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Development of a Desktop Ceramic 3D Printer for Hall Effect Thruster Fabrication

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Faculty Mentor

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Previous participation in RCEU: Yes

Project Summary

The goal of this project is to develop a process and device to produce additively manufactured (AM), commonly called 3D printing, ceramic parts for integration into a Hall effect thruster. Recently, at the Plasma and Electrodynamics Research Lab, we designed a miniature Hall effect thruster (HET) with 3D printed ABS discharge channel and propellant distributor. The use of AM allowed us to produce intricate internal passages in the propellant distributor that would not be possible with traditional manufacturing. The thruster performance was measured at NASA Glenn Research Center in spring of 2017 and showed performance on par with traditional HETs of a similar size and power. However, the thermal limitation of the ABS plastic was evident as the channel and distributor would warp and melt after exposure to the hot plasma plume. To advance this research, an AM method for high temperature ceramic materials such as alumina or porcelain is needed. While a handful of commercial services exist to produce 3D printed porcelain, the resolution is insufficient for complex internal geometries.

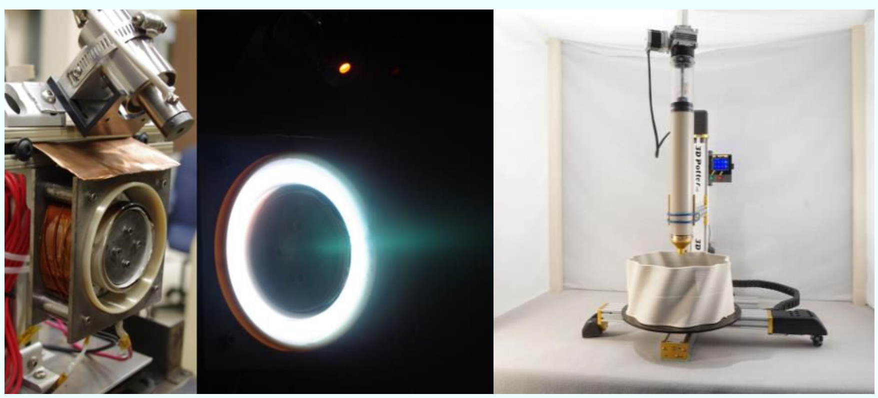

Figure 1. (Left and middle) The UAH-78AM at undergoing performance testing at NASA Glenn Research Center. (Right) A commercial pneumatic clay paste extruder 3D printer use for pottery.

The field of ceramic AM has significantly lagged behind polymer and metal printing. Due to the lack of commercially available solutions with high resolution, we seek to develop an in-house 3D printer to produce ceramic parts for HETs. While certain ceramic printers could be bought directly, this project seeks to utilize the information available from the 3D printing hobby community to produce a new process for partially or fully ceramic HET parts. The project will be primarily experimental, with some CAD and electronics design as needed. As the project is intended to be wholly or majority in-house built and developed, the student will need to study and understand the design of desktop 3D printers and how to modify them for ceramic materials. After successful modification of the printer, HET parts will be printed and integrated into the UAH-78AM for test firing in the lab's vacuum chamber to determine material survivability. The student will learn to operate the thruster and the associated vacuum equipment. Assistance from graduate student and the professor will of course be available.

The RCEU student’s tasks in the project include:

1) Research different ceramic AM methods and their complexity and benefits for HET use.
2) Modify the desktop printer for ceramic AM method of choice.
3) Produce HET components and assemble and test the thruster at PERL.

<u>Student Prerequisites</u>

The student should be comfortable with hands-on electronics and building parts. The student should have experience writing technical reports. The student should be familiar with computer programs such as Excel, Matlab, and Solid Edge or another CAD program, and a CFD tool such as Ansys. Experience with Arduino programing would be helpful.

<u>Student Duties</u>

The student will have primary responsibility for studying the different current ceramic AM methods, modifying the desktop 3D printer, producing the HET parts, testing the thruster, collecting the data, and analyzing the results. Any necessary materials and parts will be provided. Graduate student support as well as my support will be available for the project. A tentative timeline for 12 weeks is as follows:

Weeks 1-2: Introduction to the lab, equipment, and background of our 3D printed HET research. Begin research into ceramic AM methods.

Weeks 3-4: Review literature on ceramic AM methods and present at least two solutions.

Weeks 5-7: Purchase required parts and being modification of the desktop printer.

Weeks 8-10: Produce HET components and test in vacuum chamber.

Weeks 11-12: Analysis and documentation of the results including a poster.

The RCEU student is expected to be a self-motivated and diligent professional. He or she will have significant independence on the project, though assistance is always available. The student is expected to contribute to group meetings, read necessary background material, and conduct any independent learning necessary to do the research. This project will provide the student a chance to conduct hands-on research in additive manufacturing as well as electric propulsion for small satellites. The student will have the opportunity to see the project from beginning to end, from experimental design to documentation of the results. The work will build on topic in materials and propulsion and provide new experiences that cannot be gained in class or through internships and co-ops. This project is a great way to experience experimental research for future graduate pursuits. The main expected deliverable is a poster and a detailed report of his or her work. I encourage submission of quality work to society or national conferences and journals.

<u>Mentor Supervision and Interaction</u>

During the summer semester, I spend 3-4 days a week personally at the lab. I may assist with the student projects or do work on my own. Thus, I will have regular interactions with the RCEU student. The student will also have daily interactions with the graduate students who work with me and conduct research in the lab. Direct supervision, mentoring, and evaluation of the project by me will occur once a week at the regularly scheduled project meetings. In the meetings we will discuss the current status of the project, recent results, difficulties encountered, what to do next, and address any other issues that may come up. Indirect interactions and mentoring by graduate students and I will occur throughout the semester as part of the day to day activities. The student will either report to me on the overall progress.