The Office of Undergraduate Student Affairs and Global Programs
& the Engineering Student Council Present

THE UNDERGRADUATE SUMMER RESEARCH SYMPOSIUM AND FAIR

THURSDAY, SEPTEMBER 27, 2012
5:00 - 8:00 PM
555 LERNER

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Faculty Participants

Shih-Fu Chang, Richard Dicker Professor of Telecommunications and Professor of Computer Science and Senior Vice Dean

Ioannis Kymissis, Associate Professor, Electrical Engineering

Siu-Wai Chan, Professor, Applied Physics and Applied Mathematics

Mehmet Yilmaz, Graduate Student, Professor Jeff Kysar's lab, Mechanical Engineering

Student Research Posters

Three Dimensional Microtubule Assembly in the Presence of Poly-L-Lysine
Megan Armstrong, SEAS '13, Biomedical Engineering; Ruchir Khaitan, SEAS '15, Computer Engineering; Hari Raman, SEAS '14, Biomedical Engineering; Veronica Reynolds, SEAS '14, Materials Science and Engineering; Elyse Shapiro, BC '14, Biology

Exploration of Conductance Properties of Single-Molecular Circuits
Tanay Doctor, SEAS '15, Earth and Environmental Engineering

Lightweight, Inexpensive, and Human-Friendly Methods for Design in Assistive Robotics
Haris Durrani, SEAS '15, Applied Physics; Brendan Chamberlain-Simon, SEAS '15, Mechanical Engineering; Angel Say, SEAS '13, Mechanical Engineering

Plasmid Constructions for Analysis of CRISPR-Cas System in *Escherichia coli*
Claire Duvallet, SEAS '13, Biomedical Engineering

Classification of Heart Enhancers in Drosophila
Julian Haimovich, SEAS '13, Applied Mathematics

Hydrology Simulations on Basalt Soil for the Landscape Evolution Observatory (LEO)
Christina Hernandez, SEAS '14, Earth and Environmental Engineering

Optimizing the Conductivity of Textiles via Atomic Layer Deposition for Pressure Sensitivity
Jeremy Jones, SEAS '14, Chemical Engineering

CAD Modeling of Tall Building Structural Systems for use in FEM Simulations
Claire Kao, SEAS '14, Civil Engineering; et al.

On-chip Security Test for High-Dimensional Quantum Key Distribution
Prashanta Kharel, SEAS '13, Electrical Engineering; et al.

Identification of a Novel Long Non-coding RNA in Cardiac Differentiation
N.H. Diane Kim, SEAS '14, Biomedical Engineering

Q-Potts Simulation of Breast Cancer Cell Morphologies
Esha Maharishi, SEAS '15, Computer Science

Projecting Future Farm Distribution
Andrew Mercer-Taylor, SEAS '15, Computer Science

Microalgae Preconcentration by Sedimentation and by Addition of Montmorillonite Clay Coagulant
Elizabeth T. Murray, SEAS '13, Chemical Engineering; et al.

Novel Efficient Microbial Fuel Cell Anodes Using Activated Carbon Nanofiber Nonwoven
Radhe Patel, SEAS '15, Chemical Engineering; et al.

Effect of Thermal Cycling on Barrier Layers for Environmental Protection of Nickel-Based Alloy 617
Connie Phung, SEAS '15, Mechanical Engineering; et al.

Mediated Reality for the Masses: An Investigation into the Viability of a Low Cost Mediated Reality System
Andrew E. Pope, SEAS '15, Computer Science

Electronics for the Vertical Slice Test of the MicroBooNE Light Collection System
Kathleen Tatem, SEAS '13, Applied Physics

Conductance of Nickel and Iron Mononuclear Complexes in Methyl-Sulfide Linked Single-Molecule Junctions
Ari B. Turkiewicz, SEAS '15, Chemical Engineering

Diagnosis of Osteoarthritis via Laser Speckle Rheology
Kapil Wattamwar, SEAS '13, Department of Biomedical Engineering; et al.

Pickering Emulsion Optimization Using Silica Nanoparticles
Kendra Windsor, SEAS '13, Chemical Engineering; et al.

Three Dimensional Microtubule Assembly in the Presence of Poly-L-Lysine

Megan Armstrong, SEAS ’13, Biomedical Engineering; Ruchir Khaitan, SEAS ’15, Computer Engineering; Hari Raman, SEAS ’14, Biomedical Engineering; Veronica Reynolds, SEAS ’14, Materials Science and Engineering; Elyse Shapiro, BC ’14, Biology, Columbia University

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Sponsor/Location of Research

Professor Henry Hess, Department of Biomedical Engineering, Columbia University

Abstract

The polymerization of tubulin dimers results in the formation of long, hollow, and rigid structures known as microtubules. Current techniques involving microtubules and cargo transport situate the microtubules on a horizontal plane, parallel to a glass surface. We sought to create novel structures of microtubules in synthetic biology. We designed a 3D mesh of microtubules by coating the glass surfaces in a flow cell with the polymer poly-L-lysine. This caused the microtubules to orient themselves orthogonally to the glass surface and to form web-like structures spanning the height of the flow cell. We observed attachment due to electrostatic interactions between the rhodamine-labeled microtubules and the poly-L-lysine coated surfaces almost immediately in the flow cell. The poly-L-lysine in solution is conjectured to have acted as a bridging mechanism between the microtubules that created the observed structures. This new mesh has potential to add to the biosensing field in physical filtration devices.

Keywords

microtubule, poly-L-lysine, flow cell, biosensing

Exploration of Conductance Properties of Single-Molecular Circuits

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Sponsor/Location of Research

Latha Venkataraman, Applied Physics and Applied Mathematics, Columbia University

Abstract

The Venkataraman laboratory where I worked during this summer explores electrical conduction through single molecules. As we all know that certain elements (metals) conduct electricity well while others (plastics) do not. These are however macroscopic properties caused by the interaction of many thousands of molecules and the passing of millions of electrons. The properties of these elements and many other elements at the single molecule level are very different than what is observed at the regular ohms law conduction and even semiconductor devices. The aim of the lab is to explore how different single molecules (usually organic molecules) and metals conduct electricity at the single molecule level. The most obvious implications of this research is its use in a new paradigm of electronics that use these single molecules as basic transistors and diodes that are the building blocks of computer memory and processing in order to have computers that are much more powerful, smaller and energy efficient. In addition to its commercial applications this research explores a completely uncharted area in physics and has implications in molecular biology research, solar energy research and in many other fields that try to understand nature.

I had a couple of projects that I had to undertake in the laboratory. First I had to make an accurate video representation of the setup and how the molecules behave at the atomic level. After that I had to figure out how to cool the experimental setup that was currently being used to measure the conductance properties of these single molecules to see how cold temperatures affected the molecules and then over the semester I will run experiments on this cooled apparatus.

Keywords

quantum electronics, single molecule conductance, applied physics, electrical conduction

Lightweight, Inexpensive, and Human-Friendly Methods for Design in Assistive Robotics

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Sponsor/Location of Research
Peter Allen, NSF REU Columbia University Robotics Lab

Abstract

While the field of robotics has achieved great strides in the past few decades, one challenge remains: mimicking the machinery of the human body itself. An industrial robot is capable of performing impressive tasks, but its operation is limited to areas free of human interaction. Aside from military and industrial incentives, there is an increasing demand for robots in the home -- especially for the disabled. While there already exist many robotic arms for the disabled, most are costly and heavy. Our aim was to explore ways to design a relatively inexpensive, lightweight, and human-friendly mobile manipulator system (a robotic arm mounted to a moving platform). In the future, we plan to mount this arm to an electric wheelchair. This is part of a broader, National Science Foundation-funded project at Professor Peter Allen’s Columbia Robotics Lab to create a Brain Computer Interface (BCI) controlled robotic assistive device for those with full-body disabilities. Furthermore, the project will incorporate the Columbia Hand, an under-actuated hand designed at the Robotics Lab, and GraspIt!, a program also created by the Lab which uses BCI to quickly recognize and determine the most effective grasp for picking up objects.

An extensive literature review was performed throughout the summer to gain insight into existing commercially-available technologies and projects at other universities. This insight was then applied toward designing a robotic arm using as many off-the-shelf components as possible. We also concluded that new methods of manufacturing, such as laser-cutting and 3D-printing, led to a cost-efficient, simple, and easily-reproduced design. To learn about safety precautions and the various user needs for an assistive robotic arm, we consulted doctors at the Columbia Medical Center. Because assistive robotic arms are often used in domestic environments, safeguards are necessary to prevent injury to people and obstacles during collisions in close quarters. One major solution involved series elastic actuators (SEAs), a growing trend in assistive robotics. SEAs’ allowance for compliance in a collision was an efficient method of increasing safety and allowing the manipulator to “feel” around. We are currently in the process of building and implementing the design.

Keywords
assistive robotics, mobile manipulator, BCI

Plasmid Constructions for Analysis of CRISPR-Cas System in *Escherichia coli*

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Sponsor/Location of Research

Cédric Norais, Ecole Polytechnique; Palaiseau, France

Abstract

Clustered regularly interspaced short palindromic repeats (CRISPR) and CRISPR-associated (Cas) proteins form the CRISPR-Cas system present in most archaea and many bacteria. This system provides resistance against invading nucleic acids by incorporating sequences derived from the foreign elements into CRISPR loci. When the CRISPR system is activated, the locus is transcribed, forming a long pre-CRISPR RNA (pre-crRNA). In *Escherichia coli*, pre-crRNA is then bound to the CasABCDE (Cascade) protein complex and is processed into smaller crRNAs. The crRNAs then guide the complex to the invading elements and allow the complex to destroy the invader.

Although the basic functionality of the CRISPR system has been well studied, much has yet to be determined. For example, the mechanism by which new spacers are recognized and incorporated is still unknown. In addition, even though the structure of the Cascade protein complex has been determined, the exact function of some of the involved proteins remains unclear. Finally, *E. coli* has been shown to contain a CRISPR-Cas system capable of responding to phage infection in laboratory settings, but the conditions which trigger a natural CRISPR response are still undefined.

During my summer internship at Ecole Polytechnique, I prepared three plasmid constructions that will be used to analyze the function of the Cascade complex and potential natural triggers of the CRISPR mechanism. Using directed mutagenesis, I modified an A-la-carte CRISPR region containing spacers corresponding to known and common phages. I then amplified the region surrounding the modified CRISPR locus and used it to modify the *E. coli* genomic CRISPR locus. Further experiments using this modified strain of *E. coli* will determine if the presence of phages that are in the locus can "turn on" the CRISPR response. In addition, I modified a plasmid containing genes for the CasABCD*E complex (with a His-tag on CasD) by adding a His-tag to CasA and isolating HisCasA on a plasmid. In parallel, I also isolated CasBCD*E. For these constructions, I employed PCR, restriction enzyme digestions, ligations, and transformations. Finally, I purified the CasBCD*E complex so that further experiments can determine the function of CasBCDE.

Keywords

CRISPR, Escherichia coli, mutagenesis, DNA, bacteria

Classification of Heart Enhancers in Drosophila

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Sponsor/Location of Research

National Heart Lung and Blood Institute, Bethesda MD

Abstract

Enhancers are non-coding genetic sequences that regulate the spatio-temporal expression genes. Genetic expression is controlled by the binding of a special class of proteins known as transcription factors to specific nucleotide sequences (motifs) along enhancers. Here, we sought to test two competing regulatory models for how transcription factor binding controls gene expression. The enhanceosome model theorizes that the spatial orientation of motifs along enhancers is necessary to regulate expression via functional interactions of transcription factors, while the billboard model focuses only on the absence or presence of transcription factors regardless of spatial organization. In order to test the models, computational techniques were developed to quantitatively analyze the presence of motifs and their spatial relationships for a number of enhancers known to drive heart differentiation in *D. Melanogaster*. We determined that single and pairwise motif enrichment is present along heart enhancers versus controls, which suggests that pairs of motifs occurring in a limited spatial window are a strong delineating feature of genetic sequences active in the heart.

Keywords

gene regulation, enhancers, transcription factors

Hydrology Simulations on Basalt Soil for the Landscape Evolution Observatory (LEO)

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Sponsor/Location of Research
National Science Foundation, Biosphere 2, University of Arizona

Abstract
The Landscape Evolution Observatory (LEO) project at Biosphere2 utilizes a non-traditional soil, specifically basalt rock that has been ground to a loamy sand texture. This engineered material is likely to have hydraulic transport properties that differ from natural loamy sands. In this study the transport properties were characterized by combining laboratory column studies and numerical modeling. Saturated hydraulic conductivity and a portion of the soil moisture release curve were studied using 7.1 cm and 91.5 cm Plexiglass columns filled with the LEO material and subjected to flux and matric potential boundary conditions. The experimental data were subsequently analyzed in Hydrus-1D using both forward and inverse modeling. This study found that the saturated hydraulic conductivity (Ks) values range between 4.05 and 16.57 cm/hr, which is substantially higher than typical values for loamy sand. The range in values is indicative of the variation expected within the LEO hillslopes, primarily resulting from bulk density variations. Additionally, we found substantial and irreversible effects of fine-particle mobility on Ks: high saturated flow rates lead to particle rearrangement and permanently elevated Ks values, which persist at lower saturated flow rates. The transport of fines may lead to an evolution of transport properties during the initial irrigation phase of LEO. Hydrus-1D modeling indicates that the observed time-series of matric potentials and cumulative outflow from a 91.5 cm column can be closely reproduced by the model. Modeling results also indicate that the effective parameters of the LEO material are substantially different from those estimated in previous studies using pedotransfer models. While the Ks value resembles that of a sand, the α and n parameters resemble the expected values for a much finer material. Further modeling, such as in Hydrus-3D, is desirable, as well as a study of different soil water fluxes to quantify the relation among transport of fines and hydraulic characteristics.

Keywords
soil physics, hydrology, critical zone, modeling

Optimizing the Conductivity of Textiles via Atomic Layer Deposition for Pressure Sensitivity

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Sponsor/Location of Research

Dr. Jesse Jur, Department of Textile Engineering, Chemistry and Science, North Carolina State University

Abstract

The ability to create a conductive coating on a textile platform allows for new designs of electronic sensors that use the construction of the textile to show variation of electrical properties with external stimuli. Atomic Layer Deposition (ALD) is useful in depositing conformal nano-scale coating using a self-limiting sequential reaction between the ALD precursors and specific substrate. ALD of aluminum-doped zinc oxide (AZO) onto different fabrics produces conformal conductive coatings allowing the substrate to be utilized in the electronic sensor applications. A range of electrical resistivity values were determined for ALD AZO by varying the number of ALD cycles, reaction temperature, and the aluminum to zinc oxide composition. These coatings were applied to cotton (plain weave and knit geometry), woven polyester, and cotton paper. The electrical resistivity of these coated fabrics was measured using the novel four point probe method. The changes in electrical behavior of the fabrics were then evaluated by compressing the porous textiles, which in effect determines the efficacy for these modified fabrics to be used as a pressure sensor. Designs are presented in which the responsive nature of textiles can be used to detect impact regions on personal wearables and for personal security.

Keywords

ALD, textiles

CAD Modeling of Tall Building Structural Systems for use in FEM Simulations

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Sponsor/Location of Research
ETH Zurich

Abstract
In recent years, radical urban development has been expressed through vertical expansion in the form of skyscrapers, yielding significant economic benefits in dense urban land use and projecting powerful symbolism in urban landscapes internationally. Despite their common use so far as commercial office buildings, tall buildings are now used more and more in residential, mixed-use, and hotel tower developments, and are thus increasingly common and are a building type with multiple possible structural systems.

This internship assisted an ongoing PhD research project at ETH, which is examining tall building systems. These systems naturally undergo significant wind loads. The focus of the internship dealt with two case studies of systems: the John Hancock Center in Chicago, considered as an exterior bearing structure example, and the Jin Mao Tower in Shanghai, an interior bearing structure. The towers’ geometries were modeled in Rhino, a computer-aided design (CAD) software, by inputting available information from literature.

Subsequently for the John Hancock Center, the Rhino geometry was given to the researchers, which they then exported as an IGS file for their simulations in ANSYS. ANSYS is a finite element engineering software that allows for the translation of the geometry from points and lines into nodes and structural elements. It allows for the definition of the material and thickness properties as well as loading information. The researchers used ANSYS to simulate the effect of wind loading on this building, which at this early stage of research, was simulated by making a simplified static load assumption. The results of the static load analysis, combined with a modal analysis, yielded the natural frequencies and mode shapes of the structure, and were cross checked with available data.

For continuing work, the researchers intend to use the ANSYS results to calibrate scaled physical models. The models would be subject to wind tunnel tests that help evaluate not only static, but also dynamic wind loading resistance for the two static systems considered, which can then be used to optimize the efficiency of new designs of structural systems.

Keywords
skyscrapers, urban landscapes, wind loads, ANSYS, structural systems

On-chip Security Test for High-Dimensional Quantum Key Distribution

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Sponsors/ Location of Research
Defense Advance Research Projects Agency (DARPA), Columbia University, NY

Abstract
Quantum key distribution protocols use quantum states of photons to generate secure keys to encode information [1]. High-dimensional quantum key distribution (HD-QKD) protocols enable extremely high information content per photon with a high rate of secret key generation. Our protocol derives its security from the temporal and spectral entanglement of photon pairs generated by spontaneous parametric down conversion [2]. We aim to implement this HD-QKD protocol in telecommunications networks using photonic integrated circuits (PIC), requiring the test of transmission security of the key. To perform this test, we measure the visibility of the Franson interference fringes using two unbalanced on-chip Mach-Zehnder interferometers [3].

References
[1] Bennett, C.H. and Brassard, G. (1984) Quantum cryptography: public-key distribution and coin tossing *Proceedings of IEEE International Conference on Computers, Systems and Signal Processing, Bangalore, India* (IEEE, New York, 1984), p. 175.

[2] Mower, J., F.N.C. Wong, J.H. Schapiro, D. Englund (2011) Dense Wavelength Division Multiplexed Quantum Key Distribution Using Entangled Photons. E-print, http://arxiv.org/pdf/1110.4867.pdf, accessed on 9/18/12.

[3] I. Ali-Khan, C. J. Broadbent, and J.C. Howell (2007) Large-Alphabet Quantum Key Distribution Using Energy-Time Entangled Bipartite States, *Physical Review Letters*. 98, 060503.

Keywords
QKD, security test, silicon photonics, photonic integrated circuits

Identification of a Novel Long Non-coding RNA in Cardiac Differentiation

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Sponsor/Location of Research

Massachusetts Institute of Technology Emergent Behaviors of Integrated Cellular Systems Research Experience for Undergraduates (MIT EBICS REU)/ Boyer Lab

Abstract

The discovery of new regulators of cardiac differentiation is of great interest in the field of regenerative medicine, as cardiovascular disease is the leading cause of death worldwide. Long non-coding RNAs (lncRNAs) are rapidly emerging as key players in development and lineage commitment. However, the transcriptional regulation of lncRNAs and how this class of RNA fits into gene networks that drive lineage-specific differentiation remain largely unexplored. Embryonic stem cells (ESCs) provide an excellent system to study early commitment *in vitro* as they have the capacity to differentiate into derivatives of all three germ layers. In particular, ESCs have been instrumental in discovering factors that govern differentiation into the cardiac lineage. The transcription factor mesoderm posterior 1 (MesP1) is a key regulatory switch for establishment of a common multipotent cardiovascular progenitor and defines one of the earliest stages of cardiac development. Thus, identifying lncRNAs that work in concert with MesP1 may reveal new pathways critical for regulating cardiac commitment. Using a mouse ESC line that harbors a drug-inducible MesP1 transgene, we directed overexpression of MesP1 during early stages of ESC differentiation. We then tested the effect of MesP1 overexpression on the levels of a pre-determined set of lncRNA candidates.

Our preliminary results showed induction of a subset of the lncRNA candidates by MesP1, suggesting that these lncRNAs represent direct targets of the transcription factor. In particular, lncRNA AK087264 showed strong induction upon MesP1 expression. Further experiments supported a direct role for MesP1 activation of this transcript, and suggested that AK087264 may function *in cis* as a transcriptional regulator of nearby genes. This study contributes to a broader goal of identifying specific lncRNAs that drive cardiac lineage differentiation.

Keywords

long non-coding RNA, mesoderm posterior 1, cardiac differentiation, stem cell

Q-Potts Simulation of Breast Cancer Cell Morphologies

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Sponsor/Location of Research
The Kaufman Group, Department of Chemistry, Columbia University

Abstract
The objective of this project was to develop a quasi-3D Q-Potts system to model the individual and collective behavior of breast cancer cell phenotypes in varying energy environments on (1) glass slides and (2) a thin sheet of dense collagen. The program was written in C++ and imaging was done in Mathematica, and relative dimensions of cells and collagen were based on previous research in the morphologies of breast cancer cell lines. Three main phenotypes (stellate, mass, and grape-like) were successfully qualitatively reproduced in the program by designating relative energy specifications for adjacent surfaces, such as cell-cell, cell-matrix, and matrix-matrix, as well as three-dimensional considerations in the case of underlying collagen.

Keywords
Q-Potts model, breast cancer, 3D simulation, extracellular matrix

Projecting Future Farm Distribution

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Sponsor/Location of Research
University of Minnesota Institute on the Environment

Abstract
As the human population increases and crop uses broaden, more crops must be produced to meet demand. While technology and farming practice changes can boost yields, expansion of cultivated areas is equally important. Various economic and environmental factors can affect the suitability of a particular region for a particular crop and the likelihood of agricultural development in that region, so the task of projecting new areas of cultivation on a global scale poses a serious challenge. A precise and straightforward algorithm was developed to estimate high-resolution cultivation areas and yields for 16 common crops as well as N, P, and K application rates and irrigation volume, taking into account historical crop production quantity ratios, area and yield data, and a "suitability layer" raster grid for each crop.

Keywords
agricultural development, crop projections, NPK application rates

Microalgae Preconcentration by Sedimentation and by Addition of Montmorillonite Clay Coagulant

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Sponsor/Location of Research

Department of Civil, Environmental, and Architectural Engineering, University of Kansas

Abstract

Microalgae holds great promise as a feedstock for biodiesel, a sustainable alternative to petroleum-based fuels. While microalgae is easily grown in a variety of waters, it is energy intensive to harvest because it grows at concentrations as low as 0.01%. Centrifugation can concentrate the microalgae to a useable 10-15%, but has a high energy cost. "Preconcentration" methods, particularly gravity sedimentation with or without the addition of a coagulant, may achieve a microalgae concentration of 2-3% at a lower cost.

The efficiency of a microalgae sedimentation tank was measured at flow rates of 50 to 680 mL/minute, as was the microalgae concentration produced by each flow rate. In a separate test, montmorillonite clay was added to microalgae to aid coagulation by neutralizing the negative surface charge on individual algae particles. Findings show that increasing the sedimentation tank flow rate decreases the efficiency but increases the concentration of microalgae produced. An optimal coagulant dosage of 150 mg/L was established for montmorillonite clay; trials using the coagulant had efficiencies as great, and produced a microalgae product with concentrations as high, as the best trials in the sedimentation tank. This prompts future investigation into the use of a coagulant dosed continuously to a sedimentation tank run at high flow rate, maximizing both efficiency and microalgae concentration in the final product.

Keywords

biofuels, microalgae, sedimentation, coagulation

Novel Efficient Microbial Fuel Cell Anodes Using Activated Carbon Nanofiber Nonwoven

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Sponsor/Location of Research

NSF Research Experience for Undergraduates, University of Connecticut. Dr. Jeffery McCutcheon, UConn Sustainable Water and Energy Learning Lab (SWELL)

Abstract

Microbial Fuel Cells (MFCs) are a technology capable of sustainably treating wastewater. In a single chamber design, the anode and cathode, traditionally spatially separated by a semi-permeable membrane, rest in the same chamber, allowing seperationless diffusion. Despite the promise MFC technology holds, they have not yet been commercialized due to high costs and low power density limitations. One of the ways to address the latter issue is through the use of better electrode materials. In a previous study, activated carbon nanofibers nonwoven (ACNFN) were introduced as a novel anode material for MFCs, where they were found to perform vastly better compared to traditional anode materials, including carbon cloth and carbon brush.

ACNFN were fabricated by electrospinning a solution of polyacrylonitrile in dimethylformamide. Precursor fibers then underwent stabilization and carbonization. Finally, they were steam activated directly after carbonization to create greater porosity and increase the active surface area. The objective of this follow-up study was to determine the effect of activation temperature and steam volume delivered on the performance of these anodes. Three different activation temperatures and steam volumes were chosen and post-fabrication, the materials were characterized for biomass adhesion and electrochemical performance in a single chamber MFC.

It was found that steam exposure during the activation period (versus only additional heating without steam delivery) increased anode power generation in an MFC. Additionally, anodes that were steam activated at higher temperatures had enhanced biomass adhesion and generated increasingly higher power outputs in single-chamber MFCs. In fact, the anode steam activated at the highest temperature tested outperformed a traditional carbon cloth anode, when measured for current drawn at specific voltages. Continued exploration of activation parameters can further increase anode efficiency to hopefully create an implementable and scalable fuel cell.

Keywords
Microbial Fuel Cell, electrospinning, carbon nanofiber

Effect of Thermal Cycling on Barrier Layers for Environmental Protection of Nickel-Based Alloy 617

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Elizabeth A. Clark, Materials, UCSB; Carlos G. Levi, Materials and Mechanical Engineering, UCSB

Sponsor/Location of Research
University of California, Santa Barbara, supported by the Department of Energy through NEUP Contract 102215, Project 10-963

Abstract
The very high temperature reactor (VHTR) is a generation IV He-cooled reactor that can conceptually reach outlet temperatures of 1000˚C. A critical component of the VHTR is the intermediate heat exchanger, which needs to be durable in the reactor He environment containing low levels of impurities (CO/CO2, H2/H2O, CH4, etc.). However, the candidate material, nickel-based alloy 617 (IN617), may carburize, decarburize and/or oxidize under these conditions, with deleterious effects on its mechanical properties. Thus, one of the goals of the project is to form a protective α-alumina scale on the surface of IN617 to protect it from the VHTR environment.

Because IN617 forms a chromia scale in oxidation, the alloy must first be coated with a material that will form α-alumina . The two coatings being developed both involve aluminizing IN617 samples to form NiAl, cladding with FeCrAlY foil in one case, followed by pre-oxidation to form a thin α-alumina scale. While the $M_{23}C_6$ and σ interlayers formed from this are considered beneficial because they stabilize the coating by slowing interdiffusion with substrate, there is some concern that on thermal cycling, the thermal expansion mismatch could cause cracking in these layers and spalling of the coating. Additionally, existing research on NiAl coatings used in turbine engines has shown that one of the effects of thermal cycling is rumpling of the oxide with increasing number of cycles. This leads to surface damage such as cracking and spalling of the oxide layer. In this work, the evolution of the multilayer structure was studied after isothermal heat treatments at 1000˚C and under thermal cycling conditions. While rumpling and spalling appear on the surface of the uncladded samples after thermal cycling, the FeCrAlY sample has shown slow surface development in general suggesting a smoother, more adherent scale has persisted throughout the thermal cycling process.

Keywords
very high temperature reactors, alpha-alumina scale, Inconel 617, oxide rumpling

Mediated Reality for the Masses:
An Investigation into the Viability of a Low Cost Mediated Reality System

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Sponsor/Location of Research
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Abstract
The seamless blending of real and virtual realities has long been the goal of the development of virtual, augmented, and mediated reality systems. One key component of this goal is the integration of feedback for the user and their environment. While nearly all mediated reality systems provide changes in the visual field of the user, very few also integrate haptic feedback; preferring, instead, to rely on a combination of optical hand tracking systems and the user’s conscious recognition of their interaction with visible objects. The goal of this research was to develop a low cost mediated reality system that provides both visual and haptic feedback while maintaining a degree of portability and allows the user the freedom to interact with physical objects in their environment. A fully integrated, low cost system allows researchers who would like to investigate aspects of virtual, augmented, and mediated reality as a secondary part of their mainline research to incorporate it into their research without incurring a prohibitively high startup cost. In order to facilitate this goal, it was first necessary to determine the effect of integrating multiple forms of haptic feedback technology into a single device on the degree to which users believe that their interaction feels real. To this end, a system was developed that utilizes skin-stretch, pressure-based, and force feedback to provide the user with a high degree of haptic resolution. Hand movement is tracked using a custom inertial measurement unit (IMU), while finger movement will be tracked using magnetic tracking that utilizes low power magnets. The user’s visual feedback is provided through a head mounted display (HMD), and two consumer-grade web cameras. The device will be tested using the Presence Questionnaire (PQ), developed by researchers at MIT, to determine how effective the system was at providing the user with a feeling of realistic interaction. Due to manufacturing delays, the system was only tested through simulation, but we are confident, based on several studies which focus on the individual technologies used, that objects represented by the system will score highly on the PQ.

Keywords
mediated reality, haptics, perception

Electronics for the Vertical Slice Test of the MicroBooNE Light Collection System

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Sponsor/Location of Research
Columbia University Nevis Labs REU Program (National Science Foundation), Fermi National Accelerator Laboratory

Abstract
MicroBooNE is a neutrino oscillation experiment currently under construction at Fermi National Accelerator Laboratory (FNAL). It is a liquid argon time projection chamber experiment that will detect muon neutrinos and electron neutrinos from the Booster Neutrino Beam at FNAL. The time projection chamber (TPC) consists of three wire planes that will detect charged particles from the neutrino interactions with the argon. The charged particles ionize the argon and the ionization charge drifts in the presence of an applied electric field within the TPC toward the wire planes. There will also be a light collection system inside the liquid argon cryostat that consists of 30 photomultiplier tubes (PMTs) that will detect scintillation photons that are also produced when charged particles traverse the argon volume.

This summer I worked at FNAL with our MicroBooNE collaborators from MIT. I worked on the readout electronics for the PMTs for a vertical slice test of the light collection system. The purpose of the test is to understand how the light collection system works as a whole for visible, ultraviolet, and cosmic ray scintillation light, and to get all components of the light collection system working and calibrated. Two photomultiplier tubes are submerged in liquid argon in a cryostat, and the electronics boards that read out the raw PMT signals are tested, as well as the software that prepares the PMT data for physics analysis. The setup and readout code were adjusted so that we trigger off a visible LED, ultraviolet LED, and comic ray light. The electronics were tested for long and short runs using these triggers, and the PMT high voltage was tuned so that a single photoelectron pulse corresponds to 20 ADC counts.

Keywords
neutrino oscillations, photomultiplier tubes, electronics

Conductance of Nickel and Iron Mononuclear Complexes in Methyl-Sulfide Linked Single-Molecule Junctions

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Abstract
Furthering the study of molecular electronics requires a deeper understanding of the electrical properties and electronic transport of quantum dots and metal chalcogenide clusters. However, achieving this understanding is complicated by the large number of electrons involved in these systems. We therefore investigate the conductance of nickel and iron mononuclear complexes using the scanning tunneling microscopy break-junction technique.

In this study we examine dichloronickel-bis(diethyl phenyl phosphine) as well as para- and meta-substituted dichloronickel-bis(diethyl thiomethylphenyl phosphine). A series of ferrocene, mono-substituted thiomethyl ferrocene and di-substituted thiomethyl ferrocene is also studied. Samples are synthesized using Schlenk line chemistry techniques and characterized by NMR as well as UV-Vis and IR spectroscopy. Conductance measurements for both series are taken at low-bias in trichlorobenzene at room temperature.

Conductance traces for each member of the nickel series appear identical to those for the respective free ligand, suggesting ligand dissociation. However, ^{31}PNMR studies show no evidence of ligand dissociation over a meaningful time scale. This may suggest force-induced ligand dissociation or alternate conductance pathways. Conductance traces for the ferrocene series point to a conductance pathway between the thiomethyl linkers through the iron core. Interestingly, individual IV traces for the di-substituted thiomethyl ferrocene reveal features of bias-induced rectification, a rare phenomenon for symmetric molecules, with a statistical rectification ratio of approximately 1.9. Both the nickel and iron series serve to further our theoretical understanding of molecular electronics and raise the potential for practical applications.

Keywords
metal complex, molecular conductance, single-molecule break-junction, rectification

Diagnosis of Osteoarthritis via Laser Speckle Rheology

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Sponsor/Location of Research

This project was conducted under HST (Harvard-MIT Health Sciences and Technology) at the Wellman Center for Photomedicine in the Massachusetts General Hospital, Boston, MA.

Abstract

Osteoarthritis (OA) is a degenerative disease of the cartilage that affects over 82 million individuals worldwide and has a long and invasive diagnostic process. This project validates the novel application of laser speckle rheology (LSR) to diagnosing OA quickly and easily. LSR is the detection of the dynamic interference pattern that results when photons from monochromatic, coherent light undergo multiple scatterings. The decorrelation rate of the speckle pattern over time, summarized by time constant τ, is an index of the sample’s viscoelasticity. LSR was used to characterize the viscoelasticities of 46 biopsied articular knee cartilage samples from patients undergoing knee repair. Samples were also scored for OA severity on established clinical scales: the Modified Mankin Scale (MMS) and histopathological detection of GAG (glycosaminoglycan) degradation in tissue. Average τ values for samples per MMS score correlated very well with MMS scores ($R=0.82$, $p<0.001$). τ values also correlated well with GAG loss ($R=0.56$, $p<0.001$). The LSR technique ranked cartilage by OA severity effectively, able to differentiate between tissues of different OA severities. These results pave the way for the first minimally-invasive and real time diagnostic tool for OA.

Keywords

osteoarthritis, cartilage, biomedical engineering, laser, speckle, rheology, interference, scattering, diagnosis, viscoelasticity, optics, medical device, translational, biomechanics

Pickering Emulsion Optimization Using Silica Nanoparticles

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Abstract
Emulsions involving oil and water have been created extensively using liquid surfactants. It has been found, however, that these emulsions can also be created using solid nanoparticles in what is known as Pickering emulsions. Pickering emulsions have the advantages of better stability and reduced coalescence and coarsening than the liquid surfactant counterpart. This study serves to investigate the optimal conditions for creating long-term stable Pickering emulsions between oil and water by using bare silica nanoparticles. Emulsions were induced between oil and water using 14nm and 50nm diameter silica nanoparticles at concentrations ranging from 0.5% to 2% by weight. Emulsions were characterized by either oil in water (o/w) or water in oil (w/o) and the time needed to reach a stable state.

The results suggest that larger nanoparticles tend to form o/w emulsions while smaller nanoparticles form w/o emulsions. Higher concentrations of nanoparticles allowed for a larger emulsion volume. However, emulsions were formed at low concentrations in a short amount of time, allowing for variation in the optimal conditions based on costs, time available and desired volume of emulsion.

Keywords
Pickering emulsions, nanoparticles

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