ND*nano* Summer Undergraduate Research 2016 Project Summary

1. Student name:
Juan Velazquez

2. Faculty mentor name:
Dr. Kyle Doudrick

3. Project title:

Waste-to-Value: Simultaneous wastewater treatment and energy production using solar photoelectrochemical fuel cells

4. Briefly describe any new skills you acquired during your summer research:

From this fellowship, I learned about electroanalytical methods commonly used in analyzing the properties and characteristics of fuel cells, including linear sweep voltammetry and chronoamperometry. I also learned several techniques for synthesizing electrodes including drop cast, doctor blade, and airbrush methods for application in a photocatalytic fuel cell (PFC). I was able to practice my presenting skills in a poster session where I presented my work. Generally, I also acquired valuable skills for working in a chemistry laboratory environment, as I had not worked in one since high school.

5. Briefly share a practical application/end use of your research:

A practical application of my research on graphene electrodes is in the synthesis of PFC cathodes, where graphene has the potential to be a cheaper alternative to carbon paper/cloth and platinum cathodes. More generally, application of a cost-effective and efficient PFC is in the treatment of food and beverage industry effluent, to help offset some of the energy consumption of treating the wastewater.

Begin two-paragraph project summary here (~ one type-written page) to describe problem and project goal and your activities/results:

Previously, carbon paper and cloth have been used as conductive electrode substrates, but each has limitations with regards to PFC design (e.g., paper is not flexible). Additionally, carbon paper/cloth alone is not a suitable catalyst, often resulting in the use of platinum, which is an expensive material. The aim of this study was to use graphene “inks” as the counter electrode of a membrane electrode assembly (MEA) in order to reduce or eliminate platinum, thus decreasing the production cost of the MEA. Figure 1 below shows an exploded model of a PFC with each of the parts labeled—to show how the MEA fits into a PFC.

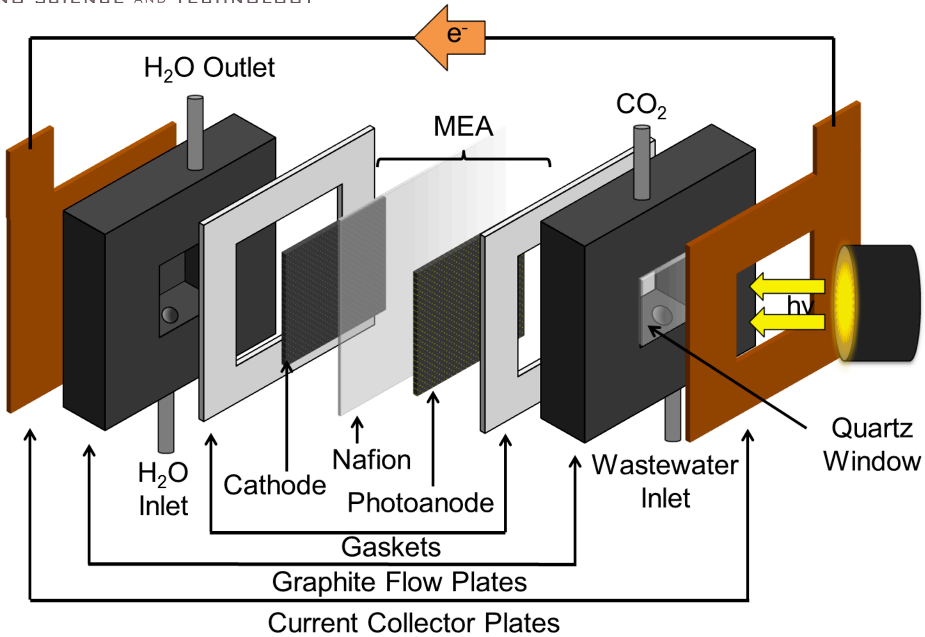

Figure 1: Dual compartment photocatalytic fuel cell (PFC) diagram

In the duration of this summer fellowship, four sources of graphene were tested, including graphene oxide (GO), reduced GO (r-GO), polarized graphene nanoplatelets (P-GNP), and few-layer graphene nanoplatelets (FL-GNP). Each sample was tested for its processability, conductivity and robustness. Figure 2 below compares the current density vs. electrode potential (J-V) curves for each of the four sources of graphene, thereby showing the relative conductivities of each film for similar graphene loading densities.

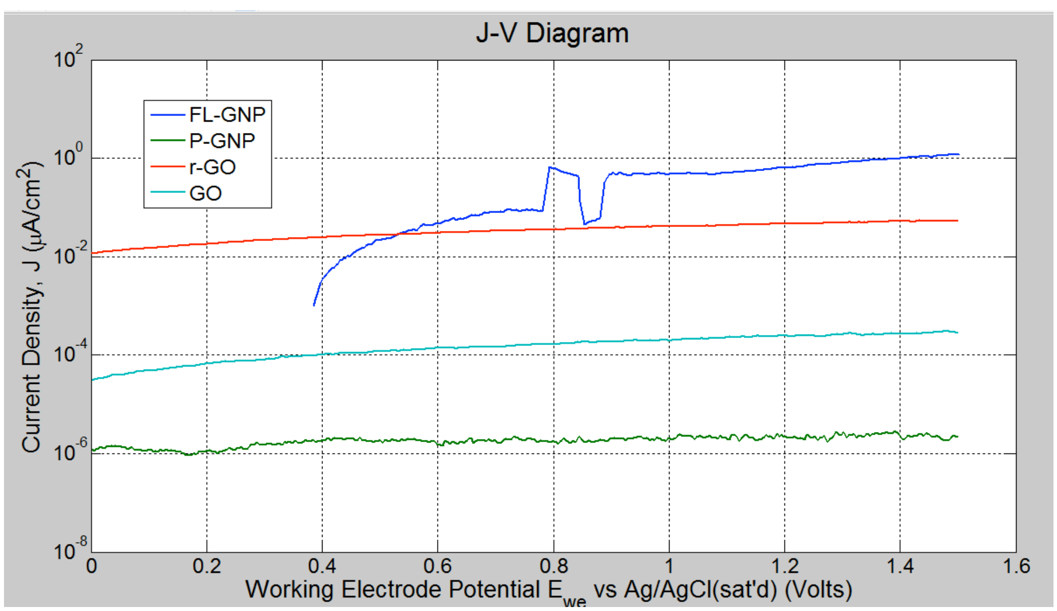

Figure 2: Current density vs electrode potential (J-V) curves on a log-linear scale for the four different sources of graphene tested at similar loading densities.

From Figure 2, we observed that current densities for FL-GNP are higher by several orders of magnitude than the other sources of graphene (at most electrode potentials). GO, as expected, had low current densities. P-GNP had very low current densities because the P-GNP film dissolved quickly after being placed in the electrolyte solution for linear sweep voltammetry (LSV) testing. R-GO, as expected, had higher current densities than GO.

In order to examine graphene particle stability and homogeneity in solution, different samples were prepared in ultrapure water or organic solvents (e.g. ethanol, citric acid). Both the citric acid solutions and the ethanol solutions dispersed graphene particles better than water. However, the stability of the graphene films (prepared with organic solvents) were consistently worse relative to ones prepared in water—evident when the films were rehydrated in the electrolyte solution, and the films would quickly dissolve in the solution.

In addition, the graphene films were investigated on glass and on Nafion 117(polymer membrane) substrates to compare the graphene films to other surfaces such as conductive glass (fluorine-doped tin oxide coated glass) and carbon paper. The films were loaded on the substrates using several standard methods including drop cast, doctor blade, and airbrush. These three different loading methods were preliminarily tested. However, testing of these methods has not yet yielded conclusive results. This project will have to be continued beyond the duration of the NURF program in order to get further results and move the project forward.

Publications (papers/posters/presentations):

"Graphene cathodes for membrane electrode assemblies" poster was presented at the NDnano/Center for Research Computing/ND Energy poster session (7/27/2016)