2016 REU Projects and Research Mentors

"3D Carbon Nanotube-Based Electrodes for High-Performance Li-Ion Batteries", Placidus Amama

Portable electronic devices are negatively impacted by energy and power density limitations of current lithium-ion batteries (LIBs). Architectures or materials for faster ion and electron transport are required. Since the diffusion time of ions is somewhat proportional to the square of the diffusion distance, the use of a nanoporous 3D nanocarbon-based electrode that is characterized by short diffusion length of ions will significantly improve the power density of LIBs. This research will utilize 3D carbon nanotube (CNT)-based electrodes in combination with an active material such as Fe_3O_4 or SnO_2 that has high lithium storage capacity for improved LIB performance. The CNTs will be synthesized by chemical vapor deposition (CVD) using a hydrocarbon precursor and a transition metal catalyst. The resulting CNTs will be processed to form a porous 3D nanofoam composite. The properties of the 3D nanocomposites will be characterized by electron microscopy, Raman spectroscopy and gas adsorption while the electrochemical properties will be studied by cycling the composites as an anode material in a half-cell configuration. The characterization data would illuminate the relationship between the 3D electrode properties and the LIB performance. This study is expected to enable the establishment of rational guidelines for the design of high-performance 3D electrodes.

"The production and characterisation of low viscosity plant oils", Timothy Durrett

3-acetyl-1,2-diacylglycerols (acetyl-TAGs) are unusual triacylglycerols (TAGs) with acetic acid esterified at the sn-3 position of the glycerol backbone. The presence of this acetate group rather than a long fatty acid endows acetyl-TAGs with physical and chemical properties that distinguish them from regular TAGs, making them potentially useful for a number of different applications. For example, from a renewable energy perspective, these unusual TAGs possess a lower viscosity than regular TAGs; thus acetyl-TAGs could be used as an improved straight vegetable oil (SVO) biofuel combusted directly by diesel engines without the need for conversion to biodiesel. The Durrett laboratory is currently metabolically engineering *Camelina sativa* to enable the seeds of this oilseed crop to produce high levels of acetyl-TAGs. Additional research is focused on studying the chemical and physical properties of these unusual lipids.

"Aqueous enzymatic extraction and fractionation of protein from Chlamydomonas reinhardtii", Lisa Wilken

The use of microalgal oil as a renewable feedstock for biofuel production has garnered significant attention as an alternative to petroleum fuels. Significant research and development efforts have focused on advances in upstream technologies but significant engineering and scientific challenges still exist for the efficient recovery and purification of oil and high value co-products. A process bottleneck with algae biofuel and bioproduct development is the lack of cost-effective cell lysis and cell content separation processes for intracellular lipid and protein recovery. To address this issue, Dr. Wilken's research group is currently evaluating aqueous enzymatic extraction (AEE) of protein and lipids from the freshwater microalgae, *Chlamydomonas reinhardtii (C. reinhardtii)*. AEE uses a combination of enzymes to break the cell wall and release the oil bodies and protein from the intracellular structure. This project will investigate protein extraction and recovery after primary (cell lysis) and secondary (intracellular component lysis) enzymatic treatments.

"Separation of 2,3-Butanediol from Fermentation Broth", Praveen Vadlani and Keith Hohn

2,3-butanediol has potential as a platform chemical that can easily be produced from biomass-derived sugars via fermentation and can be catalytically converted to a variety of projects. However, the fermentation broth containing 2,3-butanediol contains a variety of products which may inhibit the desired catalytic reactions. For this reason, separation schemes are needed to purify 2,3-butanediol before it can be catalytically converted. This projects will investigate potential separation schemes.

"Fabrication of Graphene Nanoribbons and their Electrochemical Testing", Gurpreet Singh

REU students will work along-side graduate student and postdoc on various aspects of graphene-based composites for energy storage applications. The students will receive hands-on training on scanning electron microscopy for imaging nanomaterials; synthesis of graphene nanoribbons films and composites using layer-by-layer assembly, spray coating and 3-D printing; introduction to chemical reduction of GO to graphene and cyclic voltammetry (CV) to study the electrochemical properties of the films. Knowledge/skills to be imparted during the course of this study: (i) Ability to synthesize graphene nanoribbons in bulk quantities, (ii) ability to operate electrochemical analyzer/workstation, and (iii) ability to independently operate a scanning electron microscope.

"Thermal property analysis of sorghum mutants", Donghai Wang

The pedigreed sorghum mutants with altered chemical and physical composition may have a great potential for biofuel production. The objectives of this research is to evaluate the elemental composition and thermal properties of the pedigreed sorghum mutants. The elemental composition of sorghum biomass samples (C, H, N, S, and O) will be measured with a CHNS/O Elemental Analyzer (PerkinElmer 2400 Series II, PerkinElmer Inc., Waltham, MA). High heating value will be determined using a calorimeter (IKA-Calorimeter C 200, IKA-Werke GmbH and Co. KG, Staufen, Germany) with a benzoic acid standard. In addition, the thermal degradation properties will be determined by using Thermogravimetric analysis.

"Production of single cell oil (SCO) from oleaginous yeast using biphasic fed-batch fermentation", Praveen Vadlani

Single cell oil (SCO) from oleaginous yeast is an important source of platform chemicals with applications in fuel, food, specialty chemical industry. In our laboratory, we have developed robust yeast systems that are capable of producing targeted lipids with specific fatty acid profile from renewable biomass sugars. In addition, novel biphasic fed-batch fermentation will enable efficient utilization of both glucose and xylose with improved lipid yield.

"Development of Electrical Energy Systems for Homes that are not Connected to the Grid", Larry E. Erickson and Ruth Miller

This project makes use of modern developments in solar and wind energy and energy storage to develop designs that are cost-effective for those living in locations where the electrical grid is not available. The costs of solar energy generation and battery storage have been decreasing, and this has made systems with solar energy more competitive. The project includes a review of the current literature.

"Wind Energy", Ruth Miller

The student involved in this project would help K-12 schools ensure their wind turbines are communicating with the KSU database, probably helping repair a few wind turbines, analyzing wind resource in western Kansas as part of a "wind power for water" trade project we are starting, and/or building a solar power database and connecting existing PV projects in Kansas to it. The student might also help to develop exercises/homework problems that use the wind and PV data, for K-12 teachers to adapt.

"Understanding the Electroreduction of C–O Bonds by Liquid-Phase Proton for Chemical Production", Bin Liu

Electrochemical processes present a great opportunity for chemicals production. Some examples include: electroreduction of CO and CO_2 into ethanol, methanol, and hydrocarbons (**Figure 1**); and electroreduction of furfural – a biomass-derived compound – into furfuryl alcohol and methylfuran. Innovations of these electrochemical processes are able to mitigate our dependence on fossil-based fuels, and alleviate the adverse impacts on the environment during chemicals production.

There are two critical technological barriers we need to overcome in order to design and optimize efficient electrochemical devices (e.g., fuel cells): (i) reaction mechanisms and the influence of the electrochemical environment (e.g., external voltage, solvent); and (ii) intrinsic properties of the electrocatalyst materials (e.g., structure, composition).

The electroreduction of C–O bonds in CO, CO_2, and biomass compounds by the proton (H^+) in liquid phase is an important electrochemical step. In this project, the student will obtain first-hand experience in using *the state-of-the-art modeling tools (at Dr. Bin Liu's group)* and *high performance computing facility (Beocat)* at Kansas State University to model this key reaction in the electrochemical process. The students shall benefit from this project by developing the capabilities of: (1) establishing connections between important engineering and societal issues and accompanying molecular processes; (2) gaining novel molecular perspectives on using molecular modeling to understand the relevant physical and chemical processes; and (3) proposing solutions using theoretical and modeling tools to generate solutions.

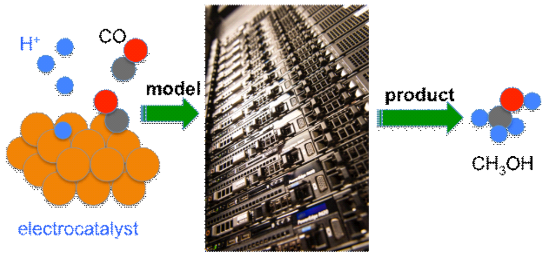

Figure 1. A schematic representation of the electrochemical process converting CO and protons into methanol based on the method of computer modeling.