How and/or on what were the SSI Research Grant funds expended?

All of the SSI Research Grant funds were used to support student wages. All other funds needed to complete the project (i.e. money for materials, equipment, tools, etc.) were supplied by the CBEE department.

A brief summary of the work conducted; including a discussion of the information gathered, how the data are being analyzed and if you are far enough along, describe how the data collected supports or refutes your original hypothesis or discovery goal(s).

The majority of the 300 hours I spent on this project were dedicated to finding a way to make filament for 3D printers from recycled plastic. At the beginning of the summer, I started by getting acquainted with some of the different equipment I would need to complete my project (i.e. Differential Scanning Calorimeter (DSC), Thermogravimetric Analyzer (TGA), Melt Flow Indexer (MFI), etc.). All of those aforementioned tools are used in the characterization and identification of various polymers (plastics). The use of these machines turned out to be particularly important for both the collection of the recycled plastics and the processing of these plastics into usable filament. After the initial learning curve, I began work on the actual “meat” of the project. To simplify the steps I went through to reach my current point in this research, I would break the project down into 4 parts:

1.) Collection and preparation of recycled materials for processing.

To begin the project, I needed a source of plastic that had previously been thrown into a recycling bin somewhere on campus. I contacted Campus Recycling, and they were happy to direct me towards the site where they keep all the commingle recycling from the dining halls. I went out to the storage site, and began collecting the used plastics. Based on the discussion I had with campus recycling, I decided to collect HDPE (Milk bottles, Detergent containers, etc.). The reason for this being that HDPE is one of the most common recycled plastics, and it has no redeemable value (as opposed to something like PETE soda bottles).

After collecting the material, the next step was cleaning and grinding. I used a simple method of soap and water to clean any residue from the plastic. The tough part was finding an effective method for turning the large plastic pieces into a coarsely ground powder. After much searching, and many different tested methods, I finally found an effective way to get the material to a size where it would properly perform in the extruder (machine used to make the filament).

The last step was drying the ground plastic to make sure it was void of any moisture. I used large drying ovens (low temperatures, overnight) in Richardson hall to accomplish this step. The plastic was now ready for testing and extrusion.

2.) Processing and quality control (Filament Production)

With my recycled HDPE ready to go, I ran a few tests on the material to find out what would be the best settings for the extruder in order to make my filament. Before I was ready to start making the filament, I needed a way to wind it up as it came out of the extruder. I did some research and built a relatively simple, yet effective, filament winding unit. As I began producing the filament I ran into a few speed bumps, mainly involving quality control (3D printer
filament must be of very high quality with tight diameter tolerances in order to make successful prints). This required me to make some custom machined parts for the extruder tip in order to account for the swell that occurs when extruding plastics. Eventually, I was able to make some good quality filament that was ready for use in our MakerBot 3D printer.

3.) Filament testing and adjustments

This is the step in the research where I have had the toughest problems, and I am still working through them as of now. When printing with HDPE filament, we experienced issues that are consistent and widely acknowledged in the industry as a downfall of using this type of plastic for 3D printing. Due to the properties of HDPE, the prints typically fail after the first couple layers. This is largely due to shrinkage/warping that occurs when the plastic cools after leaving the printer nozzle. When the plastic part shrinks, the printer doesn't know it, and it continues to print as if the part was still its original size. What generally happens is that the printer will eventually be printing onto thin air (because the shrinkage is so extreme), which is obviously not possible. There are a few solutions that some have found to combat the problem to a degree. The issue I have with these solutions, is that they require a special type of printer, or serious modifications to an existing printer. Neither of these are user friendly options. What we intend to do is modify the material properties of HDPE instead, in order to create a filament that can be used in any home printer. As a side note, I am also looking into using the compostable PLA cups used by OSU catering and various campus cafes. PLA one of two materials widely used for 3D printing today.

4.) Printed Part testing

This is the final stage of the project. I have not reached this point, but I will describe what it entails, and how I will execute it when I am ready. Once I have made successful prints using my own filament, I will be able to test the mechanical properties of the part (strength, flex, durability, etc.) and compare it with that of commonly used filaments such as ABS. If the parts do not have the desired mechanical properties for everyday 3D printing applications, it is possible that we can tweak the composition of our filament in order to achieve a higher performing polymer.

State the benefits from the SSI award; including additional scholarly activities, research progress, collaborative relationships, and any publications or other funding made possible for the student as a result of this award.

This research project funded by the SSI award is by far one of the most valuable learning experiences that I have ever had. Not only did it allow me to gain relevant work experience in my field of study, but it also provided me with the opportunity to learn about the typical research process, project management, and collaborative learning/research. Going into this project, I had no experience with research jobs. As I made progress on my project, I obviously learned a ton about polymer science, polymer processing, and 3D printing. However, some of what I learned had nothing to do with the project itself, but more about science and research in general. This was possibly even more valuable to
me at the moment, because I discovered that I really do enjoy research. In turn, this experience has fueled an interest in graduate school that I did not previously have (my original plan was always to work in industry right after finishing my undergraduate studies). In addition to that, I also had a fantastic experience learning how to communicate with other departments and students in order to complete my research. Without some of the connections I made, I never would have had certain resources at my disposal that were necessary to complete the project. Overall, it was a tremendous experience that I would recommend to any student looking to gain practical skills in a wide variety of disciplines. It is impossible to know what your school has to offer until you really explore. I am glad I took advantage of such a fantastic opportunity.