NDnano

Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research
2021 Project Summary

1. Student name & home university:

Nicholas Slusher, University of Notre Dame

2. ND faculty name & department:

Hirotaka Sakaue, Aerospace Mechanical Engineering

3. Summer project title:

Adsorption of Luminescent Probe on a Porous Surface for Luminescent Sensor Development

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

This summer, I have gained a much better understanding of the Python programming language and computer science skills in general. Additionally, I have begun to familiarize myself with luminescent chemistry, fluid dynamics, and aerospace research basics. I have also gained a greater understanding and appreciation for the research process and all of the steps involved in obtaining quality data. Another important skill I have developed is discussing and presenting my work to various groups with different backgrounds. This variety requires me to tailor my presentation and message according to each group's level of knowledge and experience.

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

If the process for pressure-sensitive paint (PSP) is refined, then it has widespread applications throughout the aerospace industry. PSP is beneficial for unsteady flow measurements due to its fast response time and ease of application. PSP allows a visual method for determining pressure distribution across an entire surface rather than at a given point. Another practical application is for testing the pressure distribution for small items during high-speed flights because PSP does not change the items' geometry or overall weight balance.

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

During the production of AA-PSP, anodized aluminum is submerged into a solution containing the luminophore. It is necessary to understand the effect of temperature during the dipping process has on the characteristics of the AA-PSP. The results demonstrated that a change in solution temperature affects pressure sensitivity, temperature sensitivity, and intensity. The amount of variability and possible error throughout the collected data was high. Therefore no clear trend could be established. The findings demonstrate that this area of study is promising though more refinement to testing methodology is required.

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

[1] Sakaue, Hirotaka, and Keiko Ishii. "A Dipping Duration Study for Optimization of Anodized-Aluminum Pressure-Sensitive Paint." *Sensors*, vol. 10, no. 11, 2010, pp. 9799–9807., doi:10.3390/s101109799.

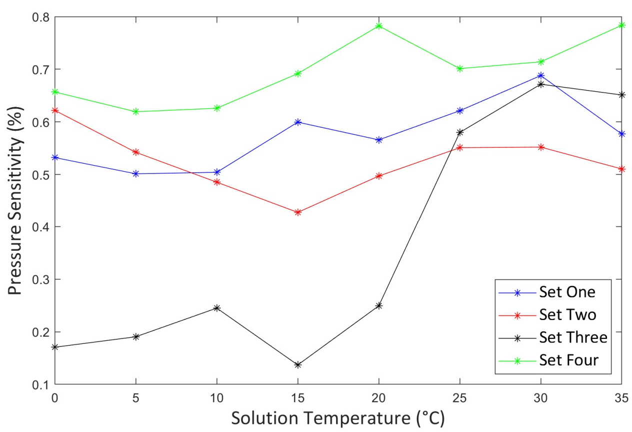
[2] Kurihara, D., Saitoh, K., Sakaue, H., "Uncertainty Analysis of Motion-capturing Pressure-Sensitive Paint Method based on Unsteady Surface-Pressure Measurement on Fluttering Airfoil," *Aerospace Science and Technology*, Vol. 102, 2020.

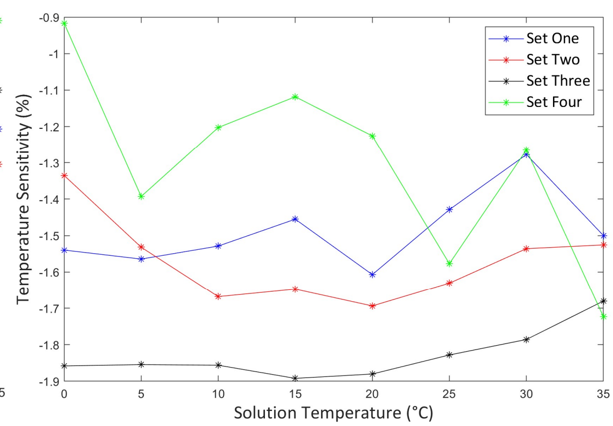
[3] Sakaue, Hirotaka, and Keiko Ishii. "Optimization of anodized-aluminum pressure-sensitive paint by controlling luminophore concentration." Sensors (Basel, Switzerland) vol. 10,7 (2010): 6836- 47. doi:10.3390/s100706836

Anodized aluminum pressure-sensitive paint (AA-PSP) is widely used to correlate luminescent output to pressure in unsteady flow measurements. During AA-PSP preparation, an anodized aluminum sample is submerged into a solution consisting of a luminophore and some solvent such as dichloromethane. During this dipping process, the luminophore attaches to the anodized aluminum and remains on the surface even after the sample is removed from the solution. This process allows for direct deposition of the luminophore onto a very high surface area without the need for a polymer layer. This direct deposition decreases the response time of the pressure sensor drastically, making it much more useful for flows where fast pressure changes occur. There have been several previous studies regarding the different variables involved in the dipping process, such as dipping time and the solvent used. However, no work has been done to understand the effect that temperature has on the process.

The project's goal was to understand better how temperature during the dipping process affects the properties of the AA-PSP. In particular, the goal was the understand the effect on pressure and temperature sensitivity and overall luminescent intensity.

Initially, the project began by controlling the temperature of the solution. This setup means that the anodized aluminum sample was kept at room temperature until placed in the solution. For each of the four sets, eight samples were created with solution temperatures ranging from 0°C to 35°C. This temperature range was chosen because of the boiling point of dichloromethane being 40°C and the equipment available only going as low as 0°C. The data from this initial set of trials are shown below in Figures 1, 2, and 3





Figures 1 and 2. AA-PSP Sensitivities for Various Solution Dipping Temperatures

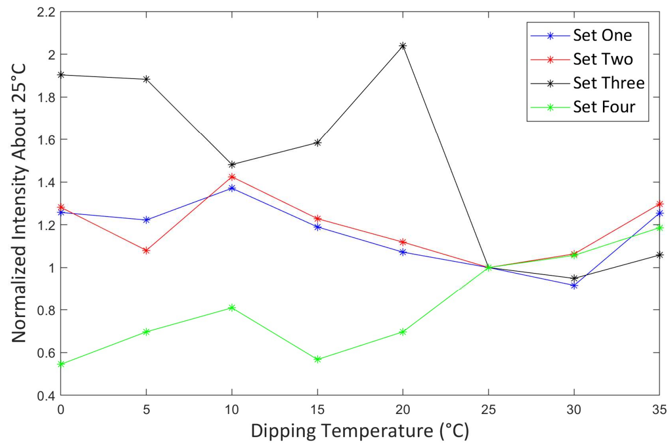


Figure 3. Overall AA-PSP Intensity for Various Solution Dipping Temperatures

As can be seen in Figures 1, 2, and 3, there is no clear trend between sample sets, and there is a wide range of variability. After examining the data, it became clear that other factors were influencing the properties of the AA-PSP. Much of the work then shifted to determining these factors and how to mitigate their effects.

An example of how one of these factors was investigated was with the AA-PSP drying process. After the sample is removed from the solution, it is typically placed in a vacuum chamber for twenty-four hours to allow all remaining dichloromethane or traces of water to evaporate. We found that if the sample was removed with a large amount of the solution remaining on the surface, then the luminophore would remain after the evaporation process. This process created an uneven coating of luminophore, making some areas brighter than others, as shown in Figures 4 and 5 below

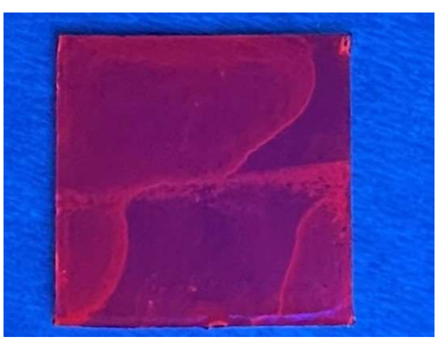


Figure 4. Sample Before Cleaning

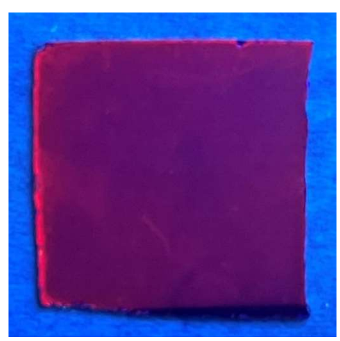


Figure 5. Sample After Cleaning

To improve the consistency of the coating, the samples were then cleaned with dichloromethane allowing any non-attached luminophore to wash off. Additionally, the samples were removed from the solution much more quickly and at an angle to reduce the residue further.

Several other noise sources were also investigated, including the quality of the anodized aluminum, exposed surface area, solution quality and degradation, atmospheric conditions, storage, and testing methodology. After controlling more variables, it is hoped that the data from the next set of samples will produce a useable trend or at least will not have as much noise. Also, the next step in the process will be to control the sample and solution temperature independently to maintain a large temperature gradient throughout the dipping process.