NDnano Summer Undergraduate Research
2023 Project Summary

1. Student name & home university:
Maximilian Niebur, Johns Hopkins University
2. ND faculty name & department:
Dr. David B. Go, AME & CBE
3. Summer project title:
Understanding the Interactions Between Non-Equilibrium Plasma and Nanomaterials in a Fluidized Gliding Arc

4. Briefly describe new skills you acquired during your summer research:
Learned simple lab skills such as soldering electrical connections. Learned professional skills relating to presenting research via slides or posters.

5. Briefly share a practical application/end use of your research:
Gliding arc methane plasma could be used to recycle methane waste from oil wells and refineries into valuable organic compounds such as pyrroles and pyridines that have important chemistry and pharmaceutical applications

6. 50- to 75-word abstract of your project:
Gliding arc plasmas are a promising frontier in plasma catalysis research due to the high number of reactive species they generate and the amount of gas they can process. We constructed and parametrized a gliding arc to recycle gaseous hydrocarbons by reacting them with oxidants such as nitrogen to create organic compounds.

7. References for papers, posters, or presentations of your research:
Niebur M, Akintola I, Yang J, Go D. Understanding the Interactions Between Non-Equilibrium Plasma and Nanomaterials in a Fluidized Gliding Arc. Poster presented at: Summer Undergraduate Research Symposium; July 28, 2023; South Bend, IN, USA

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One-page project summary that describes problem, project goal and your activities / results:

Non-equilibrium plasmas have emerged as a way to enhance traditional thermal catalysis methods. They produce a highly reactive environment of radicals, free electrons, and high energy gas molecules that can drive unfavorable reactions at atmospheric temperature and pressure, as opposed to traditional thermal catalysis methods. Plasmas can also work in conjunction with traditional chemical catalysts, and often the two enhance the effects of one another. Some interest has risen in reacting methane, a common byproduct of oil refining, with nitrogen (N_2), which is readily available in the atmosphere, to produce value-added chemicals such as pyrrole and pyridine. Previous work done using dielectric barrier discharges (DBDs) has shown promising results, however DBDs may not be optimal for this task.

Gliding arcs are a relatively new non-equilibrium plasma reactor configuration that produce a plasma with unique, spatially varying properties by flowing gas between diverging, knife-like electrodes. Gliding arcs are very promising for catalysis purposes because of their ability to handle high throughput of gas, (the proposed reactor operates at over 10 L/min opposed to other reactors which operate at under 1 L/min) and produce a large number of reactive species relative to other plasma reactors. The high flow rates of gliding arcs make them very promising for catalyzing hydrocarbon reactions at point-of-source refining operations. In order to test the feasibility of using a gliding arc for catalysis, I designed and fabricated a gliding arc reactor with a sprouted bed to support a chemical catalyst.

I defined operating parameters for this gliding arc (flow rate, plasma voltage, plasma power and gas composition) to catalyze reactions in a mixture of methane (CH_4), argon (Ar), and nitrogen gas, as a model chemical system for methane recycling. The aim of this research was to define working conditions that ensured fluidization of the catalyst as well as plasma electrical stability. Fluidization allows the catalyst particles to be maximally contacted by the reactive species from the plasma, allowing for the highest degree of conversion. Electrical stability was defined by repeatable periodic formation of arcs in the plasma that are represented by sawtooth-like waves as shown in Figure 1. I was able to generate electrically stable arcs by varying the ballast resistors and determine the breakdown voltage needed for a pure Ar, Ar/N_2, Ar/CH_4, and Ar/N_2/CH_4 arcs. A visually stable arc (2% N_2 and 98% Ar with a plasma power of 200 W) is shown in Figure 2. I also determined that fluidization of the catalyst bed was possible at flow rates higher than 9 L min^{-1} with particle sizes less than 150 μm. Future studies will investigate the nature of the chemical reactions performed in the arc, and attempt to optimize their productivity and selectivity.

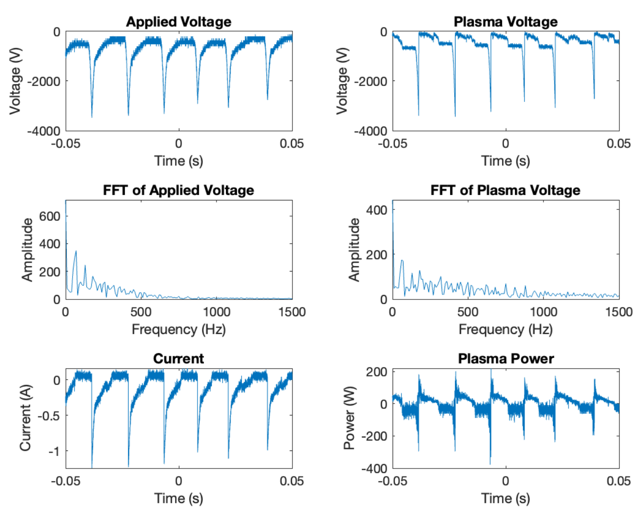

Figure 1. A sample of the electrical data used to characterize the gliding arc.

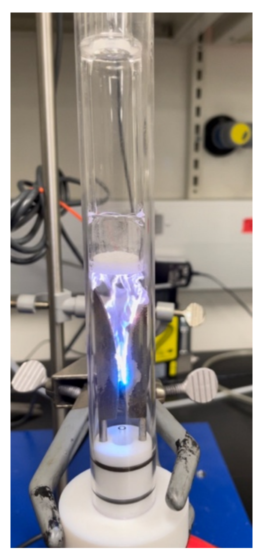

Figure 2. An image of the arc that produced the sample data in Fig. 1.