NDnano
Center for Nano Science and Technology

NDnano Summer Undergraduate Research 2019 Project Summary

1. Student name & home university:

Federico G. Hita Martínez – University of Notre Dame

2. ND faculty name & department:

David B. Go and Seong-Kyun Im (both AME)

3. Summer project title:

Generation of Plasma Activated Water (PAW) using Mechanical Actuation of Piezoelectric Crystals

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

Learned how to use lab equipment like oscilloscopes, breadboards, transistors, DC motors and gas pumps in order to collect data. Learned how to use drill presses at the ND SFL to machine parts for research purposes. Learned how to prepare a research poster/presentation and how to properly communicate findings with peers.

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

Plasma activated water can have high concentrations of nitrate, which enhances plant growth by acting as a fertilizer. Developing a mechanical system for piezoelectric actuation to produce plasma activated water can facilitate agriculture in countries with low resources as a zero-power consuming source of fertilizer for crops.

6. 50- to 75-word abstract of your project:

A hand-cranked system for piezoelectric actuation was developed to observe plasma-surface interactions with water. The pH of water was measured to decrease drastically from 7 to approximately 2 over an activation time of 5 minutes. Nitrate concentrations were measured to be approximately 1.5-2.5 mg/L. These values were promising when compared to concentrations recorded using other forms of plasma generation. The findings from this study have strong implications in the field of plasma agriculture due to the potential of plasma activated water for enhancing plant growth.

7. References for papers, posters, or presentations of your research:

- Dayonna, P., et al., Current Applied Physics 13 (2013): 19
- Megan, W., et al., J. Phys. D, Appl. Phys. 45 (2012): 4
- Thirumdas, R., et al., Trends in Food Science & Technology 77 (2018): 24

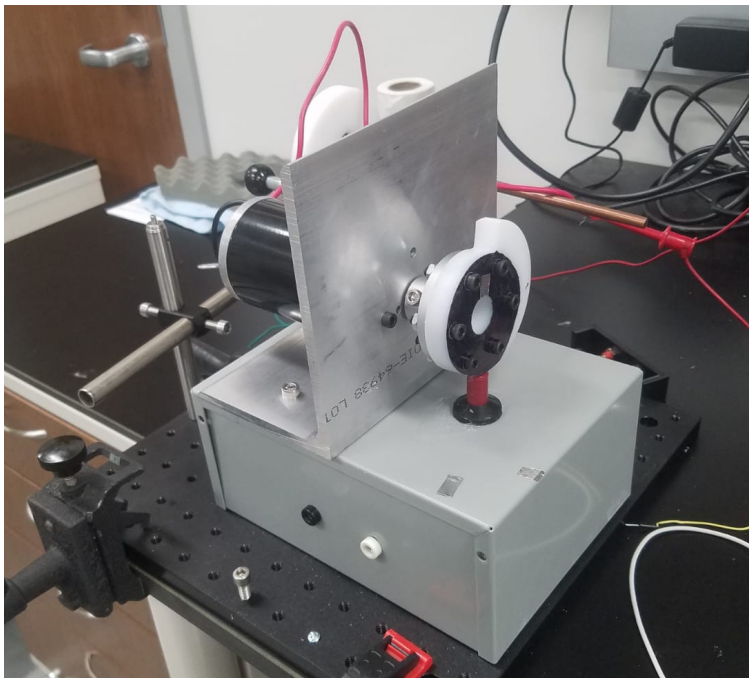
One-page project summary that describes problem, project goal and your activities / results:

The problem for this project consisted of making an effective mechanical system for piezoelectric actuation that could be operated continuously with the user's hand. This problem was to be solved using a piezoelectric igniter that contained a cylindrical lead zirconium titanate piezoelectric crystal inside of the igniter casing. The goal of the project was to plasma activate water using the developed mechanical system. Plasma activated water (PAW) generated from the developed mechanical system was to be analyzed in order to determine nitrate concentration. Nitrate concentration present in the exposed solution was to be measured because of the potential of nitrate as a fertilizer in the field of agriculture. Both the problem and the goal of the project were accomplished in the duration of the summer.

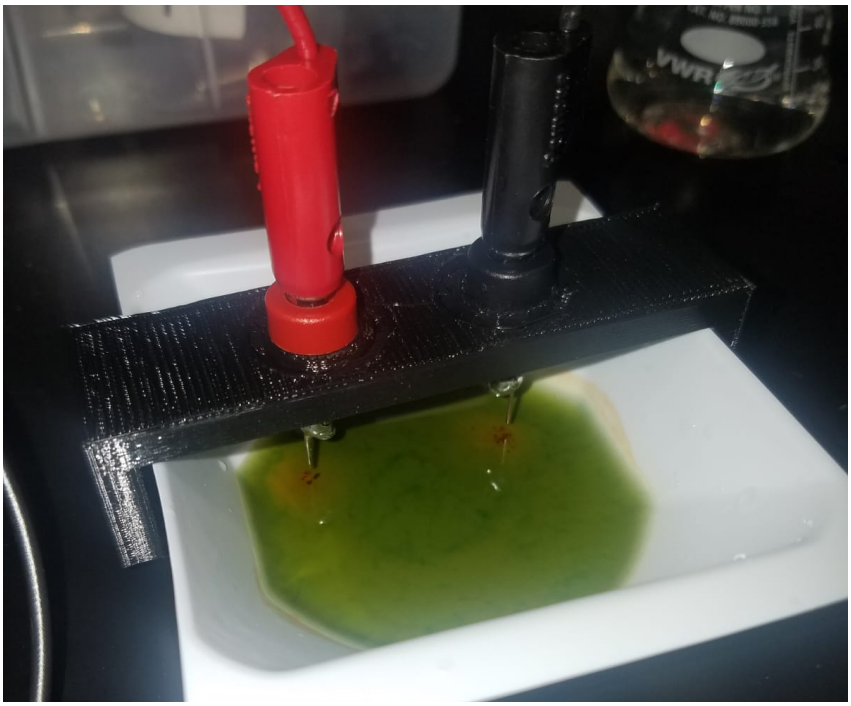
The first two weeks of the project were spent collecting information about plasma science and designing initial models for the hand-crank system. The first design for the mechanical system consisted of a snail drive connected to a rotating shaft. The snail drive had a protruding knob for the user to freely rotate the snail drive and activate the piezoelectric igniter. The hand-crank system was constructed using an optical breadboard and metal rods that connected to the breadboard. The piezoelectric igniter was fixed using a metal clamp and the snail drive was carefully positioned directly above the igniter. This design proved to be successful during testing. A sodium chloride solution mixed with pH sensitive dye was exposed to plasma generated from electrodes that were connected to the piezoelectric igniter. Initial tests showed that the pH dye in the solution changed color from yellow (neutral) to dark orange (acidic). Additional experiments were conducted where nitrate concentrations were measured and a new mechanical system with a motor was developed in order to provide mechanical actuation in a more controlled manner.

Sodium perchlorate was used to set the conductivity of the solution during experiments. Increasing conductivity helped promote the generation of nitrate and decreased pH faster. Solutions were exposed to 5 minutes of hand-cranking at an approximate ignition rate of 10 Hz (3000 sparks per 5 minutes). Using 1 M of sodium perchlorate, a pH change from 7 to approximately 2 was measured for an actuation time of 5 minutes. Nitrate concentrations were measured using a *Salifert* nitrate test kit. For the same actuation time and solution conditions, 1.5 - 2.5 mg/l of nitrate were measured from a 3 ml test vile. The reason for the range of the results is that the *Salifert* nitrate test kit only allowed to perform measurements on a 1 mg/L scale.

The next step of the project was to create a mechanical system that could expose the solution to a plasma spark for more than 5 minutes. Developing this motorized system would allow more controlled actuation that would facilitate the study of the physics and chemistry of plasma-surface interactions with experimental solutions. A motor was attached to a medium-sized bud-box that held the piezoelectric igniter. The motorized system was tested at max intensity (approximately 4000 RPM) with a solution exposure time of 3 minutes. A pH change from 7 to approximately 2 was measured. A MOSFET circuit was used to control the motor speed and frequency of ignition. Future work will focus on testing this new mechanical system on a sodium perchlorate solution and measuring nitrate concentrations with ignition times longer than 5 minutes.



Developed mechanical system with motor. When the motor is turned on, the snail drive pushed on the igniter tip and sparks electrodes connected to box.



Sodium perchlorate solution with pH sensitive dye exposed to 2 minutes of hand-cranking. The solution is orange colored surrounding both electrodes because of pH changes caused by plasma reacting with air.