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Poster Abstracts

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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

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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 mS/cm and pH of 6-7, under applied fields between 400 V/cm and 1500 V/cm, the 5-mm, 7-mm and two types of 10-mm polystyrene particles were observed to become immobilized due to negative electrophoretic trapping. In addition, it our experiments have reveled that the amount 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

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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 mm) 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 ∇Erms2 , the only unknown for each particle is Re[fCM] The field is applied and Re[fCM] 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[fCM] 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.