NDnano Summer Undergraduate Research
2021 Project Summary

1. Student name & home university:
Nathaniel Moller, University of Notre Dame

2. ND faculty name & department:
Dr. Jennifer L. Schaefer and Dr. Nosang V. Myung, Department of Chemical and Biomolecular Engineering

3. Summer project title:
Development of Polymeric Piezo-Electrolytes for Self-Charging Batteries

4. Briefly describe new skills you acquired during your summer research:
I learned how to crosslink a condensed polymer network around a piezoelectric nanofiber mat. While I have worked with crosslinked monomer solutions before, this was my first time polymerizing these materials. Depending on the piezoelectric material, I determined the best methods for polymerizing and reducing the overall thickness of the mat. Additionally, I learned how to measure bulk piezoelectricity using a cantilever device, which measures the voltage output of the material at different applied stresses.

5. Briefly share a practical application/end use of your research:
A self-charging battery would be feasible in any device where constant mechanical energy is being supplied. Initially, it is likely that a self-charging battery could be implemented at the bottom of someone's foot such that the act of walking charges the battery or in a sports watch where constant mechanical energy is supplied. Furthermore, a self-charging battery could also be used in an arm patch device for health monitoring or diagnosis.

6. 50- to 75-word abstract of your project:
Typically, energy generation and storage are two distinct processes that occur in different entities. In this project, the two processes are coupled together where mechanical energy is converted into electrical energy and then stored as chemical energy to create a self-charging battery. More specifically, a charge will be generated across the piezoelectric separator when a stress is applied, and the polymer electrolyte will enable ion transport, converting the electrical charge generated from the piezoelectric into electrochemically stored energy.

7. References for papers, posters, or presentations of your research:
K. Deng, Q. Zeng, D. Wang, Z. Liu, *Single-ion conducting gel polymer electrolytes: design, preparation and application*, Journal of Materials Chemistry, 2020, 1557-1577.
X. Pu, Z.L. Wang, *Self-charging power system for distributed energy: beyond the energy storage unit*, Royal Society of Chemistry, 2020, 34-49.

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

Problem:

There exists situations where a battery needs to be charged without access to an electrical power source. For example, a member of the military stationed in the desert or someone who is on an extended voyage at sea could utilize a self-charging battery. A seemingly simple solution to this problem is the conversion of constant mechanical energy that a person creates into electrical energy and then into chemical energy for storage to later charge a battery. This would allow someone in an isolated area without electrical energy to charge a battery for a variety of applications. While a self-charging battery would likely start on a smaller scale such as this, in the future it could theoretically be used on larger scale processes and prove to be a breakthrough in energy conservation.

Project Goal:

The goal of this project is to work towards a self-charging power system (SCPS) that effectively harvests, manages, and stores energy simultaneously. There had not been extensive research done on this in the group before, so the goal was to standardize a process for creating a polymer electrolyte around the piezoelectric nanofiber mats provided from collaborators. From there, the polymerized mats were tested in a cantilever device to see if the voltage generated could be feasible in a SCPS. The polymerized mats also needed to be soaked in electrolyte and tested before incorporation in a SCPS could be considered.

Activities/Results:

Most of my time on this project was spent perfecting the polymerization process of the piezoelectric mats. For each mat, I applied a crosslinked monomer solution consisting of polyethylene glycol diacrylate (PEGDA) to the mat, wedged the sample between two glass plates, and placed in the oven for an hour and a half at 75 degrees Celsius to initiate polymerization.

Throughout the summer, I learned different techniques to ensure that the mat was fully soaked in the PEGDA solution and to reduce the mats' thickness after polymerization. We want to reduce the thickness of the polymerized mat as much as possible because successful incorporation into a battery will require a thin polymeric piezo-electrolyte. In early trials, the thickness of the polymerized mat increased by an order of magnitude compared to the as-spun piezoelectric mat. I found that placing mass on the glass plates during the polymerization process reduced the thickness significantly and using a diluted monomer solution with less PEGDA also reduced the thickness. Additionally, I observed that using Teflon instead of glass plates for polymerization successfully reduced the thickness for mats containing polyvinylidene fluoride (PVDF); however, Teflon did not work for polyacrylonitrile (PAN) due to polar and static interactions between the mat and the Teflon.

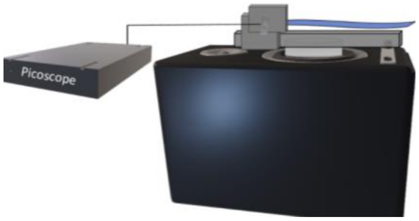

Figure 1. Cantilever device setup

I then took the polymerized mat and tested a sample in the cantilever, which is a device that measures the voltage generated by the piezoelectric material at different applied strains. It was observed that the polymerized piezoelectric mats generated a higher voltage than the as-spun piezoelectric mats, which is likely due to pores in the mat being filled with PEGDA. These results are very promising for future incorporation of the polymerized mat into a battery.

After successfully polymerizing the piezoelectric mats, I proceeded to the next step of soaking the polymerized mat in electrolyte in an attempt to create a polymeric piezo-electrolyte. I swelled the polymerized mat in electrolyte consisting of 1M LiTFSI in Diglyme. Although the polymerized mat appeared to swell successfully in the electrolyte, problems have arisen measuring the voltage generated from the swelled mat in the cantilever. After conducting several trials, my hypothesis is that soaking the mat in the electrolyte inhibits the contact the sample has with the copper tape in the cantilever device, preventing an accurate voltage from being measured. Going forward, the cantilever device will have to be revised in a way to accurately measure the voltage of the polymeric piezo-electrolyte.

After revising the cantilever, the hope is that the polymeric piezo-electrolyte will generate enough voltage to be used in a SCPS. At that point, further conductivity and impedance testing will be conducted on the polymeric piezo-electrolyte to determine its feasibility in a battery. If it seems feasible, then the polymeric piezo-electrolyte will be incorporated into a battery and tested. Going forward, I hope to also try different polymers other than PEGDA and see their effect on the voltage generated. In a separate project, I have worked with a different crosslinked monomer called polytetrahydrofuran diacrylate (PTHFDA), and I discovered that incorporation of an anion salt into the backbone of the polymer enhances the efficiency and effectiveness of the battery, which is something that I want to test as well.