# SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
# FINAL REPORT

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| **SCHOLAR NAME:** | Annika Barron |
| **FACULTY ADVISOR:** | Jay LaVerne |
| **PROJECT PERIOD:** | January, 2021 |
| **PROJECT TITLE:** | Radiolysis of Lunar Regolith and Surrogates |
| **CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):** | **( ) Energy Conversion and Efficiency** **( ) Sustainable and Secure Nuclear**<br>**(X) Smart Storage and Distribution** **( ) Transformation Solar**<br>**( ) Sustainable Bio/Fossil Fuels** **( ) Transformative Wind** |

## MAJOR GOALS AND ACCOMPLISHMENTS

Summarize your research goals and provide a brief statement of your accomplishments (no more than 1-2 sentences). Indicate whether you were able to accomplish your goals by estimating the percentage completed for each one. Use the next page for your written report.

| RESEARCH GOALS | ACTUAL PERFORMANCE AND ACCOMPLISHMENTS | % OF GOAL COMPLETED |
|---|---|---|
| **Rad Lab Training** | Received training on FTIR and BET, learned how to prepare samples for radiation using purge and vacuum techniques, practiced running FTIR independently, learned how to use OriginPro software | 100% |
| **MCF Training** | Received training on Raman Spectroscopy, XPS, and TGA-DSC, practiced running Raman independently | 100% |
| **Plan Research Methods** | Spent time investigating the source of FTIR irregularities and found that it was due to the method used to clean the tools, researched different components found in lunar regolith | 25% |
| **Analyze Lunar Regolith Surrogates** | Ran temperature studies using FTIR for $Al_2O_3$ and $SiO_2$ in order to decrease presence of water peak within FTIR spectra. | 10% |

## RESEARCH OUTPUT

Please provide any output that may have resulted from your research project. You may leave any and all categories blank or check with your faculty advisor if you are unsure how to respond.

| CATEGORY | INFORMATION |
|---|---|
| EXTERNAL PROPOSALS SUBMITTED | (Sponsor, Project Title, PIs, Submission Date, Proposal Amount) |
| EXTERNAL AWARDS RECEIVED | (Sponsor, Project Title, PIs, Award Date, Award Amount) |
| JOURNAL ARTICLES IN PROCESS OR PUBLISHED | (Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s) |
| BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH | (Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s) |
| PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH | (Event, Presentation Title, Presentation Date, Location) |
| AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT | (Purpose, Title, Date Received) |
| INTERNAL COLLABORATIONS FOSTERED | **Melissa Fairley-Reir, LaVerne Lab:** Aided with training in Raman and sample preparation, worked together about once per week<br>**Anna Matzner, MCF:** Facilitated training in Raman, XPS, and TGA-DSC, worked together almost every day for a week<br>**Ian Lightcap, MCF:** Answered any questions about Raman Spectroscopy while working independently, interacted twice during January<br>**Hanna Hlushko, LaVerne Lab**: Training simultaneously within the lab, worked together to practice FTIR and sample pre techniques, worked together about twice per week for the last two weeks of January |
| EXTERNAL COLLABORATIONS FOSTERED | (Name, Organization, Purpose of Affiliation, and Frequency of Interactions) |
| WEBSITE(S) FEATURING RESEARCH PROJECT | https://energy.nd.edu/research/fellowships/slatt-undergraduate/ |
| OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, | **OriginPro:** Computer software used to convert raw data into graphs and perform data analysis |

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| curricula, instruments, education programs, outreach for ND Energy and other groups) | **FTIR:** Used to perform infrared spectroscopy and characterize materials based on bonds present within molecules. Samples are placed inside the machine and reflectance at each wavelength is measured by detectors after hitting the material.<br>**Raman Confocal Microscope:** Uses a laser to characterize materials based on atoms and bonds present within molecules. Material is placed on a slide and then a laser beam shines on the material. The instrument measures changes in wavelength that occur when the laser hits the sample.<br>**X-ray Photoelectron Spectroscopy:** Analyzes the surface of a material using x-rays which cause photoelectrons to be emitted by the material. The energy of the emitted photons is measured which indicates the elements present within the material.<br>**TGA-DSC:** TGA measures the weight change of a sample as it is heated, allowing water loss to be measured precisely. DSC records the energy required to heat a sample.<br>**BET:** Measures the surface area and porosity of a material by coating it in nitrogen and carefully measuring changes in pressure. |

**RESEARCH EXPERIENCE**

Please let us know what you thought of your research experience: Did this experience meet your expectations? Were lab personnel helpful and responsive to your needs? What else could have been done to improve your experience or achieve additional results?

Going into this research experience, I wasn't necessarily sure what to expect because the lab was a novel environment for me. But there was certainly a lot that I learned throughout the process. I would say that the biggest thing that surprised me was how long the research process actually takes. Because of all the training that I had to do, we did not have much time to get started on the actual project. That was the goal all along, but the long and tedious process still surprised me. However, I am very glad that I had the opportunity to take this time to complete all of the trainings and learn how to use all the instruments, because it would have taken way longer if I had to learn everything with more limited time during the semester. As a result, the start of my actual project would have been delayed even further. A lot of the analysis process also took longer than expected. With some of the techniques, running a sample usually takes a couple of hours and the process can even last all day! This does not deter me from my research work, but it was definitely important to realize that scientific research is a long process which requires a lot of patience.

Everyone who I encountered throughout my work this month has been extremely kind, patient, and helpful. They were always willing to answer my questions and even stop what they were doing to help me out when I needed it, even though they were probably very busy with their own work. This really showed me their passion and how much each of them cared about science as a whole rather than just their own individual work. They were also very patient during trainings and put up with me asking tons of questions. They definitely showed a lot of empathy for me throughout the learning process, which helped me to realize that they all had to go through a similar process at the start of their careers which made me hopeful for my future in science.

While we have not gotten super deep into my research project thus far, there is not much I would change about my experience. I am super grateful to have had the opportunity to spend this time training and preparing for my project. Without January, the training process would have taken much longer, and I would not be able to be as independent later on in the process. Because of this time, I am starting off with a strong foundation and have the confidence to really impact this project. I would say that the only thing that would have potentially improved my experience would be having more of a set schedule of when we would do certain trainings throughout the month. I occasionally had short periods of down time where I was just practicing or was slightly unsure of what to do next, and a set schedule may have helped to avoid some of that confusion. However, I was still able to get a lot done and learn so much during my break spent in the lab.

## FINAL WRITTEN REPORT

(Please use the space below to describe your research project and objectives, any findings and results you can share, and graphs, charts, and other visuals to help us understand what you achieved as a result of this research experience.)

Earlier this year, NASA's Stratospheric Observatory for Infrared Astronomy discovered water on the sunlit surface of the moon. While it was only a tiny amount, this discovery raises very important questions about where this water came from, whether it will last, and the implications for the future of space exploration. One theory is that the proton bombardment of metal oxides creates both surface hydroxides and water. Our research seeks to understand the effects of radiation chemistry on lunar regolith, the fine powder on the surface of the moon, and whether this radiation process could have led to the formation of water on the moon's surface.

In order to answer these questions, we will begin by examining iron oxides and silicon oxide nanoparticles (which act as surrogates for lunar regolith) to develop protocols and an effective process, and then we will examine real lunar soil. Radiolysis will be performed using accelerated protons from the 9S accelerator in the Nuclear Science Laboratory, as well as gamma rays from other resources in the Radiation Laboratory. Before and after radiolysis, spectroscopic techniques, including UV-visible, infrared, Raman spectroscopy, and x-ray scattering will be used to examine the materials and determine the ways in which the elemental composition and properties may have changed. Using this analysis, we hope to understand the effects of radiation on lunar soil, hopefully leading to a conclusion about the formation of water on the moon's surface. This important discovery holds many implications for the future of space travel and colonization. Hopefully, understanding the characteristics of the lunar surface can allow us to conserve and create energy in the future.

Before I could begin working on this project, I needed to learn the techniques and instrumentation necessary to perform material analysis and radiolysis. During the past month, I was trained to use Fourier transform infrared spectroscopy, Raman Spectroscopy, X-ray photoelectron spectroscopy, TGA-DSC, and BET. I also learned how to prepare samples for radiation using vacuum and purge methods. All of these skills are essential to measuring and understanding data later on in my experiment, and after spending this time training and getting comfortable with the instruments I will be using, I am much better prepared to be more independent as I work to analyze lunar regolith.

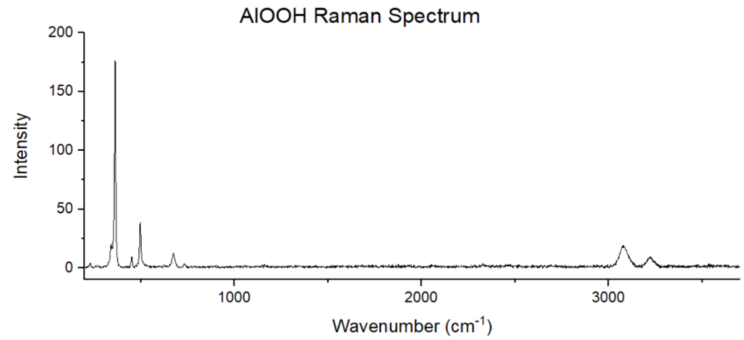


*Figure 3:* Raman spectrum for Boehmite obtained while practicing using Raman Spectroscopy.

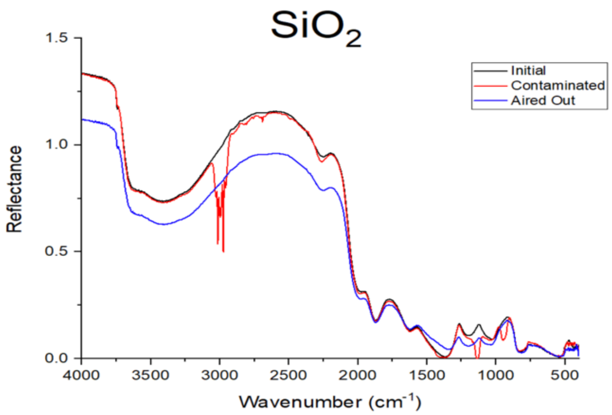


*Figure 2:* $SiO_2$ before and after contamination with difluoroethane. A measurement was also taken after airing out the contaminated sample for several minutes in order to allow for the evaporation of difluoroethane from the instrument.

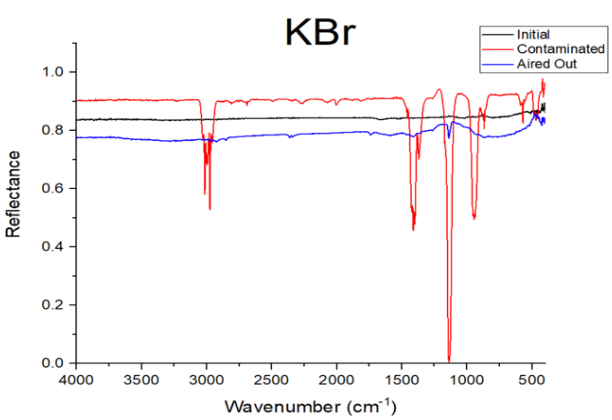


*Figure 2:* KBr before and after contamination with difluoroethane. A measurement was also taken after airing out the contaminated sample for several minutes in order to allow for the evaporation of difluoroethane from the instrument.

Alongside my training, I was also able to run some initial experiments with FTIR. First, I worked to understand the source of contamination that we were finding within our spectra. While training on the instrument, we noticed that there was a rather large organic peak that was not found in any of the accepted literature on the compounds we were using. It was found in both $Al_2O_3$ and $SiO_2$, so we believed the issue to be caused by the instrument itself. Using KBr, $Al_2O_3$, and $SiO_2$, I spent time changing numerous small variables within the samples and the FTIR instrument, looking for patterns that could be causing the contamination. After many hours, I discovered that the cause was an air duster used to clean the instrument after removing a sample. The canned air duster was very effective in making sure that all sample was removed, however the cans contained difluoroethane which caused organic contamination as it evaporated from the surface of the instrument and interacted with the light reflecting off of the material surface. In order to solidify this theory, I took measurements of both KBr and $SiO_2$ before and after contamination by the duster. Finding the source of this contamination was essential for our later project in order to ensure that results obtained provide a clear indication of what is actually present in the lunar regolith.

Finally, I was able to perform a temperature study on both $SiO_2$ and $Al_2O_3$. This is the first data of my actual experiment and will become important references to our work with lunar regolith, as both aluminum and silicon are found in abundance on the surface of the moon. In this experiment, I heated the samples to 500 degrees Celsius while obtaining spectrum every 50 degrees. As the temperature increased, water was evaporated from the material, allowing a cleaner spectrum to be obtained with a more defined water peak. This is an important starting point as I prepare to launch into the realm of space.

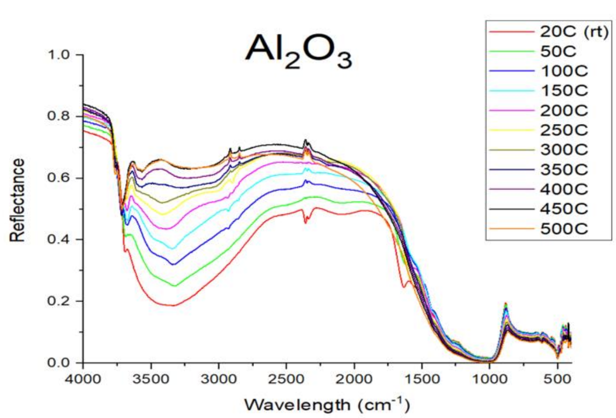


*Figure 5:* FTIR temperature study of $Al_2O_3$.

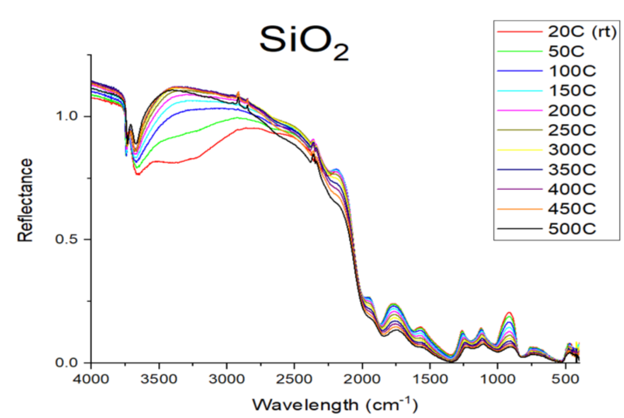


*Figure 5:* FTIR temperature study of $SiO_2$.