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Online Proceedings

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CHEMISTRY AND BIOCHEMISTRY

Session Moderator: Michael Heinekey, Chemistry

JHN 022

12:30 PM to 2:15 PM

* Note: Titles in order of presentation.

Biodegradable Fluorocarbon Modified Polyethylenimine for High Gene Transfection

Xinyu Gu, ,

Mary Gates Scholar, UW Honors Program

Mentor: Miqin Zhang, Materials Science & Engineering

Polyethylenimine (PEI) is considered as the most promising alternative gene carrier to viral vectors. PEI-based carriers minimize unwanted immunogenicity and promote loading capacity. However, PEIs' nondegradable nature determines their high cytotoxicity. To minimize the toxicity and improve gene transfection efficacy, biodegradable cross-linking agents have been screened to synthesize biocompatible PEIs. Various cross-linkers have been linked to low molecular weight PEI (MW = 800) and tested across multiple cell lines (xPEI). N,N'-Methylenebis(acrylamide) (NDA) showed the lowest toxicity and highest transfection rate among all cross-linkers. To further optimize gene transfection efficacy, xPEIs were modified with increasing amount of fluorocarbon (xPEI-FC). DNA that expresses red fluorescence protein are bound to xPEI and xPEI-FC and then incubated with cells for 48 hours. Green fluorescence light is later used to examine the presence of RFP. xPEI-FC has demonstrated higher biocompatibility as well as higher transfection rate in vitro with higher level of RFP. The best-performing candidates for xPEI, PEI-FC and xPEI-FC based on toxicity and transfection efficiency will be selected for nanoparticle (NP) modification. Selected candidates will be conjugated with Chitosan-poly(ethylene glycol) (PEG)-catechol copolymer (CCP) and then grafted onto iron oxide nanoparticle (IOCCP-PEI). The resulting nano-vector delivery system will be tested in vitro. Ultimately, in vivo test will be performed to evaluate its transfection efficacy in living organisms.

Effects of Peptide Microenvironments on the Electronic Properties of Tryptophan

Timothy (Tim) Welsh, ,

Mary Gates Scholar, UW Honors Program

Mentor: Stefan Stoll, Chemistry

Mentor: Ellen Hayes, Chemistry

Many biochemical processes rely on the conversion of electrical energy into chemical energy. Tryptophan is one aromatic amino acid that facilitates electron transport through proteins by means of reduction and oxidation reactions, allowing for the energy conversion to occur. The ability for a protein to tune the reduction potential of tryptophan is critical to its function in reactions within enzymes such as cryptochromes, which are involved in regulation of circadian rhythm, and photolyases, which are involved in DNA repair. This tuning of the reduction potential is achieved by modulation of the microenvironment surrounding tryptophan residues within a protein. In order to study the relationship between protein environment and tryptophan oxidation, we have designed and synthesized a series of model peptides to engineer specific environments which have the same geometry but differing charge states and levels of solvent exposure. The reduction potential of each peptide was determined via differential pulse voltammetry over a pH range from 1-7.5 in order to determine how the pH dependence of tryptophan's reduction potential responds to changes in its microenvironment. The results indicate that the reduction potential of tryptophan at the physiologically relevant pH=7.5 increases with increasing positive charge in the surrounding microenvironment. The results across the entire pH range indicate that the pKa of oxidized tryptophan increases with decreased solvent exposure. Finally, our entire series of peptides indicates that the tryptophan oxidation reaction does not directly follow the expected Nernstian behavior for pH dependence of a single proton-coupled electron transfer reaction and thus indicates that the oxidation process may have differing degrees of reversibility in different environments.

Orientation Changes of Diamond Nitrogen Vacancy Centers by High Temperature Annealing

*Christopher Jonathan (Chris) Moore, ,
Mary Gates Scholar*

Mentor: Kai-Mei Fu, Physics/ECE

Quantum information systems are reliant on the fidelity of the spectra of their qubits. Diamond nitrogen vacancy centers present many of the best traits among qubit candidates and show promise for scalable quantum computing. Preferential lattice orientation of these nitrogen vacancy centers is a technically difficult, yet essential step to improve the signal to noise ratio of quantum sensing and the efficiency of quantum computing. My research seeks to test our theoretical knowledge of nitrogen vacancy center orientation changes through annealing diamonds at high temperature. I present the techniques I use to return to the same single atomic defects to compare, through confocal microscopy, orientation changes as a function of annealing temperature. I show our preliminary data in relation to the nitrogen vacancy density distributions and orientation changes throughout the diamond to test current theory regarding vacancy diffusion through the diamond lattice near substitutional nitrogen. Finally, I discuss some unexpected results from our first run of this experiment and share our remaining questions and future efforts to preferentially orient nitrogen vacancy centers. This research is contributing to progress through the Noisy Intermediate-scale Quantum era with reduction of noise generated by local strain near qubits and better signal-to-noise for quantum sensors.

Metal Vapor Adsorption Calorimetry on Calcium Niobate Nanosheets: Energetics and Adsorbate Structure

John Ehren Eichler, ,

Mentor: Charles Campbell, Chemistry

Mentor: Wei Zhang, Chemistry

The catalytic activity of many metals can be increased when the catalyst exists as tiny nanoclusters as opposed to large bulk-like metal particles. Thus materials, or supports, that facilitate the growth of nanoparticle catalysts are highly desired. Of these supports, the most widely used are metal-oxides. The growth of catalysts on these supports can be better understood by studying the chemical bonding at the metal-oxide interface. The Mallouk group has found a calcium niobate nanosheet, $\text{HCa}_2\text{Nb}_3\text{O}_{10}$, that when used as a support both resists and reverses the coalescence of metal-oxide or hydroxide nanoparticles on the surface. These nanosheets are of additional interest because they are smooth on the atomic scale, similar to single crystal surfaces, with a large ratio of terrace sites to edge sites. Here, calorimetric measurements of the adsorption energies of silver and copper vapor on oxide thin films composed of four layers of these nanosheets are directly measured using adsorption calorimetry in ultra-high vacuum. The initial heat of adsorption of silver atoms was found to be ~ 112 kJ/mol which closely resembles the

predicted density functional theory (DFT) values for silver monomers. The growth mode of silver was determined using a surface sensitive spectroscopy technique, low-energy He⁺ ion scattering spectroscopy (LEIS). The number density of silver particles, as estimated from the LEIS data, was found to be $\sim 2.2 \times 10^{10}$ particles/cm² at 1.7 monolayer silver coverage. This is much lower than the particle densities on other metal-oxide supports and is attributed to the lower density of step/nanosheet edges on this support. The evolution of the LEIS signal indicates that silver grew as 3D nanoparticles. This data encourages further investigations of the adsorption calorimetry of different metals on this interesting support.

Negative Photoresist Process Optimization for Metal Deposition on Silicon Wafers

Vladimir Vladimirovich (Vlad) Yarmolik, ,

Mentor: Darick Baker, Electrical Engineering, Washington Nanofabrication Facility

The goal of the project is to determine whether ma-N 1420 photoresist can be used with Heidelberg laser direct write tool, and to optimize the ma-N photoresist sidewall profile. The process starts by applying a negative photoresist onto a surface of a silicon wafer followed by an exposure to an ultraviolet light using a Heidelberg laser tool. The 410nm laser is applied directly to the photoresist without the use of a photomask, which is normally used for the purposes of exposing the wafers. The Heidelberg process is optimized in a manner that has not been possible previously at UW. This requires studying the thickness of the photoresist using reflectometry and optimizing the spin speed during spin coating. Various exposures on the Heidelberg system are then tested to make sure that the ideal exposure conditions have been achieved. The next step is to deposit a thin metal film on top of the photoresist. The deposition is achieved via an evaporation of metal inside the chamber of the device in which the metal is melted and evaporated by high speed electrons and is then deposited on a cooler silicon surface. The undesired metal is then stripped away from the surface of the wafer by removing the photoresist from under the metal film in a process the engineers refer to as "liftoff." The optimization part of the project refers to testing different development times to make sure the development gives ideal photoresist overhang for the liftoff process. Finally, the sidewalls of the photoresist mask are analyzed using Scanning Electron Microscope (SEM). An SEM is used as the thickness of photoresist can be thinner than $1\mu\text{m}$. The research was performed to verify that ma-N photoresist is suitable to use with Heidelberg system to complete a nanofabrication process.