

NDnano Summer Undergraduate Research
2022 Project Summary

1. Student name & home university:

Sam Chen

University of Notre Dame

2. ND faculty name & department:

Jennifer Schaefer, Department of Chemical and Biomolecular Engineering

3. Summer project title:

Polymers in next-generation rechargeable batteries

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

I learned how to fabricate full cell batteries and perform electrochemical stability testing and battery cycling

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

The goal of my research is to improve the safety of Li-ion batteries.

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

Electrolytes enable a battery to function by enabling the movement of ions between the electrodes. However, commercially used electrolytes are carbon-based and have high risks of causing fire hazards. My project focuses on reducing such risks by adding perfluoropolyether diacrylate to our electrolytes. Conductivity and potential stability were measured for different weight percent of polymers added to select the optimal composition.

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

<https://doi.org/10.1016/j.jiec.2018.04.006>

<https://doi.org/10.1073/pnas.1314615111>

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

Due to environmental concerns and the limitation of fossil fuel resources, society is shifting more use of renewably generated electricity, resulting in a higher demand for batteries. However, commercially used electrolytes, an essential part of the battery, are highly volatile and flammable. We need to develop batteries that have a higher energy capacity to fit the market demand, while also improving safety. Therefore, in this project, I investigated how polymers, perfluoropolyether diacrylate especially, can influence the performance and safety of the battery.

I started this project with another graduate student in Spring 2022. Two types of carbonate electrolytes were made, one conventional electrolyte and one partially fluorinated electrolyte. Then, different amounts of perfluoropolyether diacrylate (PFPEDA) and Bis(trifluoromethane)sulfonamide lithium salt (APTFSI) were combined to create a variety of polymer gel electrolytes. Throughout the spring semester, we collected data on our electrolytes' conductivity at room temperature. In the summer, I worked on testing the electrochemical stability of my electrolytes.

Further, we made six batteries to investigate how each control will influence electrochemical stability. The machine slowly increases the voltage across the battery and records the magnitude of the current. A peak in the potential v.s current graph indicates the reaction of impurities present within the electrolyte; a high ending current shows the instability of the battery. For our test, the voltage will increase from 3V to 6V, back to 3V, and then up to 6V. The result raises two issues: 1. Partially fluorinated electrolyte leads to a very high current; 2. the absence of free salt also leads to an early dissociation of the electrodes. Thus, I decided to continue my project without running testing for partially fluorinated electrolytes and electrolytes without free salt. Next, we need to test the potential stability of our electrolytes with the potential-static method. We increased the voltage across the battery from 3V to 5V with 0.1V increments. The battery stays at each voltage for 2 hours, and the computer records the current every 100 seconds. Such a test takes 42 hours to complete, and I refer to it as the long-time potential stability test. We used this method to check whether the presence of water influence our battery significantly. Though it shows

Further, we test the conductivity of our batteries with different separators, the layer of microporous polymer placed between the cathode and anode to prevent short circuits. Four separators, PvdF, PAN, Celgard, and Cellulose, were tested. The result shows that electrolyte cured on PvdF and PAN shows a better conductivity, almost 10 times higher than that of Celgard and Cellulose. We noticed that such difference is due to the slower absorbance speed of Celgard and Cellulose. Despite being widely used commercially, Celgard and Cellulose are harder to wet by our electrolyte due to the PFPEDA we added, thus resulting in much lower conductivity.

Above are the results I obtained through the summer research project. In the future, I will keep working on this project, and testing the energy capacity of the batteries fabricated with those electrolytes with good conductivity and potential stability. The goal is to find a composition of electrolytes that have good performance while maintaining high stability, and I believe such a goal is certainly feasible with our present data.