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Poster Abstracts

2017 Annual Meeting, Minneapolis
Monday, October 30, 2017, 6:00-7:30 pm
Hilton Minneapolis – Marquette IV/V/VI/VII

AES 1 - 250a

Flow Regulated Anodic Growth of TiO2 Nanotubes in Microfluidics

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Electrochemical anodization of titanium (Ti) in a static, bulk condition has been used widely to fabricate self-organized TiO2 nanotube arrays. Such bulk approaches, however, require extended anodization time to obtain long TiO2 nanotubes and produce only vertically-aligned nanotubes. To date, it remains challenging to develop effective strategies to grow long TiO2 nanotubes in a short period of time and control the nanotube orientation. Here, we show that the anodic growth of TiO2 nanotubes is significantly enhanced (~16-20 times faster) under flow conditions in microfluidics. Flow not only controls the diameter, length, and crystal orientations of TiO2 nanotubes but also regulates the spatial distribution of nanotubes inside microfluidic devices. Strikingly, when a Ti thin-film is deposited on silicon substrates and anodized in microfluidics, both vertically- and horizontally-aligned (relative to the bottom substrate) TiO2 nanotubes can be produced. Our results demonstrate previously unidentified roles of flow in the regulation of growth of TiO2 nanotubes and provide powerful approaches to effectively grow long oriented TiO2 nanotubes and construct hierarchical TiO2 nanotube arrays on silicon-based materials.

AES 2 - 250b

Dielectrophoretic Separation of Large Microscale Particles (dp>5 um) By Exploiting Charge Differences

Danielle Polniak, Eric Goodrich, Blanca H. Lapizco-Encinas
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Electrokinetics is the family of phenomena that depend on the electrical double layer. Electrokinetic techniques are one of the main pillars of microfluidics, due to their ease in application. Electric-field driven technique such as electroosmosis, electrophoresis and dielectrophoresis have been successfully used for the analysis, sorting and separation of a wide array of bioparticles, in applications than range from environmental assessments to biomedical and clinical analysis. In this current project, efforts have been made to analyze the equilibrium between the electrophoretic, electroosmotic and dielectrophoretic forces and how this equilibrium is affected by particle size. As the motion of larger particle under electric fields has yet to be fully characterized, the primary focus has been particles with diameters ranging from 5-10 microns. In theory, these “larger” particles should be easier to “trap” in our insulator-based dielectrophoresis (iDEP) systems when compared to smaller particles, since DEP force depends on particle volume, however, this is not the case. Throughout this study an iDEP microchannel, with an array of cylindrical insulating structures and direct current electric fields have been employed. Results from current and preliminary experiments have showed that larger carboxylated polystyrene particles (diameter > 5 mm) require much higher voltages than expected and also have shown to move very fast through such iDEP systems. Employing suspending media with conductivity of 15-20 μS/cm and pH of 6-7, under applied fields between 400 V/cm and 1500 V/cm, the 5-μm, 7-μm and two types of 10-μm polystyrene particles were observed to become immobilized due to negative electrophoretic trapping. In addition, it our experiments have revealed that the magnitude of surface charge of the particles may also have an impact of the ability to trap these larger particles and will be further explored as the project moves forward. The results of this project will hopefully be able to help explain why these larger particles do not behave according to theory. The recent finding in reference to amount of surface charge also has the potential to become another method by which biological particles can be separated through the use of iDEP.

AES 3 - 250c

Dielectrophoretic Assessment of Sub-Micron Particles By Exploiting Charge Differences

Eric Goodrich, Maria Romero-Creel, Danielle Polniak, Blanca H. Lapizco-Encinas
Rochester Institute of Technology

Dielectrophoresis (DEP) has an immense potential for particle sorting and separation in microscale systems. Specifically, insulator-based dielectrophoresis (iDEP) devices are both inexpensive and effective for the analysis of biological particles or cells. In previous work, it has been seen that submicron carboxylated particles (dp < 500 nm) experience a positive DEP force when exposed to a non-uniform electric field, while larger particles (dp>1 μm) experience a negative DEP force [1]. In this research, the effect of particle surface charge magnitude on the DEP force is investigated. Two different particle surface functionalizations are also analyzed: carboxylated and aminated (negatively and positively charged, respectively). Being able to separate sub-micron particles by exploiting charge differences offers great potential in bioanalysis.

[1] Mario A. Saucedo-Espinosa Mallory M. Rauch Alexandra LaLonde Blanca H. Lapizco-Encinas, "Polarization behavior of polystyrene particles under direct current and low-frequency (<1 kHz) electric fields in dielectrophoretic systems," Electrophoresis 2016, 37, 635–644.

AES 4 - 250d

Research of DNA Separation By Post Array Under Intermittent Electric Field

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We applied an intermittent electric field to replace the continuous one to separate λ-(48.5kbp) and T4(165.6kbp) DNA in a fused silica microchannel with a hexagonal post array of 1 micron diameter and 3 micron pitch. In the post array, the mobility of DNA decreases with molecular weight since larger DNA has higher probability to hit and hook on the post. However, the occurrence of channeling phenomenon restricts not only the operating condition but also the separation efficiency of a fixed length post array. By using intermittent electric field, the electric field(E) is repeatedly turned on for a time interval ton and turned off for a time interval toff. With an intermittent electric field, the channeling phenomenon was suppressed by the relaxation of DNA during the "off" period. We also correlated ton with the trapping time of DNA. The results indicated that ton set in between the trapping time of T4 and λ-DNA has the best resolution of separation for a fixed separation time while ton set close to the trapping time of λ-DNA yields the best resolution of separation for a fixed channel length. Compared to continuous electric field, an intermittent one enables the separation to be conducted under higher Pe. With properly tuned ton and E, the resolving power of a channel with fixed length increases only at the expense of time. For a given post array, intermittent electric field offers much more flexibility in choosing operation conditions for optimized separation.

AES 5 - 250e

Insight into Coal Structure Based on Benzene Carboxylic Acids from the Coal Via Oxidation

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Coal structures, the basis of its applications, have been widely studied. Benzene carboxylic acids (BCAs, 12 types) can be generated from different aromatic clusters of coal via oxidation, and it has been found the 12 BCAs have different yield distributions for different coals. The results suggest that there is a certain relationship between BCAs and coal structure that provides a favorable basis for us to study the coal structures. In this work, based on the BCAs distributions and 13C-NMR analyses, we investigated the structure characters of coal with different ranks. The results indicate that with the increase of coal rank, the yield of BCAs increase, and the structures of coal becomes more and more difficult to be degraded. There are great differences in the yield distributions of BCAs with the increase of coal rank, and more and more BCAs with a small number of carboxyl are obtained in high rank coal. Single-ring aromatic clusters and double-ring aromatic clusters are mainly aromatic structures in low rank coal. With an increase in the process of coalification, the aromatic clusters increase in size and the degree of condensed of aromatic rings also increases. When the carbon content of coal was approximate 87 %, the structure of coal had a mutation. At last, we proposed a structural model of Huolinhe lignite based on the yield distribution of BCAs. The work provides a new way to study the coal structures and construct the structural model of coal.

AES 6 - 250f

Multiphysics Modeling of Microfluidic Device to Investigate the Effect of Electric Field on Drug Delivery into the Tumor Cell

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Studying the uptake rate of the macromolecules under the effect of electrokinetics phenomena (electrophoresis, electroporation, and electroosmosis) has an application in personalizing electrochemotherapy treatment. The uptake rate of chemotherapeutics can be a marker for single cell characterization. In this study, the COMSOL Multiphysics simulation to solve equation-based computational model on coupled electroporation and mass transfer theories is presented. The outcome of the improved mathematical model can predict the outcome of electrochemotherapy based on the drug physical properties. The design of current microfluidic devices can be optimize for the consideration of the electroosmosis effect on drug uptake rate. We have simulated the novel microfluidic device to study the effect of simultaneous electrokinetics phenomena on cell lysis and uptake rate of the macromolecules by the COMSOL Multiphysics simulation.

AES 7 - 250g

Nvu-on-a-Chip: Optimizing Brain Endothelial Cell Culture for Microfluidic Modeling of the Nvu

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Organ-on-a-chip devices are an emerging class of in vitro models that combine microfabrication and spectroscopic techniques with cell culture to study organ physiology. We are developing an organ-on-chip model of the neurovascular unit (NVU), NVU-on-a-chip, which analyzes real-time NVU dynamics in a controlled microenvironment. NVU-on-chip incorporates human brain endothelial cells (hBECs), astrocytes and neuronal cell lines to mimic physiological phenomena of the neurovascular unit (NVU). A key component of the NVU is a selectively permeable layer of endothelial tissue, the blood-brain barrier (BBB), which prevents passage of most small particle nanotherapeutics from the bloodstream into the brain. We have optimized brain endothelial cell culture in a monoculture, microfluidic device for future incorporation with NVU tissue. Endothelial cells are seeded into a microfluidic organ-on-a-chip device containing a single microfluidic channel and two electrode interfaces; tissue integrity is analyzed with electrical impedance spectroscopy (EIS). The device contains a pair of (5 nm Titanium, 25 nm Gold) interdigitated electrodes that form the top and bottom layers. It contains a 100-300 μm thin PDMS channel (500 × 18000 μm) between the two electrodes which complete the microfluidic device. The PDMS channel is necessary to facilitate gas exchange to the cells in the microfluidic channels. Cell death is observed if other materials like laser cut PMMA channels are used. The top and bottom electrode/channel pairs sandwich an extracellular matrix (ECM) coated Transwell membrane seeded on one side with rat brain microvascular endothelial cells (RBMEC). The ECM coating needs to be uniform which allows the cells to grow in the microfluidic channel. The uniformity of the ECM coating is validated by using a fluorescent microscope.Cells mature for several days in a 37°C, 5% CO2 humidified incubator post-seeding to allow the formation of barrier properties. The fabricated device is characterized using optical imaging, permeability assays, such as fluorescence microscopy, and EIS. Optical imaging confirms endothelial cell adhesion and confluency. Fluorescence microscopy signifies the presence of ZO-1, an accessory protein indicative of tight junction formation. EIS measures resistance and capacitance across the seeded endothelial membrane. A resistance value of ~1000Ω indicates a functional blood-brain barrier, while lower values implicate a compromised or ‘open’ BBB. EIS measurements are advantageous because they provide real-time capacitance and resistance measurements of transient BBB activities, such as permeability changes. Additionally, EIS capacitance data distinguishes transcellular resistance from paracellular resistance. This novel approach provides insight to transcellular BBB kinetics as well as paracellular (tight junction) kinetics. The device will be incorporated into a more sophisticated NVU-on-a-chip. NVU-on-a-chip will be used to characterize the interaction and mechanistic pathway for drug-loaded nanoparticles.

AES 8 - 250h

Electrohydrodynamic scaling laws analysis in a microfluidic IsoDEP device

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Dielectrophoresis (DEP) is the phenomenon in which a particle, such as a living cell, is moved by the interaction between a non-uniform electric field and its induced polarization. Isomotive dielectrophoresis (isoDEP) is a cell analysis and characterization technique that uniquely utilizes a constant gradient field-squared (∇Erms2) resulting in a uniform DEP force. The resultant constant (isomotive) particle translational velocity that can be tracked using particle tracking velocimetry (PIV) software to extract the cell/particle dielectric properties. Inspired by initial analysis by Herbert Pohl, we have developed modified electrode geometry for isoDEP. Fabrication of extruded electrodes is straightforward via microfabrication methods (DRIE of conductive wafers) or sub-millimeter machining. A sample is injected and flow is halted before field

activation. Digital images will extract particle size and, due a constant $\nabla Erms^2$, the only unknown for each particle is $Re[f_{CM}]$ The field is applied and $Re[f_{CM}]$ is extracted through particle tracking. The particle's velocity will change as the AC frequency is swept over a specified range to obtain a comprehensive $Re[f_{CM}]$ spectrum. Through simultaneous particle tracking such spectra are obtained for every particle in the imaging area, enabling parallel analysis of cells. IsoDEP can extract the dielectric properties of each cell (ex: membrane capacitance) – these properties directly correlate to the cell physiology. Any unwanted flow will disrupt the trajectory of the particles and compromise their analysis. To that end, we have conducted an electrohydrodynamic study and scaling law analysis to reduce electrothermal hydrodynamics in an isoDEP device. Numerical simulations (COMSOL Multiphysics) are in good agreement with experimental measurements via micro-PIV. In addition to experimental results, current and future IsoDEP platform designs will be shared.

References
[1] H.A. Pohl, Dielectrophoresis: The Behavior of Neutral Matter in Nonuniform Electric Fields, Cambridge; New York: Cambridge University Press (1978).
[2] Allen, D. J., Accolla, R. P. and Williams, S. J. (2017), Isomotive dielectrophoresis for parallel analysis of individual particles. Electrophoresis. doi:10.1002/elps.201600517.

AES 9 - 250i

Fundamentals, Calibration and Preliminary Results Using the DSC Technique for Hydrogel Thermoporometry

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Hydrogels are cross-linked polymeric networks. They can be used in many biomedical applications such as drug delivery, tissue engineering and bio-separations. Characterization of the hydrogel pore structure is very important in order to select the appropriate gel type for a particular application. Thermoporometry is a powerful technique that is may be used to study the structure of hydrogels. Both pore size and pore-size distribution may be measured by using an instrument called the differential scanning calorimetry (DSC). This technique relies on the melting or freezing temperature depression of the water confined in a pore. Thermoporometry by DSC is a unique method for characterizing gel networks. Since there is no general procedure for measuring pore-size, further investigation is required to establish guidelines for the analysis of specific materials. Although some formulas have been developed, choosing the right equation for calculating pore size is still challenging. Many of the parameters incorporated in these equations are specific to the gel type (e.g. the natural of the porous material, the range of the pore size tested, and the probe liquid used). For this reason, it is important to develop an equation for the specific pore size of the hydrogel of interest.
In this work, the DSC has been well-calibrated with high purity mercury. Two gel types will be characterized: regular (non-templated) gels and nanotemplated hydrogels with a modified pore structure. The results will then be analyzed in order to study the effects of the size, geometry and shape of the templating agent on hydrogel performance. Details about the implementation of the DSC Technique and discussion of the preliminary results will be included.

AES 10 – 250j

Validation of A Novel Algorithmic Approach To Solve The Poisson-Boltzmann Equations In Electrokinetics

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Many exploratory studies rely on the ability to make accurate estimations of the variable under study. In electrokinetics applications, appropriate prediction of electro-osmotic velocity profiles is crucial to the study of electrokinetic processes, such as electro-assisted drug delivery, micro-electrophoretic separations, soil remediation, and material processing. All these applications require the mathematical solution of the complete Poisson Boltzmann (P-B) equation for the systems under study. This equation is a complex mathematical expression characterized as a secondary nonlinear ordinary differential equation. Not long ago, Arce and Oyanader* proposed a novel and simpler solution of the P-B equation using a recursive function, f_{AO}. In this work, the previous contribution of Arce and Oyanader will be revisited using a new, more analytical approach, but validating the simple predictor-corrector method developed and introduced by Arce and Oyanader as an alternative tool for nonlinear phenomena problems.
This validation seeks to persuade practitioners from different discipline areas, such as hydrodynamics, electrostatics, and mass and heat transfer that the recursive function, f_{AO}, is of simple and practical use. In particular, this novel approach has proven to be an exceptional tool in modeling the electrical field for applications of interest such as the separation of a mixture of macromolecules and the removal of contaminants on soil cleaning processes. Several examples will illustrate the benefits of the methodology. Comparisons to numerical solutions are also included.

(*) Oyanader, M., Arce, P., "A New and Simpler Approach for the Solution of the Electrostatic Potential Differential Equation. Enhanced Solution for Planar, Cylindrical and Annular Geometries," *Journal of Colloid and Interface Science*, 2005, 284, 315.

AES 11 – 250k

Mathematical Analysis of Bone Remodeling under Influence of Electrical Field

Joshua Ashworth, Steffano Oyanader, Mario Oyanader
California Baptist University

Bone remodeling, defined as the replacement of bone tissue, is a process consisting of two basic mechanisms, bone resorption and bone formation. It has been found that bone formation can be influenced by the presence of an electrical field. If this finding continues to test true, applications of electrical fields may lead to novel treatments in this area of study, including bone fractures, transplant, and osteoporosis.

Numerous mathematical models have been proposed to study the bone remodeling process influenced by different types of precursors, hormones and vitamins for example. Unfortunately, none of them have analyzed the effects of electrical fields. The main focus of this contribution is to proposed a mathematical model for net bone formation and to analyze theoretically and numerically the effects of electrical field on osteoblast cells associated with bone production.

The proposed model was conceived following a second order bio-kinetic model limited by precursor availability and controlled by endogenous decay. In particular, osteoblast cellular specific growth rate was modeled using an Arrhenius type function, electrical field dependent.

Preliminary results indicates that electrical fields have a significant impact on bone formation. Increased levels of osteoblast cells are predicted when different order of magnitude of the electrical field are imposed on the system. These results provide important insights into the development of new treatment protocols for patients with bone injuries, diseases, and/or implants.

AES 12 – 250l

Analysis of Lipemia Levels from Human Blood Samples Using Microchips

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Lipemia is a transient status of high lipid levels in the blood that adversely affects health, donated blood quality for diagnostic tests/other. This project aims to develop a microchip device to detect lipemia with high speed, small sample, high sensitivity, and good stability analyze lipid levels in different bio-fluids. Four measurements were compared: (1) plasma electrical characterizations, (2) RBCs dielectrophoresis, (3) RBCs lysis, and (4) plasma UV-vis absorbance. UV-Vis absorbance results effectively detected free lipids level in blood of a healthy young donor for two cases: fasting for 10-12 hours, and post-meal 2-3 hours after a high sugar and fatty meal. Plasma UV-Vis absorbance results revealed substantial spectral differences between the cases. The overarching goal for this project is to detect lipemia states using a single drop of blood, which would enable nutritional and CVD screenings for medical interventions.

AES 13 – 250m

Unamplified and Sensitive DNA Sensor for MRSA Detection by Capacitive Sensing and Low Voltage AC Dielectrophoresis

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Motivation:
Methicillin-resistant *Staphylococcus aureus* (MRSA) is one of the most prevalent causes of nosocomial and community-acquired infections with worst clinic consequences. MRSA-colonized patients face significantly higher mortality and morbidity rates than patients infected with methicillin-susceptible S aureus. Therefore, fast and reliable methods for detection of MRSA are warranted to limit the spread of infection. This work presents a low-cost, highly sensitive, and specific DNA sensor as a screening tool for rapid detection of MRSA.

Mechanism:
The sensing mechanism for our bacterium DNA detection is based on alternating current (AC) electrokinetics-enhanced capacitive sensing. A special AC measuring signal is applied between a pair of functionalized interdigitated microelectrodes (IDMEs). Innovation includes (1) low voltage dielectrophoresis (DEP) enrichment of DNA molecules for rapid hybridization and high sensitivity; (2) Use of interfacial capacitance (C_{int}) as the indicator of specific binding, and the direct measurement of C_{int} for robust operation and minimal matrix effects; (3) Simultaneous execution of (1) and (2) during assay to achieve a single step operation.
Experiments:

Voltage optimization: The measuring AC signal was carefully chosen. As such, it will induce sufficiently strong DEP attraction of DNA molecules and yet not so strong for the detection to be non-specific. 7 mV, 10 mV and 15 mV was tested, and 10 mV was found to be the best of three.

Electrodes and probe density: Two types of electrode materials were tested, electroplated gold on printed-circuit-based IDMEs and aluminum IDMEs. The plated gold electrodes were shown to immobilize more probe than aluminum electrodes, and yielded larger responses. However, their capacitive responses cannot distinguish between positive and negative samples. Aluminum electrodes had lower probe density, which allows target DNAs to approach the IDME to exhibit a decreasing capacitance change, while non-targets lead to an increasing capacitance change. So aluminum IDMEs were adopted.

Results and conclusions:
This sensor is capable of direct DNA detection with a response time of 30 s. The LOD was calculated to be 8 pg/mL in standard buffer. The dose response was found to be, where x is DNA concentration in pg/mL. The sensor is specific against MRSA. The detection does not need any signal amplification, which considerably simplifies the sensor operation and makes it highly suitable for point of care disease diagnosis.

AES 14 – 250n

Electro-hydrodynamics of Soft Liquid Metals at Low Voltages

Ishan Joshipura, Michael Dickey
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This work characterizes the behavior of a eutectic alloy of gallium and indium (75% Ga, 25% In, by weight, 'EGaIn') in response to electric fields. The metal is a liquid at room temperature (M.P., 15.5 °C) and exhibits low toxicity. These fluidic metals may be injected into microfluidic systems, fibers, and capillary networks to form soft electronic devices that are soft and compliant. Once injected, the metal remains in its place because of the adhesive nature of its thin native oxide. Preventing the oxide adhesion within microchannels enables reversible actuation of EGaIn. Actuating liquid metals may be useful for soft actuators, reconfigurable optical displays, frequency tunable antennas, and other opto-fluidic technologies.

In this work, we utilize low voltages (<2 V) to reversibly move droplets of EGaIn through microchannels. Pre-wetting the channels with an aqueous solution prior to injecting the metal prevents oxide adhesion; the water forms an interfacial 'slip-layer' the metal and channel wall. Thereafter, an applied electric field (~10-20 V/m) actuates the liquid metal by establishing a gradient of surface tension; this effect is known as continuous electrowetting (CEW). Although CEW has been utilized before with mercury, which is toxic, the adhesive nature of the Ga oxide complicates CEW behavior. This work utilizes optical microscopy, cyclic voltammetry, and electrochemical impedance spectroscopy (EIS) to characterize electro-hydrodynamics of the system under a variety of conditions. Specifically, we elucidate the influence of electrolyte (i.e., composition, pH, and viscosity) on the metal-electrolyte interface. In addition, we compare electro-hydrodynamic behavior of EGaIn with and without the presence of an oxide 'skin.' Finally, this work explores novel microfabrication strategies to design interfaces that prevent oxide adhesion.

AES 15 – 250o

Rapid and Sensitive On-site Serodiagnosis of Pseudorabies by AC Electrokinetics-enhanced Capacitive Sensing

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Motivation:
Pseudorabies, also called Aujeszky's disease, is caused by infection of animals with pseudorabies virus (PRV). Since early 1980, pseudorabies spread worldwide and caused significant economic loss to swine industry. In the U.S., the annual cost for eradication of pseudorabies is estimated to be $30 million including $17 million for vaccination efforts. Serological surveys in the U.S. for pseudorabies in feral hog populations revealed up to 61% of tested animals (average 21.5% with 95% confidence interval of 13.4-29.8%) were positive for PRV infection, showing widespread of the disease in the animal populations [1]. Therefore, detection and control of PRV infections both in domestic and wild pigs (feral hogs) are critically important to prevent outbreak of the disease.

Diagnosis of pseudorabies is currently conducted mainly by serology, such as enzyme-linked immunosorbent assay (ELISA), serum neutralization test (SNT) and latex agglutination test (LAT) [2]. Although the serological tests are reliable, they do not differentiate naturally infected animals from vaccinated animals. Also, they cannot detect infection until adaptive immunity is developed enough for the animals to produce antibodies against the virus, which usually takes seven days. Fluorescent antibody tissue section test (FATS) can be used to confirm PRV infection by detecting virus in a matter of hours but requires tissue samples from suspected animals. Virus isolation (VI) also detects virus particles but it requires mammalian cells to propagate the virus. These tests are conducted in diagnostic laboratories and therefore suffer from long turn-around time and high cost. Therefore, there is an urgent need for a rapid, inexpensive, field-deployable diagnostic test for this disease.

Mechanism:
This work is based on alternating current electrokinetics (ACEK) capacitive sensing method. The major innovation with this sensing technology is its ability to simultaneously generate microfluidic ACEK effects with the sensing electrodes and to interrogate directly the sensor's interfacial capacitance. It is based on measuring the interfacial capacitance (C_{int}) on functionalized microelectrodes with an AC signal capable of inducing ACEK effects. With binding process continuing, the thickness of interfacial layer, d_{int}, keeps increasing, which leads to a decrease of C_{int}. By monitoring the change rate of C_{int}, specific binding of analyte with probe molecules can be detected. The change rate in interfacial capacitance is tracked and used as an indicator of probe-analyte binding.

In order to accelerate binding reaction occurred on the electrodes surface, the AC signal will also induce movement of proteins towards the electrode surface and accelerate the binding to immobilized probe molecules. Based on our prior work [3], electrodes with larger characteristic length have remarkably higher response at the same electric field strength because the electrode geometry is more amenable to ACET convection. The findings have been applied here to achieve faster and more sensitive detection. Both positive dielectrophoresis (pDEP) and AC electrothermal (ACET) effect have been induced to transport target proteins towards the sensor. Positive DEP will caused a particle to move towards high electric field region due to interactions between a particle's dipole moment and a non-uniform field, while ACET effect will generate vortices-like microflows around an electrode and transport bioparticles by convection. Since DEP force is short-ranged, concomitant generation of ACET flows will significant improve the effective range of macromolecular enrichment.

Results:
In this work, a capacitive immunosensor based on ACEK has been developed for detection of pseudorabies virus antibody in serum samples. Interdigitated electrodes with critical dimension of 100 μm have been used as the sensor. Comparing with previous work using 2 μm electrodes [4], the optimal frequency has shifted from 100 kHz to 75 kHz. This is because ACET effect becomes more important relative to DEP with larger electrodes, and capacitive response is larger at a lower frequency with ACET effect, generally speaking. The sensor is very sensitive with a limit of detection of 4.5 fg/mL when testing analytical samples. When testing clinical samples, using 35 serum samples from feral hogs, a diagnostic sensitivity of 91.1-% and a selectivity of 90.9-% are achieved, as confirmed by ELISA results. This sensing method has a response time of 30 seconds and requires minimum pretreatment without washing process, which make it a promising method for on-site disease detection and diagnosis.

AES 16 – 250p

Chemo-Electro-Thermotherapy in Capillary Systems: Simplify Model and Simulation

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The use of electrical fields in medicine include a long range of practical applications for diagnosis and treatment of recurrent contemporary illnesses. A few examples of these applications are biological imaging, neurology, iontophoresis, drug delivery, and the most recently Chemo-Electro-Thermotherapy for cancer

therapy. In a previous contribution, these authors identified a framework for undergraduate research on the subject[1]. This exploratory research included multiple categories: Cancer and the major effects of Angiogenesis, Tumor Growth and Electrical Fields. From a mathematical modeling approach, it was concluded that further effort was needed in five distinctive areas to conduct effective product design and development within the field. In this current work, at least two areas of efforts are reported and further developed to analyze the role of electrical fields, Joule heating, interstitial pressure and systemic or intramural drug injection. The main contribution of this research is demonstrating the effects of the order magnitude of the applied electrical field and drug concentration gradient across a capillary bed on malignant growths. The results will show temperature gradients in the arterial and tissue domains as a consequence of the applied number of voltages. Preliminary report on the cell count as well as drug uptake will be also shown.

AES 17 – 250q

Electro-Aided Peritoneal Dialysis: A Fundamental and Modeling Analysis Approach

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Renal replacement therapy can be conducted by using processes including Hemodialysis, Peritoneal dialysis, and a few others. Hemodialysis is not very popular among patients due to the possible yet debilitating side effects, which may involve low blood pressure, headache, tiredness, skin irradiation, and muscle cramps. Peritoneal dialysis, the alternative, is considered a much more patient friendly therapy when compared hemodialysis. Although, the most important drawback in Peritoneal dialysis is the low permeability of the peritoneal membrane, which makes the treatment significantly slower, often requiring between three to four batches of treatment per day. Membrane permeability can be modified by imposing a low value electrical field adjacent to the peritoneal wall. This soft tissue has been observed to be susceptible to electrical impulse and therefore allowing this characteristic to be exploited. This contribution analyzes the fundamental principles involved in permeability manipulation, and a mathematical model has been proposed to further study the phenomenon. The influence of different order of magnitude of the electrical fields has been studied to assess potential enhancement of the treatment in time duration and number of batches per day. The influence of blood shear thinning characteristics have also been investigated and illustrative results will be presented in the analysis.

AES 18 – 244h

A Shear-Enhanced CNT-DEP NanoSensor Platform for Single Cell Protein Assay

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Breast cancer is the main cause of cancer deaths among women, with approximately 1.4 million new cases and nearly 0.5 million deaths worldwide per year. As the growth of tumor varies from patients to patients, its mortality rate can be reduced if the hormone receptor status of ER, PR and HER-2 can be accurately determined from cells within tumors. Since tumor cells are heterogeneous, it is desirable to analyze individual cell rather than an average bulk measurement in order to extract accurate information. However, current high-throughput and quantitative technology Reverse Phase Protein Array (RPPA) still require at least 10 cell equivalents of sample [1]. Hence, there is a need to develop a detection platform for single-cell proteomics that will enable precise treatment plan based on individual's specific information within tumor cells and will severely reduce the drug side effect.

We report a new nanoscale protein sensor platform that uses irreversible electrokinetic phenomena to achieve single cellular sensitivity and specificity for HER-2 protein assay. The sensitivity is achieved with irreversible rare events, driven by a DEP (dielectrophoresis) driven Ab-Ag-Ab ELISA complex association, which can nevertheless be detected with a sensitive CNT electron tunneling conductance sensor design. The selectivity is achieved by working at a critical shear rate that is between the dissociation shear rate of the target and the non-target. Specific components of this new protein sensing platform include: 1. Accelerated DEP association of protein target with an Ab probe functionalized onto an electrode pair with high electric field; 2.Transportation and trapping of the second linking Ab probe functionalized CNTs with long-range DC electrophoresis and short-range AC DEP to the electrodes (lock); 3.Selective removal of assembled CNTs with non-targets by an optimized nanoshear protocol; 4.Conductance quantification of remaining bridging CNTs with target linkers (switch). Steps 1 and 2 involve rapidly driven dynamic events to prevent the captured targets from dissociating from the probe to reach the thermodynamic coverage. Optimized shear at the nm-high hydrodynamic slip length in step 3 irreversibly removes CNTs with non-targets due to the large Stokes drag of their high aspect-ratio cylindrical geometry. With only target-linked CNTs remaining, the digital conductance by electron-tunneling across the Ab-Ag-Ab complex allows us to reach a detection limit of 10,000 molecules (10 fM) for pure HER2 sample. Irreversible capture and shearing also allow us to tune the dynamic range up to 100 billion (100 pM or 6 decades) by increasing the CNT number. We will also carefully conduct experiments with real tumor cell lysate, and the number of proteins detected will be correlated with respect to tumor cell numbers.

References

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AES 19 – 250r

DNA Gel Electrophoresis via Entropic Trapping: Insights From Monte Carlo Simulations

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The ability to precisely manipulate transport of charged macromolecules (DNA, proteins) in nanoporous surroundings plays a critical role in the design of microfluidic electrophoresis systems. Reptation is the predominant transport mechanism in most hydrogel-based separation matrices, where the characteristic macromolecular size scale is larger than that of the surrounding pores. DNA electrophoresis in the reptation regime yields a scaling of mobility with the inverse of macromolecular size. Alternatively, when the characteristic macromolecular size is the same as that of the surrounding pores, transport occurs via an entropic trapping mechanism. In contrast to reptation, transport in this regime occurs via discrete hops between larger pores joined by narrow interconnecting spaces, leading to a stronger size dependence of electrophoretic mobility that is desirable for enhanced separation performance.

We have previously shown how application of a time varying electric field driving force can enable the activated hopping process to become synchronized, leading to a resonance state that can be exploited both to obtain improved separation performance and to extract nanoscale physical parameters of the macromolecules (contour length, persistence length). In these initial studies, our transport model was focused on the activated process by which molecules enter the narrow space between adjacent large pores (activation time), but assumed a simplified representation of transit through the confined interconnecting region (migration time). Specifically, migration was described in terms of a simple function of the macromolecule's radius of gyration and the applied electric field. Although this representation is consistent with previous frameworks that have been developed to describe electrophoretic entropic trapping, it does not realistically capture the hydrodynamic forces and conformational changes that occur during migration through the confined interconnecting pore spaces.

Here we apply a more realistic representation of migration through the nano-confined interconnecting spaces linking adjacent large pores. Our starting point is a model is based on a Monte Carlo algorithm developed by Slater, et. al. that directly incorporates frictional and entropic forces. The portion of the macromolecule located outside of the pore space experiences frictional interactions with the surrounding fluid, while the portion inside the pore experiences drag due to spatial confinement in the narrow interconnecting space. Entropic forces are related to conformation differences between the portion of the macromolecule at the entrance and exit of the pore space. Embedding each of these effects into our model enables the size dependence of electrophoretic mobility to be computed by integration over the pore size distribution of the hydrogel matrix. The resulting predictions are validated by comparison with experimental data. These new insights can suggest optimal operating conditions (electric field amplitude and frequency) and nanoporous gel matrix architectures (pore size distribution) to deliver enhanced separations in microfluidic electrophoresis systems.

AES 20 – 250s

Dielectrophoretic lipid content differentiation in *Neochloris Oleoabundans* for biomass harvesting optimization

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The dielectrophoretic behavior of *Neochloris oleoabundans* microalgae with heterogeneous cytoplasmic lipid content was characterized by dielectrophoresis using carbon interdigitated electrodes. For this purpose, two samples of microalgae were cultured: one under nitrogen-replete (N+) and the other under nitrogen-deplete (N-) conditions to allow low and high lipid growth, respectively. Cell population was monitored by spectrophotometry and the difference in lipid content among the samples was determined by Nile red fluorescence. The microfluidic device consisted of a carbon castellated microelectrode array fabricated using the Carbon-MEMS process—photolithographic patterning of a carbon precursor, followed by pyrolysis—bonded to a poly(dimethylsiloxane) microchannel. A Finite element model was developed to determine the electric field distribution across the microchannel and dielectrophoretic trapping zones. Experimental tests were carried out on wide frequency window (from 100 kHz to 30 MHz) at a fixed amplitude of 7 V_{PP}. Results showed a significant difference between the dielectrophoretic behavior of N+ and N- cells at low frequencies (100-800 kHz), whereas a weak response for mid and high frequencies (1-30 MHz). These results suggest that pyrolyzed carbon, obtained from a low-cost and straightforward fabrication process, is an attractive electrode material for microalgae dielectrophoretic characterization and isolation, based on their lipid content.

AES 21 – 250t

Toward the design of a multi-module fluidic device for the simultaneous detection of Lyme disease and Babesiosis

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In our previous work on the dielectrophoretic separation of Babesia-infected erythrocytes from its mixture with healthy ones, we leveraged the pathogenesis and clinical courses of both Babesia and Plasmodium to

theorize their interchangeable electrophysiological properties, which were used to simulate the trajectory of the Babesia-infected erythrocytes in a 1.4mm long fluidic device. When the Trends in Parasitology released one of its issues in 2015, it clearly reported some statistical events which showed that 40% of patients with Babesia-infected erythrocytes are not mutually exclusive with patients who were infected with Borrelia-the main cause of Lyme disease. This sets the diagnostic activities of these pathogens out for both deterministic and stochastic considerations. A foundational necessity is the characterization of these pathogens. This work, therefore, focuses on the characterization of Babesia-infected erythrocytes in a perpendicularly arranged electrode pair of 75 μm inter-electrode spacing sizably contained in a PDMS-constructed micro well. Trapping and streaming activities at 8Vpp and various frequencies, which led to the determination of the cross-over frequencies at various buffer conductivities were observed and recorded. Curve fitting procedure for these data (crossover frequency v. buffer conductivity) led to the estimation of both shell and cytoplasmic electrical parameters. Ongoing work will characterize Borrelia.

AES 22

Dielectrophoretic Response of Condensed DNA Clusters in AC Fields

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Insulator-based dielectrophoresis (iDEP) has been applied in analytical research as a method to separate and fractionate DNA in lab-on-a-chip devices. The development of similar continuous-flow, size-based separation techniques for DNA Next-Generation Sequencing (NGS) could advance the speed, efficiency, and accuracy of in situ analysis of genomic/biological data. When low-frequency and high-amplitude AC potentials are applied to homogeneously disperse λ-DNA, reversible segregated clusters are observed in high frame rate imaging. However, the fundamental physics of such cluster phenomena are poorly understood and limited studies have been published referencing the aggregation formation realized under these conditions. This recently observed clustering phenomenon has gained the attention of colloidal physicists who wish to understand the physical parameters that influence clustering of λ-DNA. We believe applied low-frequency potentials generate this clustering behavior, which influences the dielectrophoretic response of DNA molecules. As a result, this phenomenon could be used to improve DNA sample preparation and pre-concentration using microdevices for future NGS applications. Research investigating cluster formation through modeling and computer simulations has shown that this phenomenon may be due to electrohydrodynamic instability including by not limited to dipole-dipole interactions between molecules. However, these models often address simpler DNA systems and fail to predict the unexpected switch we observe from positive to negative DEP in DNA clustering. Clustering behavior has the potential to enhance the efficiency of DNA fractionation by exploiting strong AC electric fields to induce condensation and separation of DNA molecules, thus it is important that we understand the physics behind this phenomenon. Our recent work examines DNA cluster formation and migration characteristics using various electric field parameters in order to quantify the movement of DNA particles in solution. Preliminary evidence suggests that the electrokinetic mobility of DNA clusters changes negligibly with changes in frequency. Various amplitudes and frequencies of applied potential were examined to determine the extent of correlation in DNA clustering. DNA clustering was largely observed with frequencies ranging from 10 to 100 Hz and electric field strengths above 800 V/cm. Similar electric field parameters have produced some of the highest-observed sorting efficiencies in an iDEP constriction sorter for DNA molecules ranging in size from 10 - 50 kbp. Future work will aim to enhance techniques capable of automatically tracking DNA clusters throughout high-frame rate imaging to further understand clustering and transport mechanisms. Such techniques will significantly reduce biosensing and bioanalytical processing times.