The identity is defined by TBR1, PAX6, BRN2 and SATB2. Microglial cells were generated by initiating mesoderm induction using Activin A, BMP4, SCF and VEGF, followed by SCF, Flt3L, IL-3, and GM-CSF treatment. Non-adherent cells were replated to tissue culture-treated plates in the presence of IL-3 and M-CSF to derive glial cells. Dorsal spheroids (day 30) were co-cultured with isogenic microglia-like cells at 4:1 ratio (8×10^5 neurons to 2×10^5 microglia-like cells) in 50% DMEM/10% FBS and 50% neural differentiation medium composed of DMEM/F12 plus 2% B27. After three days of co-culture (day 33), the dorsal spheroids containing microglia-like cells (D-MG group) and the microglia-cells only (MG group) were harvested for RNA-sequencing.**Results and Discussion:** The central metabolic pathways were verified, and the values were shown as an increase in glycolytic and pentose phosphate pathways in D-MG group as well as the increased amino acid synthesis. Hypoxia is an important factor in affecting stem cell metabolism and phenotype. Our results did not show higher HIF-1α gene expression in the D-MG group but showed the increased expression of HIF-1α pathway downstream genes. In order to investigate how metabolic reprogramming is orchestrated, the status of critical pathways for cellular function, including PI3K/AKT/mTOR, Myc, p53, nuclear factor kappa-B (NF-kB), Wnt, and Notch, were analyzed. Our results showed that the expression of mTOR (0.66) was slightly elevated in D-MG spheroids and the downstream effects were inhibited. Also there was a reduction in Myc activity inside the D-MG spheroids indicating the slow proliferation of cells. The canonical Wnt pathway is reduced in the D-MG spheroids, whereas the non-canonical Wnt pathway was activated in the spheroids. Notch ligands were up-regulated in the D-MG spheroids. **Conclusions:** The D-MG spheroids had higher expression of genes for glycolysis and hypoxia signaling, showing the metabolic shift to aerobic glycolysis, consistent with M1polarization of microglia. Signaling pathway activities (activation of mTOR and p53, repression of NF-kB and canonical Wnt) are consistent with slower proliferation rate and the accumulation of differentiated cells. The additional NADPH needed for citrate and lipid synthesis was mainly generated by pentose phosphate pathway activation. The D-MG group enriched genes for NOTCH signaling, but not canonical Wnt signaling. The MG group had higher expression of genes for cell cycle and proliferation.

Reference Jiang, L., Shestov, A.A., Swain, P., Yang, C., Parker, S.J., Wang, Q.A., Terada, L.S., Adams, N.D., McCabe, M.T., Pietrak, B., Schmidt, S., Metallo, C.M., Dranka, B.P.,Schwartz, B., DeBerardinis, R.J., (2016) Reductive carboxylation supports redoxhomeostasis during anchorage-independent growth. Nature 532, 255-258.

Student Poster Presentation #8 (Session 1)

Study of Diffusion of Lithium Salt in Block Copolymer

Kyoungmin Kim and Daniel T. Hallinan, Jr.

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Abstract

Lithium-ion batteries are most widely used in portable devices and vehicles, but there has been demand for safer electrolyte material that are less reactive and flammable. The conventional liquid electrolytes can be replaced by solid polymer electrolytes to enhance the safety and chemical stability, but lower ionic conductivity of solid electrolyte is a technical barrier to commercialization. Understanding the transport of ions through the polymer electrolyte is required to improve the performance of the polymer electrolytes. The transport can be characterized by ionic conductivity, diffusion coefficient, and cation transference number. There have been a number of studies on ionic conductivity, but, the study of the other two parameters has been restricted by their difficulty of measurement. We investigated the diffusion behavior of lithium salts in a diblock copolymer using time-resolved Fourier Transform infrared - attenuated total reflectance (FTIR-ATR) spectroscopy which is a simple, straightforward and validated method for diffusion of small molecules in polymer membranes. Unlike electrochemical measurements, the only driving force of diffusion is a concentration gradient, such that it can be measured without electrochemical techniques. The effect of salt concentration on the diffusion coefficient was studied above the melting temperature of the electrolyte. We obtained concentration-dependent diffusion coefficient, but the behavior was non-monotonic as observed by restricted diffusion measurement.

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Influence of environmental Magnetite on human stem cell-derived brain spheroids for studying neural degeneration

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Abstract

Alzheimer's disease (AD) is a common neurodegenerative disorder. Although several hereditary factors contribute to AD, it has been shown that environmental toxins may increase the risk of AD development. Magnetite nanoparticles, Fe2+/Fe3+ mixed iron oxides, were found to be highly present in AD human brain tissues compared to normal control. While previous work has shown a correlation between the presence of magnetite and AD, no previous work on human brain organoids has been done to prove that magnetite nanoparticles cause AD. Magnetite that are thought to have formed during biological process are characterized by a euhedral (cubo-octahedral prismatic) shape. However, spherical magnetite nanoparticles were found in brain samples of people who have been exposed to polluted air and are thus thought to have been inhaled. Some studies have been conducted on mice and populations that have been exposed to air containing particulate matter (including magnetite) and showed a potential association with AD. However, the effect of exogenous magnetite alone on humans has not yet been investigated. To investigate the effect of human brain exposure to spherical magnetite, we used human induced pluripotent stem cells to generate 3-dimentional forebrain cortical organoids and treat them with magnetite nanoparticles to check for neural degeneration. We used 3 different magnetite nanoparticle sizes and 3 different concentrations and found no toxic effect on the viability of the spheroids after 24 hours of exposure. The expression of Aβ42 was investigated after 24 hours and the expression was minimal. After 48-hour of incubation the expression of phosphorylated tau, an AD marker, seemed to increase compared to the untreated control.

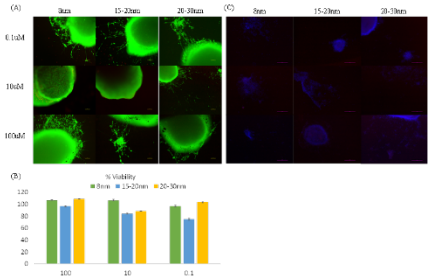

Figure: (A) Images of the cerebral cortex after treatment with different nanoparticle sizes and concentrations. Green indicates live cells and red indicates dead cells. (B) Cell viability using MTT assay. (C) Immunocytochemical staining for Aβ42.

Computational studies of Beyond Li-Ion Battery Technologies and Electrochemical Hydrogen Evolution Reactions

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Abstract

More efficient and affordable technologies should be developed to meet the growing demands for batteries in portable and wearable electronic devices, electric vehicles, smart grids, and other green and sustainable energy storage devices. Here, we present results from three different projects that focus on developing advanced battery technologies and on generating fuel through electrochemical water splitting. In the first project, we show a rational design strategy for fabricating anode materials for Li, Na, and K ion batteries.[1] In the second work, we investigate the novel use of unique organic molecules to boost the voltage stability of rechargeable Li metal batteries.[2] Finally, we study the mechanisms for the electrochemical hydrogen evolution reactions by a new p^H-neutral and noble-metal-free electrocatalyst.[3] We use density functional theory (DFT) calculations for designing battery materials and to study related chemical and physical phenomena. We treat the solid-state systems by using plane-wave DFT methods with a PBE-PAW pseudopotential approach. Molecular and cluster model calculations are performed by using hybrid DFT methods by implementing Gaussian-type orbitals method.

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Aggregation of expanded hMSC restores stemness by induction of integrated stress response through EIF2α phosphorylation

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Abstract

Mesenchymal stem cells (MSCs) are the most commonly tested cells in cell therapy in a wide range of diseases. Studies have shown that transplantation of MSCs aggregates or aggregate-derived MSCs improves tissue repair and regeneration capability due to enhanced cell survival and engraftment, improved cell adhesion and retention, and increased secretory functions. Although several studies have proved that cytoskeleton organization and tension can regulate MSCs properties and contribute to functional enhancement of aggregates, the underlying molecular mechanism has not been fully understood. In the current study, proteomic analysis is performed to investigate the differential expression of proteins to determine the key pathways that are altered during 3D aggregation. A total of 246 differentially expressed proteins (DEPs) were identified based on label-free analysis. Canonical pathway investigation by Ingenuity Pathway Analysis (IPA) highlighted that DEPs were enriched in EIF2 signaling. Western blotting results indicated increased EIF2α phosphorylation in 3D aggregates. EIF2α phosphorylation is a key process in PERK pathway which is a pivotal branch of integrated stress response (ISR). In our study, downstream regulators of EIF2α, ATF4, CHOP and GADD34 were upregulated in 3D aggregates, suggesting activation of PERK pathway through EIF2α phosphorylation. Furthermore, expression of Sox2 and Nanog, two representative proteins of stemness, are upregulated, suggesting the increased stemness. Together, the proteomic analysis revealed that aggregation-induced ISR as the principle mechanism in restoring hMSC stemness in 3D aggregation.

Student Poster Presentation #12 (Session 1)

Extensional Rheology: A Microstructural Probing Technique for Living Polymers

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Abstract

We used capillary break-up extensional rheometer (CaBER) and dripping on a substrate (DoS) techniques to study two series of wormlike micelle solutions; sodium oleate/octyl trimethylammonium bromide (NaOA/OTAB) and Cetylpyridinium chloride/Sodium salicylate (CPyCL/NaSal). These systems show a peak in zero shear viscosity or shear relaxation time beyond a critical salt to surfactant ratio. Cryo-TEM images have indicated that system based on NaOA/OTAB experiences a transition from linear to shorter linear micelles beyond this maximum. However, linear wormlike micelles based on CPyCl/NaSal become branched beyond the viscosity peak. In this study, we investigated whether different microstructural transitions can be distinguished via extensional techniques. Our results indicate that for most of extensional parameters, these systems behave similarly. However, we report some differences in behavior of filament life time in these two systems with both techniques. Finally, we will show that DoS experiments with wormlike micelles needs special care to prevent wetting effect.

Spectroscopy and sodium analysis of dissociated cellular therapy in ischemia at 21.1 T

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Abstract

This study evaluates biochemical markers in a rat model of ischemic stroke at 21.1 T following administration of human mesenchymal stem cells dissociated (d-hMSC) from 3D aggregates. The ability to assess treatment longitudinally and establish early indicators for tissue recovery is imperative to evaluating the efficacy of novel therapies for stroke.[1] Here, d-hMSC are injected intra-arterially immediately following occlusion in a rat model of transient ischemia to identify biochemical markers by MRS and sodium (^{23}Na) chemical shift imaging (CSI). Applying these techniques at ultra-high fields provides insight into ionic and metabolic homeostasis indicative of tissue recovery[2]. A relaxation-enhanced (RE) MRS method for selective excitation[3] provides a spectrally sensitive approach to monitor metabolic concentrations including lactate, NAA, creatine and choline, as potential early markers for tissue recovery. Evaluation of ^{23}Na CSI provides insight into cerebral ionic homeostasis and tissue recovery following acute neurodegeneration by tracking ischemic lesion volumetric. We hypothesize that administration of d-hMSC will enhance recovery and provide restoration of ionic and metabolic homeostasis as indicated by RE-MRS and ^{23}Na CSI.

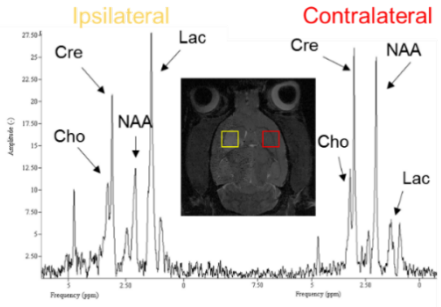

Figure 1. Representative RE-MRS 1-d post-MCAO of an ischemic rat administered d-hMSC immediately following occlusion; ischemic lesion (yellow) and contralateral (red) voxels are referenced to a T_2W MRI.

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Student Poster Presentation #14 (Session 1)

Lignin-based biodegradable polymer

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Abstract

Lignin is the second most abundant biopolymers and the most sufficient aromatic renewable resource. Lignin has strong and stiff mechanical properties that can compensate other ductile polymers during the integration. Among the ductile polymers, aliphatic polyesters have excellent biocompatibility, and biodegradability. The integration of lignin and aliphatic polyester produce a strong and ductile copolymer that has potential applications in nature. Herein we design an alternative clam nets material that is strong as well as biodegradable to reduce pollution. This material is produced by following three steps. 1) Lignin was chemically functionalized to introduce carboxylic acid groups by steglich esterification using succinic acid 2) Another counter part of the copolymer, poly(ethylene brassyalte) (PEB), was synthesized from ethylene brassylate by ring-opening polymerization. The synthesized PEB was designed to have dual hydroxyl end groups. 3) The lignin-based aliphatic polyester was produced by the polycondensation of poly(ethylene brassylate) and succinic acid functionalized lignin. This process is done by using the commonly used industrial catalyst, Sb_2O_3 for PET synthesis.

Synthesis of Cu_2O-CuO Nanowires/Whiskers Electrolessly on C-Felt Substrate for Lithium Ion Battery Anode Materials

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Abstract

Lithium ion batteries (LIBs) have dominated the energy storage industry. With this widespread use, there is a need for other anode materials other than carbon materials than can be used to improve performance. Alternatives such as transition metal oxides are promising candidates [1, 2]. One such material with higher capacity than graphite anode material is copper oxide (674 mAh/g) [3,4]. Despite the positive attribute of copper oxide anode materials, pulverization and low-cost feasible fabrication method remain some of the issues impeding its application commercially in LIBs. It is well known that high surface area films and particles reduces volume change and pulverization. As such we engineered copper oxide anode fabrication via use of electroless encapsulation technique. Conductive, porous, mesh-like, and free-standing carbon cloth that is lithium active was coated with copper electrolessly and subsequently oxidized by annealing at 150 and 300 ^{O}C in air respectively, yielding 150 Cu_2O-CuO@C-Cloth and 300 Cu_2O-CuO@C-Cloth materials that are binder-free and free-standing without the support of a current collector. SEM, XRD revealed the presence of the Cu_2O-CuO coating. The C-Cloth, 150 Cu_2O-CuO@C-Cloth and 300 Cu_2O-CuO@C-Cloth materials were used as electrodes in LIBs and the lithiation capacities at first cycle were 300 mAh/g, 450 mAh/g and 510 mAh/g, respectively. Our results indicate that it is feasible to obtain lithium storing anode materials for LIBs with high capacity by use of low-cost materials and processes that are environmentally benign.

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Student Poster Presentation #16 (Session 1)

Aggregation-Induced Integrated Stress Response in MSCs Improves Therapeutic Efficacy

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Abstract

Mesenchymal stem cells (MSCs) have shown promising therapeutic potential due to their impressive ability to secrete inflammatory modulatory, angiogenic, and regenerative cytokines. The potential can be further improved when autogenic transplantation is taken into consideration; however, there exists the problem of expansion of isolated MSCs to therapeutic levels. When MSCs are expanded *in vitro* they are plated on hard tissue culture plastic, which leads to loss of the *in vivo* phenotype, low proliferation, glycolytic metabolism, and high autophagic activity. This loss of function termed *in vitro* aging also results in differentiation of MSCs and loss of therapeutic relevance. It has previously been shown that aggregation of MSCs leads to heightened autophagy, and a reversal of metabolic phenotype back to aerobic glycolysis. For this reason, we have explored what effects aggregation has on the proteome to determine what pathways are elevated by aggregation. We observed a decrease in the eIF2 pathway which is responsible for controlling the initiation complex for protein translation a component of the induced stress response (ISR). Previously, it has been shown that embryonic stem cells hyper-control their proteome to maintain stemness by limiting initiation, increasing folding through chaperone protein content, and increasing proteasome activity to degrade build-up of misfolded proteins and prevent defects from going into daughter cells. We show here that as MSCs aggregate they increase their ISR and as a result down stream targets which lead to improved proteome control and therapeutic function.

Student Poster Presentation #17 (Session 2)

Morphology and Crystallization Kinetics of Poly (ethylene brassylate)

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Abstract

Poly (ethylene tridecanedioate), also known as poly(ethylene brassylate) (PEB), is a long-spaced aliphatic polyester obtained from a renewable source. PEB in a range of molar mass between 27,000 and 188,000 Dalton crystallize rapidly as single peaks at ~55ºC and display three major melting peaks (60 -70ºC). The original crystals melt at ~58°C and further recrystallize and melt again at ~70°C while a different type of crystal forms at the same time and melts at ~65°C. The difference between the various types of crystals formed in PEB is the number of repeating units in the crystal. Differences in the crystal thickness lead to the effect of self-poisoning at the growth front, and hence, to a deep depression in the temperature coefficient of the growth rate at temperatures approaching the melting temperature of the thin crystals from above. This minimum of the rate, first described for n-alkanes, is also observed in the overall crystallization kinetics obtained by DSC, and follows a general behavior of precision polyethylenes that develop different crystalline structures by changing undercooling.

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Evolution of Structure & Dynamics of Thermo-reversible Nanoparticle Gels

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Abstract

A coupled X-ray photon correlation spectroscopy (XPCS) and rheology study is carried out to capture the evolution of structure, fast dynamics and moduli (elastic and loss) at early times near the gel boundary of a thermo-reversible colloidal gel in order to get a microscopic understanding of the gelation process. The system is comprised of moderately concentrated suspensions of octadecyl silica in decalin ($\phi = 0.2$) undergoing thermo-reversible gel formation at weak attraction strengths. Near the gel boundary, the rate of gel formation is very sensitive to changes in attraction strength. However, we find that the system goes through identical intermediate states of microscopic and macroscopic behavior even though the time needed form a gel varies by orders of magnitude. We identify a single dimensionless time parameter, t_w/t_g (where t_w is the wait time following the temperature quench and t_g is the rheologically determined gel time) that captures the similarity in gel formation at a range of attraction strengths near the gel boundary. Following a temperature quench near the gel boundary, the system exhibits a gradual slowing down of dynamics due to the formation of small diffusive clusters (~ 2 – 3 times particle radius) which ultimately stick to form a network like structure (at the lag time t_L) indicated by a divergence of relaxation times and onset of mechanical rigidity. At the rheological gel time, t_g, the Baxter parameter obtained from Adhesive Hard Sphere fits of the structure factor date attains a constant value which corresponds to the theoretical percolation boundary thus demonstrating that gelation is percolation driven. The increase in the elastic moduli of these gels may be attributed to structural rearrangements at very short length scales that result in locally favored configurations and rigidification of bonds.

Student Poster Presentation #19 (Session 2)

Electrical Property Mapping at 21.1T

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Abstract

Electrical properties namely conductivity and permittivity are fundamental properties of biological tissues. Visualization of frequency-dependent conductivity and permittivity distribution in the range from DC to hundreds of MHz may expand our ability to provide diagnostic information about the physiological and pathological state of tissues and organs. Magnetic Resonance Electrical Property Tomography (MREPT) is a recently developed method for reconstructing images showing the complex permittivity distribution in target tissues. As such, MREPT can provide both a map of permittivity ε, which relates to energy storage in the medium, and a map of conductivity σ, which relates to the energy loss. Unlike related techniques such as electrical impedance tomography, MREPT makes use of a standard MRI system with no additional hardware or the need to inject current into the tissue under examination. Instead, the MREPT approach employs post processing of the magnetic field map of the applied RF pulse, making MREPT quantitative by yielding absolute values of σ and ε. Phantom and human experiments have proven the feasibility of MREPT, with ongoing clinical studies demonstrating encouraging results. In this study, the physical and mathematical principles of MREPT and its implementation at ultra-high field namely 21.1 T, corresponding to an operational frequency of 900 MHz, is investigated through phantom, *ex* and *in vivo* rat brain acquisitions. At this field strength, the conductivity predictions agree with the target values measured by dielectric probe. Notable accuracy in permittivity reconstructions has been achieved that provided insight into the relative permittivity differences in the ischemic brain lesion.

Student Poster Presentation #20 (Session 2)

Engineering and Characterization of Human Stem Cell-derived Multicellular Aggregates of Glial Cells

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Abstract

Astrocytes are vital components in neuronal circuitry and there is increasing evidence linking the dysfunction of these cells to a number of central nervous system diseases. Studying the role of these cells in human brain function in the past has been difficult due to the limited access to human brain. Here, human-induced pluripotent stem cells (hiPSCs) were differentiated into astrospheres using a hybrid plating method, with or without dual-SMAD inhibition. The derived cells were assessed for astrocytic markers, brain regional identity, phagocytosis, calcium-transient signaling, reactive oxygen species (ROS) production, and immune response. Neural degeneration was modeled via stimulation with amyloid-β (Aβ) 42 oligomers. Finally, co-culture was performed to for the derived astrospheres with isogenic neurospheres. Results show that the derived glial cells expressed astrocyte markers with forebrain dorsal cortical identity, secreted extracellular matrix (ECM), and were capable of phagocytosing iron oxides particles, and responded to Aβ42 stimulation (higher oxidative stress, higher TNF-a and IL-6 expression, upon stimulation). In addition, the ECM remodeling proteins MMP2 and MMP3 were downregulated with Aβ42 stimulation. Co-culture experiments show the enhanced synaptic activities of neurons and neural protection ability of the glial cells. This study provides additional knowledge about the roles of brain glial cells, heterotypic cell-cell interactions, and the formation of engineered neuronal synapses *in vitro*. The implications lie in neurological disease modeling, drug screening, studying progression of neural degeneration and the role of stem cell microenvironment.

Student Poster Presentation #21 (Session 2)

Assessment of Metabolic Alterations in the Trigeminovascular System of a Migraine Model

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Abstract

Acute and sustained biochemical changes, prominently with lactate, taurine and total creatine, have been identified previously in a ^{1}H-MRS neocortical study [1], indicative of increased neural activity/glycolysis and supported by dynamically altered sodium homeostasis [2]. However, other potential metabolites attributed to excitability (e.g., NAA and glutamate signals in neurons, myoinositol, choline and glutamine signals in astrocyte), did not display significant concentration changes with NTG. Diffusion-weighted (DW-MRS) [3-6] may prove more sensitive for detecting cell specific alterations in endogenous metabolites with migraine onset. In this study, DW-MRS was employed to measure diffusion properties and compartmental changes in an NTG rat model. Due to its central role in migraine, the trigeminovascular system is the target of these *in vivo* investigations, for which the high sensitivity of 21.1-T MRS will be leveraged to monitor concentration and diffusional alteration during progression of migraine. baseline (pre-injection) signal for each peak.

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Student Poster Presentation #22 (Session 2)

Elastic Recoil in Startup Shear Flow for a Shear-Banding Fluid

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Abstract

Shear banding complex fluids under startup of steady shear flow undergo uncommon phenomena that are still not well understood, and among them is recoil in which fluid may briefly flow against applied shear strain. We use a custom-built Taylor-Couette (TC) cell for particle tracking velocimetry (PTV) to quantify the full velocity profile during startup of steady shear flow for shear banding wormlike micellar solutions. We identified a set of treatments (surfactant concentration, salt concentration, temperature) that provide a broad range for the elasticity number while holding constant the viscosity ratio and entanglement ratio. For each, we visualized startup of steady shear flow at varying Weissenberg numbers throughout the shear stress plateau, below it, and beyond it, while simultaneously measuring shear stress. We found that the solutions undergo recoil as the stress relaxes to its steady state value following its overshoot maximum, which is consistent with the published Vasquez-Cook-McKinley (VCM) model[1,2]. The extent of recoil increases with elasticity number. Specifically, for an entanglement number near 5 and a viscosity ratio near 40,000, recoil reaches negative velocity for elasticity numbers near 10^6 and greater. This is observed throughout the shear stress plateau, though the region with negative velocity is smaller for shear rates toward the end of shear banding.

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Chemical Reduction by Aqueous Electrons in Tubular Gas-Liquid Plasma Reactors

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Abstract

Pulsed electrical discharge plasmas formed at the interface of a flowing gas-liquid film in small millimeter scale reactors have been shown to be effective for chemical oxidation of organic compounds in the aqueous and gas phases due to the efficient production of hydroxyl radicals [1]. In addition to these oxidizing species, there is strong evidence for the formation of chemically reductive species including aqueous electrons (e^-_{aq}), as well as atomic and molecular hydrogen (H, H_2) [2]. The importance of combined oxidation and reduction reactions in a single process in aqueous and non-aqueous media has long been recognized in other fields including radiation chemistry, electrochemistry, and sonochemistry particularly for use in waste water treatment and has been termed AORPs (advanced oxidative and reductive processes). This work aims to assess the production of chemically reductive species in non-thermal gas-liquid plasma discharges in conjunction with the already well know oxidative species. Of particular interest is the aqueous electron both due to its extremely high reductive potential and the fact that gas phase free electrons occur in high abundance in plasma processes. Ferricyanide dye is used to assess the production of aqueous electrons due to its high susceptibility to aqueous electron reduction and ease of quantification with UV-Vis spectroscopy [3]. Conversely, the reduced product (ferrocyanide) is susceptible to oxidation by hydroxyl radicals making this an ideal system for assessment of oxidation vs. reduction potential. Preliminary work has shown that solution pH is a strong determining factor in whether oxidative or reductive pathways dominate, therefore various concentrations of NaOH are utilized in conjunction with the dye in order to further assess this effect.

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Student Poster Presentation #24 (Session 2)

Intracellular Diffusion Patterns in *Aplysia Californica*: Examining Neural Transport Models

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Abstract

Dynamic determination of the *in situ* localization and interactions of cellular metabolites is crucial for understanding the metabolic basis of difficult to diagnose disorders. Diffusion weighted magnetic resonance spectroscopy (DW-MRS) is capable of determining both the movement and eccentricity of measured molecules, as well as correlations with MR relaxation and reaction kinetics[1]. Cellular metabolites, unlike water, are confined largely within respective cells; their movement patterns can be used as a tool to explore intracellular structure, organization and transport. Previous attempts to model neural structure using DW-MRS show apparent diffusion coefficients (ADC) that hold constant at long time scales, implying free metabolite transport along the neural cytoskeleton, as opposed to localization of metabolites around biologically relevant organelles[2]. However, DW-MRS averages molecular signal across voxels. These studies are hindered by large voxels in rodent neural tissue and a shortage of cell exclusive metabolites. To that end, we are measuring the intracellular diffusion of metabolites within the giant ganglia of *Aplysia Californica* with the aim of verifying and/or refining the current working model of neural transport. Rather than the anticipated ADC pattern, our initial results show ADC in line with those found at ultra-short time scales. Future experimentation aimed at varying the timescales and isolation of individual neurons from ganglia are planned to enable total critique of the neural transport model.

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Student Poster Presentation #25 (Session 2)

Flow of a Model Shear Thickening Micellar Fluid Past a Falling Sphere

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Abstract

In this work, we present the first quantitative measurements of a dilute micellar solution past a falling sphere. The dilute micellar solution that consists cetyltrimethylammonium bromide and 5-methyl salicylate (CTAB/5MS) in de-ionized water exhibits shear thickening behavior beyond a critical shear rate of $\dot{\gamma}_c \approx 0.4$ (1/s). Previous works have demonstrated that this CTAB/5MS micellar solution forms un-entangled rod-like micelles at equilibrium [Davis et al. J. Am. Chem. Soc. 128, 6669, 2006]. At a vanishingly small Reynolds number ($Re = 0.03$), the drag coefficient for the falling sphere is similar to that of a Newtonian fluid. However, for conditions that correspond to $0.09 \leq Re \leq 9.86$, falling spheres experience a significant drag reduction. Moreover, an unusually extended wake which spans over a long distance downstream of the sphere is detected by particle image velocimetry. These unusual results could be rationalized by invoking the phenomenon of flow induced structure (FIS) formation. We hypothesize that strong shear and/or extensional flows around the falling sphere could trigger aggregation of rod-like micelles into giant worm-like structures. Such worm-like micelles may induce significant sphere drag reduction and extended elastic wakes in the rear of sphere. This interpretation is consistent with the steady shear and transient extensional experiments, whereby a strong shear and elongational thickening have been recovered.

Aqueous Atom Transfer Radical Polymerization (ATRP) of commonly used vinyl monomers with N-heterocyclic carbene (NHC) containing homogeneous Ru catalyst

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Abstract

Ruthenium (Ru) is the first transition metal used as a catalyst of modern controlled/living radical polymerizations. In particular, Ru-NHC catalyst is an effective catalyst in not only ATRP but also metathesis reaction. An important recent issue of polymer synthesis is a green polymerization that uses water as a solvent due to sustainability and environmental concern. A desirable ligand design is important for a highly active homogeneous aqueous transition metal catalyst. In this research, we have synthesized NHC containing homogeneous Ru catalyst to perform ATRP of commonly used vinyl monomers, acrylate derivatives. The NHC of catalyst possesses poly(ethylene glycol) (PEG) as a water soluble component. Another important part of the catalyst is Ru benzylidene (Grubbs 2nd generation analog) which leads ATRP of vinyl monomers as well as metathesis reactions. The new Ru catalyzed polymerization of PEG methyl ether methacrylate (PEGMEMA, 2 kDa) demonstrated typical ATRP behavior showing low molecular weight distribution, linear increase of molecular weights with conversion, and first-order kinetics. The used alkyl bromide initiator was water soluble PEG methyl ether 2-bromoisobytyrate. Specifically, poly(PEGMEMA) of molecular weight 495 kDa (PDI: 1.27) was prepared with 96% conversion at 5 hours of reaction time (reaction temperature 80 ^{o}C) with 0.05 mol% catalyst loading. Unlike the Ru-catalyzed ATRP, thermally-initiated polymerization without catalyst showed completely uncontrolled polymerization. The new ATRP will be greatly advantageous to polymer science as an initial example of Ru-catalyzed ATRP in neat water which has significant benefits of inexpensive, nontoxic, and readily available solvent features.

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Performance for Non-noble Co-Ni-Mo-P Electrocatalyst for Ethanol Electro-oxidation

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Abstract

Multi-alloy as-deposited Co-Ni-Mo-P electrocatalyst on carbon support was investigated for the ethanol electro-oxidation. The electroless deposition method was used for the preparation and carbon substrate support (CCS) was made active for electroless deposition with Pd-ink. SEM, XRD, and EDX were used to study surface structure and composition. The electrocatalytic activity of the catalyst was measured and analyzed using cyclic voltammetric (CV) techniques. Bi-alloy composition (NiP/CCS and CoP/CCS), tri-alloy compositions (NiCoP/CCS, NiMoP/CCS, and CoMoP/CCS), and multi-alloy compositions (CoNiMoP/CCS) were tested in 0.5 M NaOH and 1 M EtOH and the catalysis activities were discussed. The CV pattern (with oxidation peaks) for CoNiMoP/CCS and CoMoP/CCS, showing a forward oxidation peak and a backward oxidation peak was a characteristic behavior for the ethanol electro-oxidation. In the present study, the goal is aimed at an effective electrocatalyst for producing hydrogen from the electro-oxidation of ethanol. Therefore, with both catalysts showing high oxidation peaks for ethanol, it can be inferred that the two catalysts have the potential to meet up with our expectations of an effective ethanol electro-oxidation catalyst. However, the current density of CoMoP electrocatalyst was found lower than that of CoNiMoP electrocatalyst, indicating that the multi-alloy catalyst provides better performance than the tri-alloy composite electrode. Overall, this study provides a novel and effective non-noble electrocatalyst for ethanol electrooxidation.

Student Poster Presentation #28 (Session 2)

Breakdown of Cellular Homeostasis in Human Mesenchymal Stem Cells with Replicative Senescence

Xuegang Yuan[1], Yijun Liu[1], Qin Fu[1], Brent Bijonowski[1] and Teng Ma[1]

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Abstract

Human mesenchymal stem cells (hMSCs) isolated from various adult tissues are primary candidates in cell therapy and being tested in clinical trials for a wide range of diseases. However, immediately after isolation and upon culture expansion, hMSCs lose their in vivo quiescent state and start to accumulate genetic and phenotypic changes that significantly alter their phenotypic properties with reduced clonogenic population and therapeutic potential [1]. The proliferation of hMSCs is limited and long-term culture-induced changes lead to cellular senescence, resulting in reduced therapeutic outcome. Since clinical application requires large-scale expansion of hMSCs, preserving hMSC cellular homeostasis during manufacturing is a major barrier for hMSCs-based therapy. Here, we reported the breakdown of cellular homeostasis in culture-induced senescent hMSCs. Replicative senescence of hMSCs including proliferation, regenerative potential, cell cycle, impairment of migratory ability and immunomodulation. Basal autophagy and mitophagy also decreases, along with mitochondrial dysfunction. Metabolomics and proteomic analysis suggested the loss of metabolical homeostasis during expansion, which reconfigured hMSC metabolism from glycolysis towards OXPHOS. Rapid production of energy leads to the breakdown of cellular homeostasis with metabolic and redox imbalance. Our results show a significant decline of nicotinamide adenine dinucleotide (NAD+) during rapid passaging of hMSCs. NAD+/Sirtuin axis plays a crucial role in restoring mitochondrial function, including mitochondrial biogenesis, membrane potential and electron transport ability. By repletion of NAD+ in senescent hMSCs, stem cell properties have been recovered. Basal autophagy and mitochondrial function were also improved to maintain cellular homeostasis of culture expanded hMSC [2].

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Development of Microdevices for Photoelectrical Stimulation of Cells

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Abstract

Photoelectrical stimulation of cells is an emerging technique with tremendous potential for expanding the toolset for tissue engineering as well as enabling new therapies for treating neurological diseases, but its potential applications are limited by the large size of the existing photoelectrical-stimulation devices. The objective of this study is to develop a novel device for photoelectrical stimulation. The device, which is termed microdevice, is featured by a sub-10 μm size and disk-like shape, a well-defined layered structure for converting light to electrical signals via the photovoltaic mechanism, and engineerable surface properties. These features potentially allow the microdevices to bind to individual cells and modulate their behaviors through photoelectrical stimulation. We have fabricated the microdevices, characterized the cell-microdevice interactions, and evaluated the photoelectrical properties of the microdevices. These results have laid a foundation for its further development into a viable tool for tissue engineering research and neuromodulation therapy.

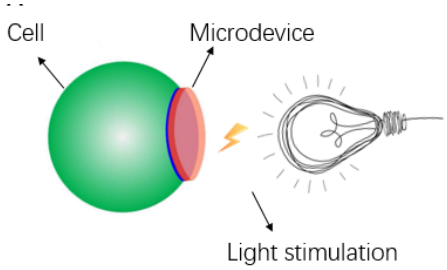

Figure. Schematic of photoelectrical stimulation of a cell with a microdevice.

Functionalizing Cells with Microdevices Through Membrane Intercalation

Yu Miao[1], Hailing Liu[1], Wenhao Cheng[1], Yang Liu[3], Sundol Kim[1], Xuegang Yuan[1], Aubrey Kusi-Appiah[2], Steven Lenhert[2], Teng Ma[1], Yi Ren[3], Hoyong Chung[1], Jingjiao Guan[1]

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Abstract

Functionalizing cell with artificial micro/nanodevices into a single entity can make a hybrid system that possesses both the functionalities of the cell and the micro/nanodevices, which can serve as a novel drug delivery system. Researchers have utilized different kinds of interactions to make cell/micro or nanodevices complexes such as avidin-biotin, maleimide-thiol and CD44-hyaluronic acid . However, due to the requirement of specific interactions, these methods are not suitable for all therapeutic cells. To solve these problems, we have designed a microdevice structure as illustrated in Fig. 1. The microdevice is disk-shaped, with one face being grafted with a monolayer of dangling PEG octadecyl ether, which is composed of a linear PEG chain in the middle and a hydrocarbon chain at the end. The hydrocarbon chains are expected to be able to intercalate into the lipid bilayer of the membrane of human cells, consequently anchoring the microdevice to the cell. The cargo layer can be used to carry various functional materials such as drugs.

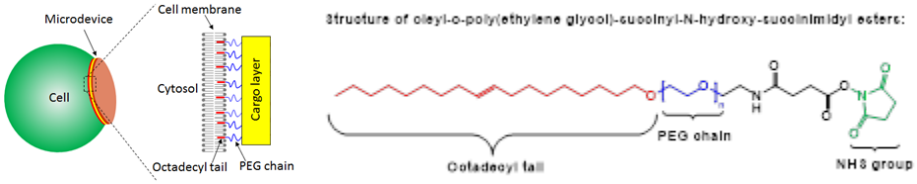

Fig. 1. Schematic of mechanism for attaching a microdevice to a cell via the membrane intercalation mechanism.

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Student Poster Presentation #31 (Session 2)

Direct Ink Writing of Modified Cellulose Nanocrystals

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Abstract

Cellulose nanocrystals (CNCs) are stiff, lightweight rod-shaped nanoscale materials that have a tensile strength 8x that of steel (7.5 GPa)[1]. The addition of CNCs into a polymer matrix has been shown to enhance the mechanical properties of the resulting composite, however, the utilization of CNCs in more common non-polar polymers is still limited to their hydrophilicity and poor dispersibility. In order to fully realize the potential of CNCs as a mechanical reinforcement, it is important to modify the hydroxyl rich CNC surface. In this work we characterize the effects of a functionalized CNC on the rheological properties and printing behavior (Direct Ink Writing (DIW)) of an epoxy resin. CNC functionalization is achieved by grafting an activated medium chain fatty acid to substitute the -OH groups. The level of CNC modification is evaluated using Fourier Transform Infrared (FTIR). Functionalized CNCs are dispersed into EPON 828 at loadings up to 20wt%. Initially, rheological studies are used in this study to assess the printability of the inks. The rheological percolation threshold is the critical concentration at which there is a transition from liquid-like to solid-like behavior. For this system, this value was found to be at ~10wt%. We found that for the final printed structure to exhibit structural integrity, it is necessary to print at loadings above this value. Future work will include microscopy of both printed and cast samples to observe the dispersion and alignment of the CNCs within the polymer matrix and mechanical testing to show the effect of the reinforcement.

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