SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
FINAL REPORT

SCHOLAR NAME:	Allison Taylor
FACULTY ADVISOR:	Hirotaka Sakaue
PROJECT PERIOD:	Fall 2020-Spring 2021
PROJECT TITLE:	Deicing and Anti-Icing of Aircraft
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	**(--) Energy Conversion and Efficiency** **( ) Smart Storage and Distribution** **( ) Sustainable Bio/Fossil Fuels** **( ) Sustainable and Secure Nuclear** **( ) Transformation Solar** **(--) 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
Categorize absorbance of coating with variable graphite mass ratio	Created multiple samples of each mass ratio mixture and tested absorbance using a mass spectrometer to characterize mixture with greatest solar radiation potential	80%
Categorize hydrophobicity of coating with variable graphite mass ratio	Created multiple samples of each mass ratio mixture and tested hydrophobicity from the contact and sliding angle to characterize mixture with greatest hydrophobicity	60%
Find the mass ratio of graphite that optimizes hydrophobicity and solar radiation potential	Combined data results from hydrophobicity tests and absorbance tests to determine the mass ratio of graphite to PTFE that yields optimal results for de-icing	60%

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	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
EXTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	(Please describe each item in detail)

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?

This experience was extremely beneficial in understanding the process of real-world scientific research. My graduate student advisor made this experience a very easy transition as this was my first higher level project done outside of the classroom setting, but I found it very rewarding to contribute to the work being done to solve a very relevant problem today in the aerospace industry. Unfortunately, I was not able to produce results as quickly as we had imagined due to Covid-19 restrictions in the lab as well as repeated problems with the technical devices necessary for testing but that is the only thing that would have made this experience better!

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.)

During flight, it is common for airplane surfaces to encounter clouds made up of small water droplets which cause layers of ice to form on the surface of planes if the environment temperature is below freezing point. Current systems of de-icing work by breaking the ice while systems of anti-icing aim to prevent the ice from forming by blowing hot air on the outer surfaces. This research focused on creating more efficient modes of de-icing and anti-icing by optimizing surface coatings to have high levels of solar absorption to provide enough natural heat to melt the ice into water droplets while maintaining high levels of hydrophobicity to repel the water droplets from the airplane surfaces. If executed effectively, this strategy could replace current cracking practices for de-icing and decrease the amount of engine power required to heat the outer surfaces on planes.

To do this, our team combined already existing chemical coatings, which use PTFE as the hydrophobic agent, with variable graphite mass ratios which is used as a darkening agent to increase the solar radiation potential of the coating. Throughout the experimental phase of the research, several of each PTFE to graphite mass ratio coating were created and sprayed onto aluminum samples to prepare for testing. A mass spectrometer was used to gather data on the levels of light absorption of the varying mass ratios. Further data analysis was executed to obtain the reflectance of each sample throughout the visible and infrared light spectrum. In Matlab, these values were normalized and integrated over the light spectrum to obtain the overall reflectance, the inverse of which gives the overall absorption of each mass ratio. Comparing this value between the varying mass ratios allows one to conclusively identify which graphite ratio optimizes the solar radiation of the coating. Though, early in the process of this research project, the mass spectrometer stopped working correctly as it needed further maintenance. Due to this issue, the testing strategy was altered to include comparing the reflectance of the varying mass ratio coatings by taking photographs of the samples in a dark room with a single beam of light, much like the setup of the mass spectrometer. The photographs of the samples were implemented into Matlab and the light spectrum of each picture was analyzed through a weighted grayscale to compare the average brightness and darkness of each sample. Comparing the average darkness of each sample served as an assessment of the solar radiation potential of the varying mass ratios which was integral in determining the optimal coating mixture for the first research goal. The results of these tests are shown in Figure 1 below.

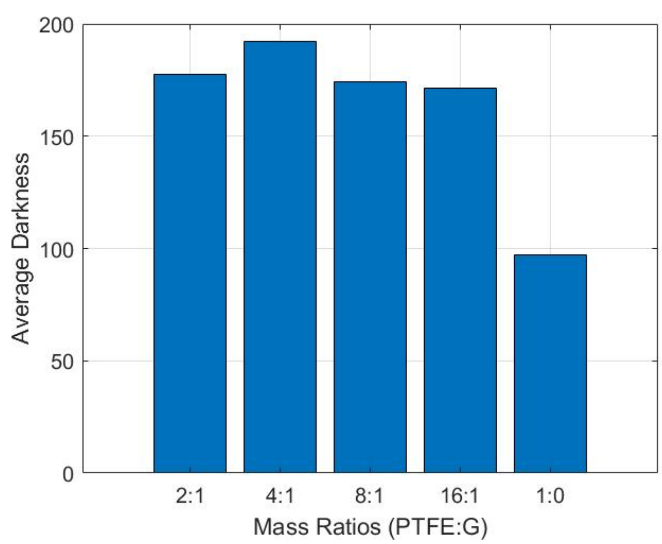

Figure 1. Average darkness value of each PTFE to graphite mass ratio sample with 1:0 being the control PTFE sample with no graphite added.

Clearly, each sample with graphite is much darker than the control sample with no graphite which positively affirms the benefits of the coatings of this research as opposed to already existing hydrophobic coatings. Furthermore, it is evident that the 4:1 PTFE to graphite mass ratio sample has a significantly higher average darkness value than the other PTFE to graphite mass ratio samples which coincides with the research done previously by the graduate student advisor on this project.

The next step in this research project was analyzing the hydrophobicity of each PTFE to graphite mass ratio sample which was carried out by obtaining the contact angle and sliding angle of a single water droplet when dropped onto the surface of each sample. The contact angle is the angle formed by a liquid at the three-phase boundary where a liquid, gas, and solid intersect. Thus, a perfectly hydrophobic surface contains a contact angle of 180˚ for water. Meanwhile, the sliding angle is the angle from the horizontal at which point the liquid droplet slides off the sample surface, so a perfectly hydrophobic surface contains a sliding angle of 0˚ for water. Usually, this data is obtained from a sophisticated device that includes a high-resolution camera pointed at a leveled stage in front of a diffused backlight. This produces clear images of the interface between the water droplet, air, and the sample surface and outputs results of the contact and sliding angle for the respective surface. Though, this stage of the testing also suffered technical difficulties as the imaging device lacked parts required for its use. Because of this, both the contact and sliding angle were measured manually. The former was done by taking photographs of the interface between a water droplet and a coating surface which was imported into Matlab for finer angle approximations and the latter was done by altering the surface angle of the sample until the water droplet slid, with the angle being measured by a digital level. The results from these tests yielded a range of contact angles between 130˚- 150˚ as well as a range of sliding angles between 4˚- 8˚. From the manual tests, the best PTFE to graphite mass ratios for hydrophobicity were found to be the 4:1 and 16:1. Though, because the high-resolution imaging device is currently working again, these results are now being reanalyzed to verify this conclusion. If these tests yield similar results, then it is likely that the 4:1 will be the optimal PTFE to graphite mass ratio for maximal hydrophobicity *and* solar radiation potential. Adding this mixture to the surfaces of planes will increase the amount of natural heat being absorbed into the surface which in turn melts the ice and repels remaining water droplets, allowing for more efficient modes of de-icing during flight.